ASSESSMENT OF STRESS-RESPONSE IN COMMON REED STANDS IN THE WINNEBAGO POOL LAKES, WISCONSIN

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FOREWORD

Since the Upper Lake Winnebago Pool Lakes (Lakes Butte des Morts, Winneconne, and Poygan) were created by the damming of the Fox River in the 1850's, extensive stands of common reed (*Phragmites australis*), known locally as cane beds, have grown in scattered patches throughout the system. Subsequent to impoundment, these stands have been subjected to a variety of stresses, including imposed water level regimes with winter drawdowns, wave action, boating activity, rough fish feeding and spawning, and competition with intrusive algal growths. Anecdotal evidence and recent observations have indicated that common reed stands have been slowly diminishing in both size and vigor and that the rate of deterioration in the past 10 - 15 years has been accelerating (Rudebeck, 1997; Techlow, 1997). However, no precise quantification of the changes in aerial extent of common reed beds in the Upper Winnebago Pool Lakes exists, nor has a recent assessment of the current status of common reed beds in the entire system been conducted.

Although limited in acreage, stands of emergent macrophytes such as these provide numerous ecological as well as recreational functions including: life support for a variety of microbial, invertebrate, vertebrate, and plant and algal populations; maintenance of water quality and geochemical storage, especially with regard to cycling of nutrients, changes in dissolved oxygen, and sedimentation of suspended solids; protection of shorelines from wave erosion and prevention of resuspension of fine sediment; and open space and aesthetics for both consumptive and non-consumptive outdoor activities. In the Winnebago system, these areas have already been identified to be extremely important as: 1) habitat for a number of waterfowl and other bird species, providing food, cover, and nesting substrates; 2) vital fish habitat, providing cover, egg-laying substrates and support of fish food fauna; 3) important hunting and fishing areas; 4) stabilizers of lake bottom sediments; and 5) erosion protection (Gabriel and Bodensteiner, 2000; Kahl, 1993; Nichols and Vennie, 1991).

Given the potential significance of these stands in a system that is already highly anthropogenically stressed, we examined the relation between changes in characteristics of common reed stands and some key environmental factors that may affect their success, especially those related to season patterns in water level management. By determining the relevant factors and stresses responsible for the changes in size and location of common reed stands, we have begun to develop information necessary for the management, protection, and possible rehabilitation of common reed stands in the Upper Winnebago Pool Lakes. To accomplish this we addressed the following objectives: 1) development of a historical, quantified record of possible changes in the spatial characteristics of common reed stands on Lake Poygan, including aerial extent, distribution, and shape; 2) development of baseline information on the current status of individual common reed stands, including stem density and uniformity of stem distribution within stands; 3) assessment of the relationship between changes in the spatial characteristics of common reed beds and environmental factors, particularly water levels, and meteorological conditions during the winter and the growing season; and 4) identification of public perception of the possible ecological importance of common reed stands to the Winnebago Pool Lakes and of protection and restoration efforts.

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BACKGROUND

Located in east central Wisconsin, the Winnebago Pool Lakes, composed of Lakes Winnebago, Butte des Morts, Winneconne, and Poygan, drain 16,654 square kilometers and compose 17% of Wisconsin's surface water area. Major watersheds include the Wolf River to the north and the Upper Fox River to the south with the system emptying from Lake Winnebago via the Lower Fox River to the southwestern end of Green Bay on Lake Michigan The Lakes lie in the vegetation tension zone between the Northern Forest and the Prairie-Forest floristic provinces (Curtis, 1971), and the watershed transects three US ecoregions, the Southeastern Wisconsin Till Plain, the North Central Hardwood Forests, and the Northern Lakes and Forests. Consequently, land use ranges from mixed hardwood forest in the north to primarily specialized dairying with some generalized farming southward.

The Lake Winnebago System is within 120 km of over 2 million people, and is central to many, often conflicting, resource uses, including outdoor recreation such as fishing and boating, wastewater assimilation for 59 industries and 24 municipal wastewater treatment plants, and as a principal water supply for over 200,000 people in Oshkosh, Neenah-Menasha, and Appleton as well as numerous small communities in the watershed (East Central Wisconsin Regional Planning Commission [ECWRPC], 1989). The Lake Winnebago System provides over one million user days during the peak month of recreation for boaters and anglers from Wisconsin and other states, most notably nearby Illinois. The dam system and water level control program, representing the largest flood control storage reservoir in Wisconsin, provide flood protection for residents and shoreland development within 17 jurisdictions.

Water levels in the Upper Lake Winnebago Pool Lakes have been controlled through dam outflows by the Corps of Engineers since the late 1800's, principally to assist commercial navigation and downstream industrial uses of waste assimilation and power generation (WDNR, 1989). As a result of a revised water level management policy instituted in 1982, lake levels in the summer are now approximately 1 m higher than previously occurring levels in the summer, and 10-30 cm higher in the winter. The Corps is required to maintain levels within a seasonal range of 1.05 m. Under the current water level management strategy, the water level rapidly increases in the spring and summer, resulting in high lake levels during early plant growth. This is followed by allowing the water levels to gradually decrease through the fall to achieve a drawdown in the winter to prevent ice damage along the lake shores and to be prepared for moderating spring runoff levels (Krug, 1981).

The current seasonal pattern of water level management may impact aquatic vegetation in several ways. First, higher spring and summer water levels coupled with high turbidity from spring runoff of the largely agricultural watershed, especially during the critical growth period from April to June, may reduce the availability of light necessary to achieve earlier and faster plant growth and decrease the rate of warming of the sediments. This effectively shortens the growing season for the plants and decreases the capacity of the plants to shunt energy into vegetative growth and production of overwinter propagules with larger energy stores, thereby adversely affecting propagation and reproduction (Kahl, 1993). In addition, higher water levels may also increase exposure to wave attack and susceptibility to other stresses such as damage by boaters and spawning activity by common carp among plants that are flowering and producing vegetative propagules. A combination of longer durations of high water levels and poor water clarity may greatly affect expansion and re-colonization. Lower water levels in the fall increase the exposure of the shoreline to wave action, especially during fall storms, resulting in shoreline erosion and resuspension of bottom sediments. Gradually decreasing water levels during this period expose successively deeper portions of a particular stand to increasing wave action at the shoreline. Drawdown during the winter may leave parts of the root system and reproductive structures exposed to destructive sub-freezing temperatures, while ice movement in shallow areas could physically disrupt senesced plants and root masses, especially on the outer edges of stands.

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Prior to the construction of two dams at the outlets of Lake Winnebago in the 1850s, the Lakes were fertile riverine marshes with dense emergent vegetation (Linde, 1975). As late as 1943 the Lakes supported a greater diversity and abundance of aquatic macrophytes than any other wetlands in Wisconsin with the exception of the Upper Mississippi River; by 1953, abundance and diversity had noticeably declined (Zimmerman, 1953). Since damming the marshes have gradually been transformed into large, turbid open-water lakes. Changes in water level regimes and increased sediment and nutrient loads due to agricultural practices and urbanization have contributed to the loss of tens of thousands of hectares of wetland habitat (Linde, 1979). The decrease in emergent vegetation was particularly rapid after 1930, especially influenced by high water levels.

The lakes continue to be hyper-eutrophic and turbid (Lillie and Mason ,1983), not only due to agricultural and urban inputs (Northeast Wisconsin Waters for Tomorrow, 1994), but also due to increasing exposure and erosion by wave action and ice scour of shoreline substrates formerly protected by vegetation. This is further aggravated by the long fetches and shallow depths of the Lakes which allow frequent resuspension of fine material (Sloey and Spangler, 1977). The mean secchi disk depth for the Lakes is 0.25 meters, indicating a very limited photic zone for aquatic vegetation (Wisconsin Department of Natural Resources [WDNR], 1989). Sediment input from the watershed and from erosion of shallow areas has posed several other system-wide problems including destruction of fish spawning areas and the filling of naturally deeper areas and navigational channels and harbors, which requires extensive dredging (WDNR, 1989).

The extensive loss of wetland habitat is an important concern as the Winnebago Pool Lakes support a diverse and unique fish and wildlife community, including the largest lake sturgeon population in the US (ECWRPC, 1989). However, numbers of this species as well as many others, have been declining despite intensive management efforts (Sherry, 1997). Of the 17 inland fish species of special concern to the Wisconsin Department of Natural Resources, 14 are found in the Winnebago System watershed with four of these occurring in the pool lakes. Notable wildlife uses of the lakes include 120,000 to 170,000 diving duck use days per annum, and the lakes provide habitat for 260 pairs of Forster terns, a state listed endangered species, and 100 pairs of common terns (WDNR, 1989). Some piscivorous fish species such as walleye and sauger have maintained relatively stable numbers, but populations of northern pike, largemouth bass, muskellunge have significantly declined, primarily due to changes in water quality and habitat losses. Other species such as freshwater drum, white bass and gizzard shad have thrived as a result of the changed conditions, causing increased interspecific competition for food and cover, increased predation on desirable sport fish, and shifts in trophic webs (WDNR, 1989). Population estimates for 1986 indicate that the lake system supports 80 million freshwater drum compared to a total of 8.5 million sportfish (Coshun, 1987). In addition, the water quality conditions have allowed exotic species like the common carp to thrive as well, further contributing to the ongoing problem of water turbidity (Sloey and Spangler, 1977), interspecific competition, and destruction of aquatic vegetation (WDNR, 1989).

Since the Winnebago Pool Lakes were created, extensive stands of common reed (*Phragmites australis*) have grown in scattered patches throughout the system. Although common reed is often treated as a nuisance species, the dense, monotypic stands in the Winnebago Pool Lakes mark the former outer margins of thousands of hectares of marshes which have been lost through increases in water levels, shoreline erosion, and widespread loss of other emergent plants, particularly cattails (*Typha* spp.)(Linde, 1975). Consequently, many of these stands now occur off shore in water up to 1.5 meters deep. These midwater common reed stands, apparently unique worldwide with respect to their location, have persisted for decades, despite having been subjected to a variety of stresses, including imposed water level regimes with winter drawdowns, wave action, boating activity, rough fish feeding and spawning, and competition with intrusive algal growths. However, recent observations suggest that these stands have been diminishing in both size and vigor and that the rate of deterioration in the past 10 to 15 years has been accelerating (Rudebeck 1997; Techlow 1997). In Lake Poygan one of four major stands suffered a 94% decrease in spatial coverage since 1985 with most of the losses occurring in only two years (Gabriel and Bodensteiner 1998). Declines in other stands ranged from 2% to 65%. Although stands were historically present in all four Pool Lakes and are still extant in all but Winnebago, changes in spatial extent of common reed stands has not been quantified, nor has an assessment of the current status of common reed stands been conducted with the exception of Lake Poygan (Gabriel and Bodensteiner 1998).

Until losses were noticeable, little effort was directed to understanding the ecological functions of midlake common reed stands within the system. Although limited in spatial extent, attributes suggest that the common reed functions as a keystone species in the ecosystems of the

Pool Lakes. In addition to typical wetland functions such as furnishing habitat and nutrition for a variety of microbial and macroinvertebrate species, maintaining water quality by storing nutrients, binding substrate material and preventing erosion, and providing open space and aesthetics for both consumptive and non-consumptive outdoor activities, these stands also serve some unique functions. Because of their midwater location they offer habitat free of terrestrial predators and have already been identified as extremely important in providing food, cover, and nesting or spawning substrates for a number of waterfowl, other bird species, and fish. By reducing the fetch and stabilizing lake bottom sediments, they also prevent erosion and wave-induced sediment resuspension (Kahl, 1993; Nichols and Vennie, 1991). In Lake Poygan, Gabriel and Bodensteiner (2000) observed that diverse aquatic plant communities consisting of both emergent and submergent plant types were associated with common reed stands on the side leeward to the prevailing wind, suggesting that the stands provide refuges conducive to establishment and growth of other aquatic macrophytes.

A major water quality problem in the Pool Lakes is the summer "bloom" of filamentous and other forms of algae. As primary producers with rapid growth during the summer, common reeds function as a sink for nutrients, particularly nitrogen and phosphorus. Although the hyper-eutrophic state of their lake habitat can be attributed to external nutrient loading via runoff from agricultural and urban areas, this condition may be exacerbated by internal loading when phosphorus bound to sediment particles is suspended from the substrate by wave action and thus made available to phytoplankters such as filamentous forms of algae. Since these lakes do not seasonally stratify, this effect can occur over the bottom of the entire system. The reduced fetch, downwind protection, and the substrate stability afforded by common reed stands can counteract this internal loading mechanism. Additionally, aquatic macrophytes such as common reed are at a competitive advantage over phytoplankton for nutrients, and so they can reduce the amount of nutrients available to phytoplankton for growth and reproduction. The result is greater water clarity, increased light penetration, and thus more available substrate for plant colonization, creating a positive feedback for establishment of macrophyte stands and reduction of phytoplankton.

The reduction in sediment and nutrient loading provided by common reed stands has other regional-scale benefits, as it helps improve downstream water quality and habitat in Lake Winnebago, the Lower Fox River, and ultimately Green Bay, Lake Michigan. These benefits in turn help meet regional management goals, including a goal of 50% reduction in phosphorous and total suspended solids outlined in the lower Green Bay Remedial Action Plan, and a similar 30% reduction called for in the Winnebago Comprehensive Management Plan (WDNR, 1989).

RESEARCH OBJECTIVES

The impetus of this project is to restore, improve, and maintain the ecological diversity and quality, and beneficial uses of the fish, wildlife and water resources of the Winnebago Pool Lakes. To accomplish this, we developed information necessary for the management, protection, and rehabilitation of midlake wetlands in the Winnebago Pool Lakes, addressing the following objectives:

1) Developed a historical, quantified record of changes in the spatial characteristics of common reed stands on the Winnebago Pool Lakes, including spatial extent, distribution, shape, and fragmentation;

2) Developed baseline information on the current status of individual common reed stands, including stem density and uniformity of distribution within stands;

3) Assessed the relationship between changes in the spatial extent of common reed beds and hydrological factors; and

4) Identified the public's perception of the ecological importance of common reed stands and the willingness to alter use patterns to facilitate preservation and restoration of these stands; and

The project also helps fulfill a number of goals, objectives and management options outlined in the Winnebago Comprehensive Management Plan (W DNR, 1989). First, the project helps address the management plan's principal goal to restore, improve, and maintain the ecological diversity and quality, and beneficial uses of the fish, wildlife and water resources of the Winnebago System. Secondly, the project addresses the following objectives outlined in the management plan:

1) increase the relative abundance of desirable emergent aquatic macrophyte beds (identified as critical);

2) develop an acceptable water level management regime that maximizes the system's potential to produce aquatic habitat, while balancing the system's various resource users' needs (identified as critical); and

3) inventory critical fisheries and wildlife habitat within the system.

Lastly, the project directly addresses the following management options outlined in the management plan:

1) survey and monitor aquatic macrophyte abundance and distribution on pool lakes, including the stability of common reed beds; and

2) model the relationships between water levels of the Upriver lakes to determine impacts of various levels on habitat.

METHODOLOGY

Study Sites

Currently, common reed stands are found in Lake Poygan, Lake Butte des Morts, and Lake Winneconne. Thirteen distinct stands, comprised of 84 individual patches, were identified in the Winnebago Pool Lakes, including: 1) East Channel, 2) West Bay, 3) Lone Willow, 4) Hindenburg Line - Lake Poygan, 5) Hindenburg Line - Lake Winneconne, 6) Wentzel Shores, 7) Clarks' Bay, 8) Wentzel Marsh, 9) Lasley's Point, 10) Terrel Island, 11) Plummer's Point, 12) Sunset Bay, 13) Miller's Bay, and 14) Highway 41((Figs. 1a and b).

Data Collection

Data was collected to determine the spatial characteristics and present status of common reed stands, as well as historical water level fluctuations.

1) Spatial Characteristics

Data collection began by compiling a historical record of changes in common reed acreage. This is an appropriate method of establishing historical changes as common reed has a particularly good signature on aerial photographs (Perciasepe and Tippie, 1996). The primary sources for this analysis were aerial photographs provided by a variety of sources, including the Wisconsin Department of Natural Resources (WDNR), Winnebago County Natural Resource and Conservation Service (NRCS) and Farm Service Agency (FSA), as well as the Robinson Map Library, UW-Madison. Shorter annual aerial photograph records of submerged and emergent aquatic vegetation in the Winnebago Pool Lakes system have also been collected by A. Linde and R. Kahl, Wisconsin DNR, for the mid-1970s and1986-94. An additional set of photographs was taken in August 1997 -1999, following the same flight paths and other protocols used for the 1986-94 data set. The photos used needed to be taken between late June and August, after the ice cover had melted, and following emergence of common reed.

The aerial photographs and map records were analyzed to determine spatial changes in the four cane beds being studied. Important spatial metrics used to identify landscape changes often include: 1) area; 2) edge metrics (e.g. perimeter of canebeds, total perimeter, perimeter to area ratios); 3) nearest neighbor analysis; and 4) shape metrics such as a shape indices that compare patch shapes to a circle which would have minimum perimeter/area (e.g. Ritters et al., 1992, 1995). Because of the method of data collection used in this study, the spatial metrics used principally compared changes and differences in area and edge metrics for the period of record (1937-99).

Image analysis was conducted in accordance with our previously established methods using public domain image analysis software available through the National Institute of Health (NIH Image Pro, Scion Corporation). Aerial photographs and slides were scanned in and cropped using Adobe Photoshop 4.0. The scanned images were imported into NIH Image Pro, which analyzes images relative to the number of pixels that correspond to a known distance. Distance per pixel was calibrated for each image set using the known distance of a feature common to the data sets, thereby allowing accurate analysis of images at different scales and in different formats (i.e. slides and aerial photographs). After manually tracing the onscreen image of each patch, NIH Image Pro automatically calculated such measures as area and perimeter lengths. Measurements were duplicated twice for each patch, and the average measurement was calculated and recorded.

This data collection method was used primarily due to the tremendous effort and cost that would be associated with photogrammetrically rectifying and digitizing the large number and variety of aerial photographs and maps that had to be examined to provide a reasonable historical record. Such an expensive and involved process, while beyond the scope of this preliminary project, would be necessary to establish the coordinates to input the digitized outlines of cane beds and accurately compare changes in such measures as location and shape for successive years using a geographic information system.

2) Field Site Characteristics

The patches of each common reed stand were sampled in regards to stem densities, as well as water depth ranges on the perimeter and the interior of each patch. Both stem densities and interior water levels were measured along systematically spaced transects running perpendicularly through the long axis of each patch. The number of transects ranged between 2-5 for each patch, depending on its size. Stem densities were measured counting live common reed stems within a floating, 1 square meter quadrat. Stem density measurements were taken 1 m within the perimeter at each end of the transect, as well as on two randomly determined points in the interior of the stand, usually along a transect. Interior water depths were taken every 5 m along each transect, following a calibrated floating line and using a depth pole. In addition, perimeter water depths were taken every 5 m along the perimeter of most patches in each stand; smaller patches had at least 4 perimeter measurements taken at the cardinal compass points.

In 1997, 40 different patches were identified and measured within the 4 stands located in Lake Poygan, including 332 stem density measurements, 610 interior water depth measurements, and 1435 perimeter water depth measurements. In 2000, an additional 44 patches were identified and measured within the 10 remaining stands located in Lakes Butte des Morts and Winneconne, including 451 stem density measurements, 698 interior water depth measurements, and 2632 perimeter water depth measurements. The different number of samples taken primarily reflect the variation found in each stand of the study site (e.g. size of stands, number of within-stand patches, high variability of water depths along the periphery, obvious differences in stem densities). Water depth information collected at each study site was also standardized relative to 2.95 ft. gage levels on Lake Poygan and Lake Winnebago.

3) Survey of Stakeholders

The demise of mid-lake common reed stands is due in part to anthropogenic disturbances caused by both consumptive and non-consumptive recreational users of the lakes. The non-consumptive user groups consist of recreational boaters, including skiers and personal watercraft operators, snowmobile operators, swimmers, and wildlife observers, while consumptive users are largely composed of anglers and waterfowl hunters. Direct impacts to these wetlands have been observed as a result of passage of watercraft and persons through the stands thereby creating passages through and openings within individual patches. Snowmobile paths through stands are evident in growth patterns the following summer (Kahl, 1993). However, indirect impacts, such as watercraft wake action and hydrocarbon emissions in the near vicinity of stands, also likely serve as stressors to plant health.

To reduce immediate anthropogenic stresses on the stands, several management options are available. In order of increasing impact to users some of these are 1) creation of no-wake zones, 2) restriction of access into stands, seasonally or year round, and 3) erection of physical barriers around stands. However, implementation of any of these requires legislative action at the state level in Wisconsin. To address the long-term stressors the current annual water level management scheme may also have to be altered. Therefore, any protection to be afforded to these wetland communities is dependent in large part on the public perception of their importance to the system and their willingness to restrict historical activities in the vicinity of these ecological communities and to adapt to changes in seasonal water levels. Furthermore, any intrusive approach to vegetation management such as through rehabilitation and restoration of previous areal coverage or creation of new stands only underscores the need for public acceptance.

We assessed public perception and willingness to protect these mid-lake wetland habitats by conducting a closed survey among the various types of users and others with a particular interests in lake management including a mail survey of shoreline property owners (56 respondents) and county and state agency personnel directly responsible for lake resources, including the Winnebago Land and Water Conservation Department and the Wisconsin DNR Land and Water Team for the Fox-Wolf Basin (19 respondents). Various other users were accessed at the monthly meetings of specific recreational user groups including two sportsmen's clubs (Butte des Morts Conservation Club and Lake Poygan Sportsman's Club - 44 respondents), a boating club (Tri-County Powerboat Alliance - 30 respondents), and the local chapter of the Audubon Society (23 respondents). A copy of the survey may be found in the Appendix.

The goals of the survey were: 1) to identify the level of recognition among the various stakeholders of the potential importance of mid-lake wetland habitats; and 2) to identify the degree of willingness to preserve existing stands, restore historical stands, and create new stands.

FINDINGS

Spatial Changes in Winnebago Pool Lake Common Reed Stands

From the aerial photo analysis, it is clear that many of the common reed stands have shown significant declines in both total area and total perimeters since either 1937 or 1950 (depending on the availability of aerial photographs) (Tables 1a-c; Figs. 2a-c, 3a-c). The largest decrease is most evident in East Channel, having decreased 94% in area since 1937, as well as in total perimeter (83%) (Table 1b). These tremendous losses are followed closely by those of Hindenburg Line - Lake Poygan, where a 65% loss in area has occurred since 1937, as well as a 54% decrease in total perimeter. Since 1950, heavy losses have also been experienced by common reed stands in Lake Butte des Morts, as shown by the 47% decrease in the Highway 41 stand and the 38% decrease in the Plummer's Point stand (Table 1a). The only common reed stands increasing in size since 1937 occur in Lake Winneconne, including an 186% increase in the Clark's Bay stand due to an additional patch being isolated from the adjacent shoreline, and a 163% increase in the Wentzel Marsh stand (Table 1c). The Lasley's Point stand has also increased 66% in size since 1971. This latter statistic may be somewhat misleading as substantial losses may have occurred already before the available photographic record, and as many other stands show lows in areal extent in the early 1970s with subsequent recovery in the late 1980s (Figs. 2a-c, 3a-c). Lone Willow has been the most stable of the common reed stands, having lost only 2% of its area since 1937, and 3% of its perimeter (Table 1b; Figs. 2b and 3b).

Besides absolute losses, it is also interesting to compare the temporal pattern of decline in area and perimeter for the stands experiencing the heaviest losses. The heaviest losses of area in East Channel occurred between 1937-1971, with the heaviest losses occurring between 1957-71 (Fig. 2b). Similarly, Hindenburg Line - Lake Poygan's area also decreased most dramatically between 1937 and 1971, though the heaviest losses occurred earlier, between 1937 and 1950. As with many of the other common reed stands, both the East Channel and Hindenburg Line - Lake Poygan stands experienced resurgences in area in the late 1980s, peaking in 1988, and subsequent declines from 1989 to the present (though much heavier losses were experienced within

East Channel). The fluctuations and declines in aerial extent are generally less dramatic in most of the other stands that have not increased in size, Terrel Island being a notable exception due to extreme lows in areal extent occurring in the 1970s (Figs. 2a-c).

The temporal pattern of changes in total perimeters is generally similar to that of changes in area (Figs. 3a-c). As one would expect, the most extreme losses have occurred in East Channel and Hindenburg Line - Lake Poygan, coinciding with the highest losses in aerial extent, while the lowest losses and least variation have occurred in Lone Willow, indicating a fairly regular area and shape. Total perimeters in most of the other stands have fluctuated over the years, closely following the pattern of changes in area.

The average size and perimeter of reed patches within the stands indicate the smallest average sizes and perimeters presently occur in the Highway 41 and East Channel stands, while the largest occur in the Lone Willow and Sunset Bay stands (Table 1a-c; Figs. 4a-c, 5a-c). The East Channel stand has shown the largest decline in these measures, despite a brief resurgence in the 1980s. Average patch sizes and perimeters have increased in the three stands experiencing growth for the period of record, namely the Clark's Bay, Lasley's Point, and Wentzel Marsh stands (Table 1c; Figs. 4c and 5c), as well as the Miller's Bay and Sunset Bay stands (Table 1a; Figs. 4a and 5a). Average patch sizes and perimeters have fluctuated slightly in the other stands, though at present both the Hindenburg Line - Lake Poygan and West Bay stands have ultimately declined to their lowest values for the period of record (Table 1b; Figs 4b and 5b).

The history and pattern of fragmentation has been documented as well, indicated by the changes in the number of patches and perimeter/area ratios for each stand (Tables 1a-c; Figs. 6a-c, 7a-c). As with both decreases in area and perimeter, increased fragmentation is most apparent in the East Channel and Highway 41 stands. The historical pattern of fragmentation is particularly interesting to note in East Channel, which is characterized by periods of gradual increases in fragmentation and corresponding losses in area, culminating in periodic losses of the smallest patches and continued aerial losses and fragmentation in the patches that remain. In addition, the patches that remain in East Channel have tended to become increasingly smaller, as indicated both by average patch sizes and perimeters (Table 1b; Figs. 4b and 5b), as well as in the size and perimeter of the largest remaining patches (Tables 1a-c; Figs. 8a-c, 9a-c). Conversely, sizes and perimeters of the largest patches have increased in the three stands experiencing growth for the period of record, namely the Clark's Bay, Lasley's Point, and Wentzel Marsh stands (Table 1c; Figs. 8c and 9c), as well as the Miller's Bay stand (Table 1a; Figs. 8a and 9a). By comparison, the size and perimeters of the largest patches has remained fairly steady for the other stands, the exception being sharp declines experienced in the Hindenburg Line - Lake Poygan and Wentzel Shores stands between 1937 and 1950 (Figs. 8b-c and 9b-c). The size and perimeter of the largest common reed patch continues to be highest in the Lone Willow and Sunset Bay stands.

Sizes and perimeters of the smallest patches also vary between stands (Tables 1a-c). The largest of the small patches are part of the Lone Willow stand, while the smallest patches also tend to occur in the Lake Poygan stands (East Channel, Hindenburg Line, and West Bay) as well as the Terrel Island stand. As one would expect, the size of smallest patches has tended to decrease the most in common reed stands experiencing the greatest losses in area, the exception being the East Channel and Highway 41 stands. Similarly, the size of the smallest patches has increased in the common reed stands experiencing growth, including the Clark's Bay, Lasley's Point, and Wentzel Marsh stands (Table 1c).

Current Status of Winnebago Pool Lake Common Reed Stands

Common Reed Stem Densities

In 1997, average stem densities in the Lake Poygan stands were found to be highest in the Lone Willow stand, followed by the West Bay, Hindenburg and East Channel stands (Table 2b). Maximum stem densities were higher in Hindenburg Line and West Bay stands than the Lone Willow stand, though also lowest in the East Channel stand. Variability around the mean, as indicated by the standard deviations, are fairly consistent within three of the stands, with the East Channel stand having the least variation. This spatial pattern of stem densities, as a measure of stand health, is consistent with the findings of the aerial photo analysis; we would expect to find the greatest densities in the healthiest stands, as well as the greatest size and stability. Using these criteria, the Lone Willow stand was obviously the healthiest of the Lake Poygan common reed stands, while the East Channel stand was the least healthy.

In 2000, average stem densities were found to be highest in the Hindenburg Line and Wentzel Marsh stands on Lake Winneconne, and the Miller's Bay stand on Lake Butte des Morts (Table 2a,c). Stem densities tended to be lower in the Highway 41 and Sunset Bay stands on Lake Butte des Morts, and the Lasley's Point and Clark's Bay stands on Lake Winneconne. Maximum stem densities were higher in the Plummer's Point, Terrel's Island and Miller's Bay stands on Lake Butte des Morts, and the Wentzel Marsh stand on Lake Winneconne (Table 2a,c). Variability around the mean, as indicated by the standard deviations, are fairly consistent within most of the stands, with the Sunset Bay stand having the least variation. This spatial pattern of stem densities, as a measure of stand health, is not as consistent with the findings of the aerial photo analysis as the we found in 1997 with the Lake Poygan stands. For example, stem densities are highest in healthy, clearly expanding or fairly stable stands such as the Wentzel Marsh and Miller's Bay stand, and lowest in small, obviously declining stands such as the Highway 41 stand. However, smaller common reed stands experiencing high losses such as the Hindenburg Line - Lake Winneconne stand have much higher stem densities than larger, relatively stable or growing stands such as the Sunset Bay or Clark's Bay stands (Table 2a, c).

In 1997, we found several relationships between patch characteristics and stem densities in the Lake Poygan common reed stands (Table 3). For the entire set of stands, we found that maximum stem density was strongly and directly related to the size of the common reed patch, both in terms of area and perimeter (Spearman rank, 0.47, 0.49). Conversely, minimum stem density was inversely correlated with the two measures of patch size, area and perimeter (Spearman rank, -0.46-0.49), further supporting the inference that larger patches have higher stem densities. When we examined the ratio of perimeter to area, which increases as the edge of a common reed patch becomes more "ragged," we found that stem density was higher in patches that are more compact, i.e. less "ragged," and lower in "ragged patches." When we considered each of these factors on a stand by stand basis, the relationships proved even stronger in West Bay.

(Note: We could not conduct a similar correlation analyses for the Lakes Butte des Morts and Winneconne common reed stands, as we did not have aerial photographs corresponding to the field data to analyze and statistically compare.)

The results from the 1997 correlation analyses indicate that stem densities correspond to patch size and fragmentation. One reason for this may be that larger patches with less ragged edges are less exposed to outside sources of stress as wind and wave action, and therefore tend to have higher stem densities. Larger patch areas result in a greater proportion of individual plants being inside the margin of the patch, and "ragged" and irregularly shaped patches have a higher proportion of plants located on the margin as compared to regularly shaped patches of similar area with smooth margins.

Water Level Characteristics

Not surprisingly, the differences in perimeter and interior water depths between stands were both found to be significant in all the Upper Winnebago Pool Lakes (Kruskal-Wallis, $p<0.05$) (Table 2a-c). Perimeter depths were greater than interior depths for all the stands combined, as well as for individual stands, the exception being the Miller's Bay stand (Mann-Whitney U-test, $p<0.05$). The Wentzel Shores stand is also noteworthy in that its average interior water depths exceeded average perimeter depths, though the maximum water depth was still found on the perimeter of the stand.

In terms of interior water depths, the deepest average depths as well as the deepest minimum depths are found in the Highway 41, Plummer's Point, and Wentzel Shores stands (Table 2a-c). By comparison, the shallowest interior water depths are found in the Clark's Bay and West Bay stands. Interior water depths are more variable in the Sunset Bay, West Bay and Lone Willow stands, and less variable in the Highway 41 and Wentzel Shores stands, as indicated both by the water depths ranges and standard deviations. In terms of perimeter water depths, the deepest average depths as well as the some of the deepest minimum depths are found in the Highway 41 and Plummer's Point stands (Table 2a-c). By comparison, the shallowest perimeter water depths are found in the Clark's Bay and Lasley's Point stands. Perimeter water depths are the most variable in the Hindenburg Line - Lake Poygan and West Bay stands, as indicated both by the water depths ranges and standard deviations.

Effects of Water Depths and Fluctuations on Common Reed Stands

In the 1997 study (Gabriel and Bodensteiner, 1998), we found that the differences in interior and perimeter water depths were also related to differences in spatial characteristics within the Lake Poygan common reed stands (Table 4), especially in Hindenburg Line. Larger patches, indicated both by area and perimeter, tend to have higher maximum interior and perimeter water depths, as well as wider ranges of water depths (Spearman rank correlation coefficients, range: 0.66 - 0.93). Conversely, there tends to be a strong inverse correlation between perimeter/area ratios and maximum interior and perimeter water depths (coefficients ranging between -0.67 and -0.80), as well as a fairly strong inverse relationships between perimeter/area ratios and water level ranges (coefficients ranging between -0.48 and -0.68). These results seem to indicate that greater water depths may limit minimum patch size. (Note: We could not conduct a similar correlation analyses for the Lakes Butte des Morts and Winneconne common reed stands, as we did not have aerial photographs corresponding to the field data to analyze and statistically compare.)

We also found that common reed stem densities in the Lake Poygan common reed stands were inversely related to associated water depths for all the stands, but the relation was not a strong one (Table 5). Overall, higher stem densities were associated with shallower water. However, examination of individual stands produced stronger relationships between these factors for some stands, particularly West Bay and Lone Willow. The relationship between stem densities and water depths was considerably weaker for Hindenburg Line (-0.19), and was not significant for East Channel. We also found significant variations in stem counts between deeper perimeter locations and shallower interior locations in all the stands (Mann-Whitney-U, $p<0.05$)

By comparison, in 2000 we found that common reed stem densities were significantly different between stands in Lakes Butte des Morts and Winneconne (Kruskal-Wallis, $p<0.05$) (Table 2a-c). However, we did not find a statistically significant relationship between stem densities and associated water depths for all the stands combined in the two lakes (Spearman rank, $p<0.05$). In examining this relationship for individual stands, the only significant inverse relationship found between stem densities and associated water depths was found in the Miller's Bay stand (-0.62). We also did not find significant variations in stem densities between deeper perimeter locations and shallower interior locations in all the stands combined (Mann-Whitney-U, $p<0.05$), though we did find a significant difference in two individual stands, namely the Highway 41 and Wentzel Shores stands.

Both our observations in the field in 1997 and 2000 and the analysis of field data indicate that the relationship between water depths and stem densities is complicated by other factors. Intermediate depths, especially those near 1 foot on the Oshkosh gauge, appear to be subject to the greatest decline within patches. Both shallower and deeper areas did not seem to experience the same declines. We believe that stem densities represent an overall response to a variety of environmental stresses of which water depth plays a key role but also includes other stresses such as severity of winter temperatures.

The Impact of Extreme Water Levels

Our 1997 study used a Spearman rank correlation analysis to compare a variety of extreme water level scenarios with percent annual changes in Lake Poygan common reed stands for 1987-94 (Gabriel and Bodensteiner, 1998). This analysis found no significant relationship ($p<0.05$) between extreme winter, spring, and/or summer levels and spatial changes, either for all the stands or individually. These results seem to indicate that the recent losses of common reed cannot be solely attributed to differences in the duration of extreme winter, spring, and/or summer levels, but may be due to either a combination of extreme water levels and other factors (e.g. extreme winter temperatures). (Note: We could not conduct a similar correlation analyses for the Lakes Butte des Morts and Winneconne common reed stands, as we did not have a sufficient annual set of aerial photographs to analyze and statistically compare with water level data.)

Since 1985 the greatest losses of common reeds have occurred in East Channel. Large decreases in areal extent were evident in this stand in the summers of 1987, 1990, 1993, and 1994 (Fig. 10). Recovery occurred in 1988 and to a lesser extent in 1991, probably aided by lower summer levels. These changes correspond to the previous winter's duration of extreme water depths for the years up to 1991 with declines associated with longer periods of high water, as measured by the number of days below 1.38 feet at the Oshkosh gauge which represents the 25th percentile for this period. However, water levels prior to two of the three greatest declines, 1990 and 1993, were only slightly higher (1990) or actually lower (1993) than during other years, but during these two years the previous winter's temperatures were the most severe of this period, as measured by the number of days below -1 F (lower 25th percentile). This was especially true for winter 1992-93. A successive decrease in stand size in the summer of 1995 corresponded to the highest winter water levels recorded for this period.

Stakeholder Survey Results

The results of the management survey can be found in the Appendix (Tables 6-11).

In terms of the survey respondents, 31% of the sample was comprised of shoreline residents, while the remainder was fairly evenly distributed between the other various management and user groups (Table 6). The shoreline location of the riparian residences was principally on Lake Poygan (23%), Lake Butte des Morts (16%) and Lake Winneconne (11%), with over 50% of the residents having lived there for over 16 years. Two thirds of the remaining non-riparian stakeholders also lived within 10 miles of the Upper Winnebago Pool Lakes. Demographically, the majority of respondents were 41 years of age or older, well-educated, and above-average household incomes.

The majority of the stakeholders surveyed have used both the Upper Winnebago Pool

Lakes and the common reed stands for a wide variety purposes (Table 7). The majority of the respondents have used the Upper Pool Lakes for boating (74%), fishing (66%), and nature-watching (54%). While 90% of the stakeholders have seen the common reed stands on the Upper Pool Lakes, approximately 74% of the respondents have used the common reed stands directly as well, the principal uses including fishing (52%), nature-watching (31%), and hunting (25%). The majority (66%) of the respondents were also aware that the common reed stands are over 100 years old in the Winnebago System.

The majority of stakeholders surveyed were acutely aware of the many important functions provided by common reed stands in the Winnebago System, strongly agreeing with the importance of most functions, especially as habitat and recreational resources (Table 8). The one exception was that respondents were unsure of the importance of common reed stands for fur-trapping. The stakeholders were more divided in their perceptions regarding the primary sources of negative impacts to common reed stands (Table 9). The majority of respondents identified a number of stressors, either strongly agreeing or agreeing that high water levels, water pollution, winter recreational vehicles, pleasure boating, jet skiing, and fishing in the common reed stands have negatively impacted the stands, especially pleasure boating and jetskiing in the canebeds. Fewer stakeholders agreed that water fowl hunting, fishing near the common reed stands, or low water levels negatively impact the stands, though 27% of the respondents stated they did not know the impacts of the latter.

In terms of management of common reed stands, the majority of stakeholders supported a number of management options, though tending to principally favor protection and restoration of common reed stands, public awareness campaigns, and prohibiting boats from entering the stands (Table 10). In terms of seasonal restriction of boat entry, a slim majority of the stakeholders (52%) believed the restrictions should occur throughout the year. Of the remaining respondents, 33-35% felt the restrictions should only occur in the spring or summer, while only 12% of the stakeholders supported restrictions in the fall, which would principally impact waterfowl hunting . While still the majority of respondents (69%), fewer stakeholders agreed with the option of creating new common reed stands or manipulating water levels to protect common reed stands.

Stakeholders were also asked their preference in regards to a range of future water level management scenarios for protecting common reed stands, including maximum summer and minimum winter targets (Table 11). In terms of the various options for each target level, the majority of respondents would prefer the water levels to remain the same, especially winter levels (40-60%). For those preferring changes to maximum summer levels, slightly more respondents wanted these levels to be raised (30.5%) than lowered (30.1%), though in either case the majority would prefer the change to be minimal (less than 6 inches). More respondents preferring changes to the minimum winter levels wanted them raised by as much as one foot (22%) rather than lowered (17%). These findings help illustrate the political difficulties in achieving consensus on a single water level management plan and "ideal" water level targets, even amongst a stakeholder group largely supportive of common reed stands, never mind including additional interests like marinas, power companies, and water utilities.

CONCLUSIONS AND RECOMMENDATIONS FOR MANAGING COMMON REED STANDS IN THE WINNEBAGO UPPER POOL LAKES

Conclusions

While deterioration may be expected in a situation of unprecedented, constant inundation, the acceleration of reed stand losses may not be simply correlated with the patterns of water level management currently being practiced on the Winnebago System. East Channel, for example, has almost completely disappeared, while other beds growing in comparable water depths retain a great deal more vigor (e.g. Lone Willow). Furthermore, the patterns of deterioration within individual beds found by the field survey simply do not match existing water level conditions. In some cases, shallow areas (15 - 50 cm water depth) are almost denuded of plants, while deeper areas (.75 - 1.2 m water depth) remain thickly populated. Such spatial patterns seem to belie the simple answer of high water level impacts; if the problem were simply one of die-off due to continued high water levels, we would expect the deeper areas to be losing common reed coverage. Such is clearly not the case.

We believe the pattern of reed decline is due to a number of cumulative stresses, many of which relate in part to the seasonal pattern of water level management that has remained essentially the same over the last 30 years (Fig. 11). Winter drawdown may leave root systems and reproductive structures at intermediate levels more susceptible to damage by ice shove and destructive sub-freezing temperatures, particularly during winters with especially severe winter temperatures. Ice shove damage may occur particularly in shallow areas, where ice movement could physically disrupt senesced plants and root masses, especially on the outer edges of stands. Root systems below the winter water line are protected and less susceptible to such damage, while higher elevations in the stands, while still exposed to frost damage, may be less susceptible to ice shove damage as the water table falls below the rhizome mat.

Repair of winter damage is subsequently hampered by the pattern of higher spring and summer water levels coupled with high turbidity from spring runoff of the largely agricultural i.e. ice + freezing w/ subsequent high water growing conditions

watershed, especially during the critical growth period from April to June, may reduce the availability of light necessary to achieve earlier and faster plant growth and decrease the rate of warming of the sediments. This effectively shortens the growing season for plants and decreases the capacity of these plants to shunt energy into vegetative growth and production of overwinter propagules with larger energy stores, thereby adversely affecting propagation and reproduction (Kahl, 1993). In addition, higher water levels may also increase exposure of the weakened plants to wave attack and susceptibility to other stresses such as damage by boaters, algal wash, and spawning activity by common carp among plants that are flowering and producing vegetative propagules.

Obviously stresses related to higher spring and summer water levels would be greatest in deeper water, and affect the plants most weakened by winter damage (i.e. the plants found at intermediate levels at more exposed locations in the stands). A combination of longer durations of high water levels and poor water clarity may also greatly affect expansion and re-colonization of damaged patches. Finally, lower water levels in the fall increase the exposure of the shoreline to wave action, especially during fall storms, resulting in shoreline erosion and resuspension of bottom sediments. Gradually decreasing water levels during this period expose successively deeper portions of a particular stand to increasing wave action at the shoreline.

While common reed is more often treated as a nuisance in other ecosystems, with the goal being to eliminate or reduce stands rather than enhance them, the dramatic losses in common reed stands identified by this study has grave implications for the Winnebago System. Although limited in spatial extent, attributes suggest that the common reed functions as a keystone species in the ecosystems of the Pool Lakes (Gabriel and Bodensteiner, 2000). In addition to typical wetland functions such as furnishing habitat and nutrition for a variety of microbial and macroinvertebrate species, maintaining water quality by storing nutrients, binding substrate material and preventing erosion, and providing open space and aesthetics for both consumptive and non-consumptive outdoor activities, these stands also serve some unique functions. Because of their midwater location they offer habitat free of terrestrial predators and have already been identified as extremely important in providing food, cover, and nesting or spawning substrates for a number of waterfowl, other bird species, and fish. By reducing the fetch and stabilizing lake bottom sediments, they also prevent erosion and wave-induced sediment resuspension (Gabriel and Bodensteiner, 2000; Kahl 1993; Nichols and Vennie 1991).

During our three field seasons (1997, 1999, 2000), we observed that diverse aquatic plant communities consisting of both emergent and submergent plant types were associated with common reed stands on the side leeward to the prevailing wind, suggesting that the stands provide refuges conducive to establishment and growth of other aquatic macrophytes (Gabriel and Bodensteiner, 1998; 2000). Common reed stands provide food, substrate, and shelter for both attached and free-living micro- and macro-biota. The submerged stems in water depths up to 1.5 m are well-suited to serving as larval fish nursery areas, and the habitat complexity would provide food and shelter for both predators and prey. In addition, the shading of the stands results in cooler interior waters, conducive to survival and growth of young-of-the-year fish and other organisms, especially in summer. Stands of many aquatic plant species including submergent, emergent, and floating leaf types occur in association with common reed grass stands, particularly on the leeward side from the prevailing wind.

Common reed stands may influence the trophic status of the Pool Lakes through both physical and biological effects. Physically, the extensive and persistent mats of rhizomes formed during plant growth stabilize the lake bottom by protecting it from erosion by wave action. These mats remain up to years after the plant has died, as observed in former stands on Lake Poygan. In addition, the density of plant stems within stands exerts considerable resistance to water movement, thereby reducing the fetch and decreasing wind-induced turbidity. In Lake Poygan, the substrate on the east sides of the larger stands consisted of much softer, finer material than the sand and hard clay bottom on the side toward the prevailing wind, suggesting that the stands also afford sedimentation sites for suspended solids (Gabriel and Bodensteiner 1998; 2000).

Management Recommendations

Given the findings of this study, as well as the many important functional roles of common reed stands, we are providing the following recommendations for the management, protection, and possible rehabilitation of common reed stands in the Upper Winnebago Pool Lakes:

1) Restoration

At this point the ability to restore previously lost areas of the common reed stands is extremely limited, based on our restoration experiments and previously conducted work (Gabriel and Bodensteiner, 2000). The success of restoration efforts is dependent in part on uncontrolled factors, the most prominent of which are water levels and weather. The success of our restoration efforts was in part affected by water levels that rose well above management targets for a critical part of the growing season, approximately 1-2 weeks after our initial planting. Submerging new common reed plants and stems, even for relatively short periods, inhibits photosynthesis and prohibits the exchange of oxygen to the roots of the plants, limiting successful establishment of new, healthy rhizomes that will be able to store enough energy to survive the winter and regenerate in the spring. In addition, the stems of the submerged plants are quickly colonized by algae, limiting photosynthesis and submerging the stems further.

Future restoration efforts may attempt planting previously established potted plants, preferably 1-2 years old, which were unavailable for our pilot study. However, any replanting of areas where common reed plants previously existed will face the challenge of having to establish healthy plants in one growing season in water depths of approximately 2.0 feet in July, providing water levels are kept near management target levels throughout the Winnebago Pool. The occurrence of water levels above management targets, even for short time periods, will likely dramatically impact the success of the restoration effort.

Additional restoration efforts may also be attempted in conjunction with pilot structural protection projects, as protecting the new plants from the stresses of wave attack and ice shove may also be critical to their success. Structural protection may also allow raising the substrate, which could then be more easily planted with common reed plants, although this may alter the current ecological characteristics of the stands.

2) Water Level Management

Our historical analysis of changes in Lake Poygan common reed stands over the last two decades has shown that differences in water levels do contribute to increases and decreases in size. Our restoration efforts have also shown that water levels can influence the health and success of new common reed plants (Gabriel and Bodensteiner, 2000). It follows that changes in water level management on the Winnebago Pool could be used to both protect and restore common reed stands, the most obvious of which is lowering summer water levels. For example, the lower water levels experienced in 1988 led to a resurgence in common reed area in the Upper Winnebago Pool Lakes, though the gains were short-lived in most of the stands.

Water level management of the Winnebago Pool also needs to be more system-based, rather than narrowly focused on maintaining target levels in Lake Winnebago, which often occurs at the expense of the Upper Pool Lakes. Rigidly maintaining summer target levels in Lake Winnebago often leads to higher water levels over extended periods in the Upper Pool Lakes, especially following high magnitude rain events in the upper portion of the watershed. The higher stream flows are stored in the Upper Pool Lakes, which drain slowly into Lake Winnebago, leading to sustained high water levels that negatively impact the vitality of common reed stands. On those occasions, the Wisconsin DNR should encourage the Army Corps of Engineers to drop the level of Lake Winnebago below target levels to assist flows out of the Upper Pool Lakes and return the system to water levels more conducive to protecting, maintaining and enhancing wetlands.

However, the impacts of additional changes to current water level management and target levels are less obvious, and may produce counterproductive results. For example, a combination of changes in winter drawdown and spring target levels may expose higher or lower elevations of the common reed stands to ice shove damage and wave attack, further increasing losses in common reed area. Before additional changes are made to water level management, more research needs to be conducted examining the possible impact of different water level regimes on common reed stands at various water depths and at various stages of the common reed life cycle. In particular a detailed bathymetry of the areas in and around the common reed stands should be developed to enable prediction of areas that will be affected by alterations in water levels.

Given the results of the stakeholder survey, changing water levels may also be a difficult management solution to implement politically. While 69% of the respondents were in favor of manipulating water levels to protect common reed stands (Table 10), the majority of respondents would prefer the water levels to remain the same, especially winter levels (40-60%)(Table 11). Reaching a consensus on water levels will be difficult even for those preferring changes. In terms of maximum summer levels, slightly more respondents wanting changes wanted these levels to be raised (30.5%) than lowered (30.1%), though in either case the majority would prefer the change to be minimal (less than 6 inches). More respondents preferring changes to the minimum winter levels wanted them raised by as much as one foot (22%) rather than lowered (17%). These findings help illustrate the political difficulties in achieving consensus on a single water level management plan and "ideal" water level targets, even amongst a stakeholder group largely supportive of common reed stands, never mind including additional interests like marinas, power companies, and water utilities.

3) Protection

Given the lack of success in actively restoring common reed stands, as well as the improbability of dramatic changes to current water level management and the uncertainty of the impacts such changes may have, effort should be focused on preventing possibly irreversible annual decreases and preserving increases, both through restricted access and limited structural protection. The stakeholder survey found that 85% of the respondents strongly supported protection of common reed stands (Table 10).

Restricted Access

First and foremost, all attempts should be made to restrict access into existing stands of vegetation. As has been noted and underscored by past research (e.g. Kahl, 1993), traffic by boats, jet skis, and snowmobiles leaves evident patterns of vegetation destruction. We also noted this during our field work in July, 1997, especially after weekends. Since the long-term successive pattern of common reed stand decline appears to progress through steps beginning with fragmentation of stands into smaller patches, additional sources of vegetation destruction that promote fragmentation and increase the exposure of stands to wind and waves, such as boat traffic, need to be stopped. Another mechanism by which snowmobile traffic adversely affects the stands may be through the destruction of standing dead stems, which have been implicated as essential to gas exchange within the rhizome mat. Accumulation of phytotoxic gases, such as hydrogen sulfide, has been identified as a cause of common reed death, and loss of one source of gas exchange, i.e. through the stems, would aggravate the effects of phytoxins both by preventing ventilation and reducing influx of oxygen to the rhizomes.

Several approaches may be utilized to accomplish protection prior to a state-mandated closure of these areas. Public education is one of the most important of these mechanisms. Educating the public can be accomplished through the various organizations with an interest in this resource. One group of these is the sportsmen's clubs, since common reeds are important both to waterfowl feeding and resting and to fish as spawning and nursery habitat. Other groups include natural history organizations such as local chapters of the Audubon Society as common reeds provide essential nesting and feeding habitat, in this case free from all but avian predators. In addition those organizations representing recreational interests, such as boat, ski and snowmobile clubs, should be approached for assistance in this task. Essential to this task is the development graphic materials such as brochure or pamphlet discussing the history, ecological significance, and current status of these stands. While the stakeholder survey indicated a great understanding of the ecological importance and stressors of common reed stands (Table 8), the general public may not be as knowledgeable. In fact, approximately three quarters of the stakeholders surveyed strongly supported more public awareness campaigns (Table 10).

In addition, all stands should continue to be posted requesting voluntary cooperation with a moratorium on passage into or through these stands. Since the stands also serve to provide habitat for a variety of aquatic vegetation and provide a substantial fishery, an alternative to a complete moratorium in vegetated areas surrounding the stands would be to designate these areas as no motors with the request that motors be removed from the water when passing into or through these areas.

Reaching agreement on moratoriums on boat entering the common reed stands may also prove to be difficult. In terms of seasonal restriction of boat entry, a slim majority of the stakeholders surveyed (52%) believed the restrictions should occur throughout the year (Table 10). Of the remaining respondents, 33-35% felt the restrictions should only occur in the spring or summer, while only 12% of the stakeholders supported restrictions in the fall, which would principally impact waterfowl hunting.

Structural Protection

Any initial shore protection efforts should be viewed as investigative because of the number of factors affecting the common reed stands. Based on our studies and the pattern of vegetation loss, the most consistent factors affecting common reed stand decline are the interaction of water levels and winter severity in terms of low temperatures, as well as location. Those areas most affected consistently correspond to a water depth of approximately 2.0 feet in July, which is represented by a 1.0 foot elevation at the Oshkosh gauge. This depth is intermediate between the depths at which we observed apparently healthy patches of common reeds, which ranged from 0 feet deep to 4 feet deep in July, 1997. In addition, the areas showing the greatest declines are often located on the windward edges of the common reed stands, which are more exposed to ice shove and wave attack, both of which may contribute to common reed losses at intermediate depths.

Pilot structural protection projects should be based on the pattern of vegetative loss, focusing on portions of common reed stands having experienced the most recent and extensive losses, as well as those exhibiting similar environmental conditions leading to greater vulnerability, primarily exposed, windward locations and intermediate water depths. In addition, such efforts should be limited in scale, and experiment with a number of structure types designed cooperatively between Wisconsin DNR biologists and engineers.

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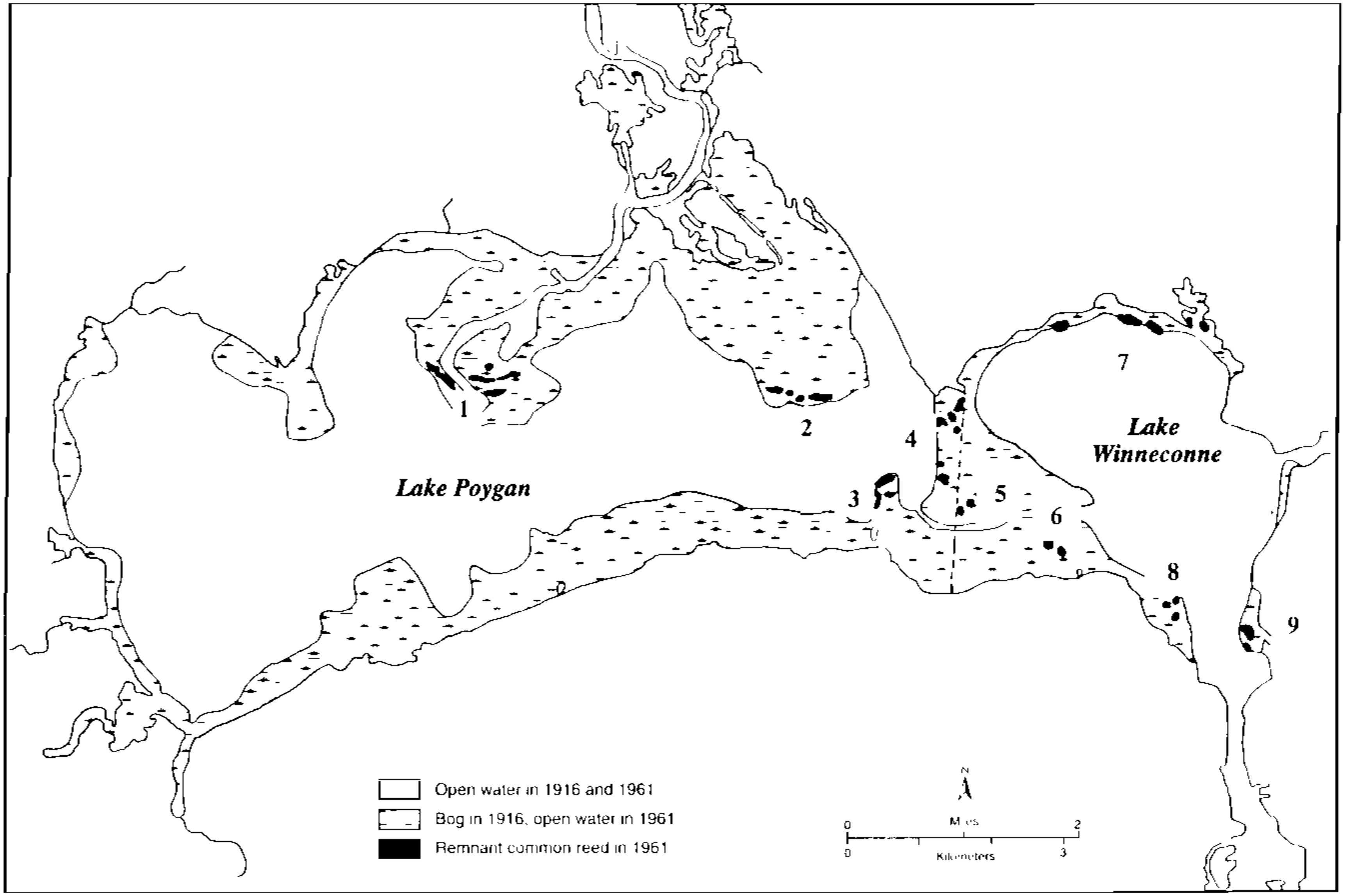


Fig. 1a. Wetland losses and remaining common reed stands, Lakes Poygan and Winneconne.
(adapted from Kahl, 1993)

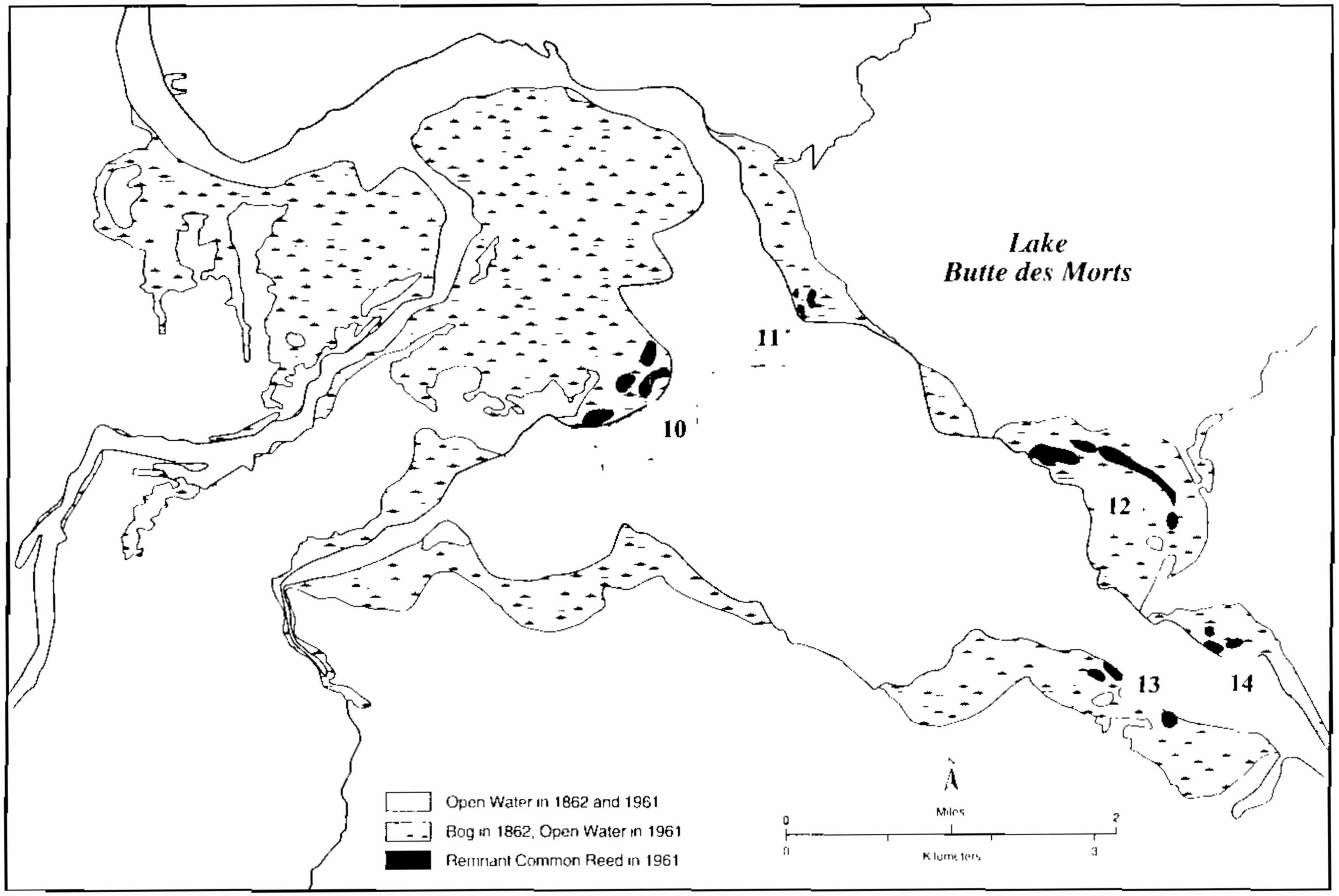


Fig. 1b. Wetland losses and remaining common reed stands, Lake Butte des Morts.
(adapted from Kahl, 1993)

Fig. 2a TOTAL AREA OF REED STANDS

Lake Butte des Morts, 1950-99

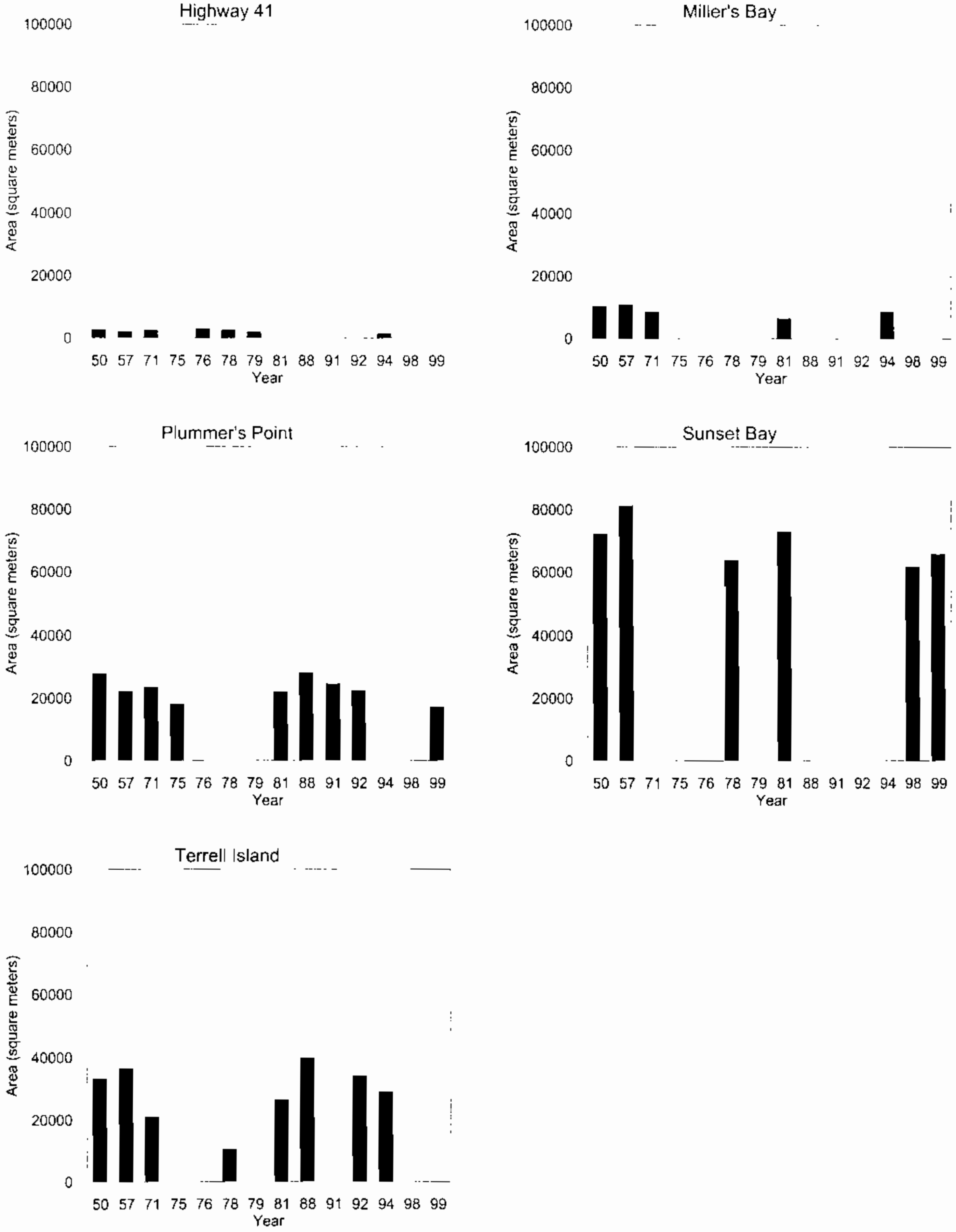


Fig. 2b TOTAL AREA OF REED STANDS

Lake Poygan, 1937-97

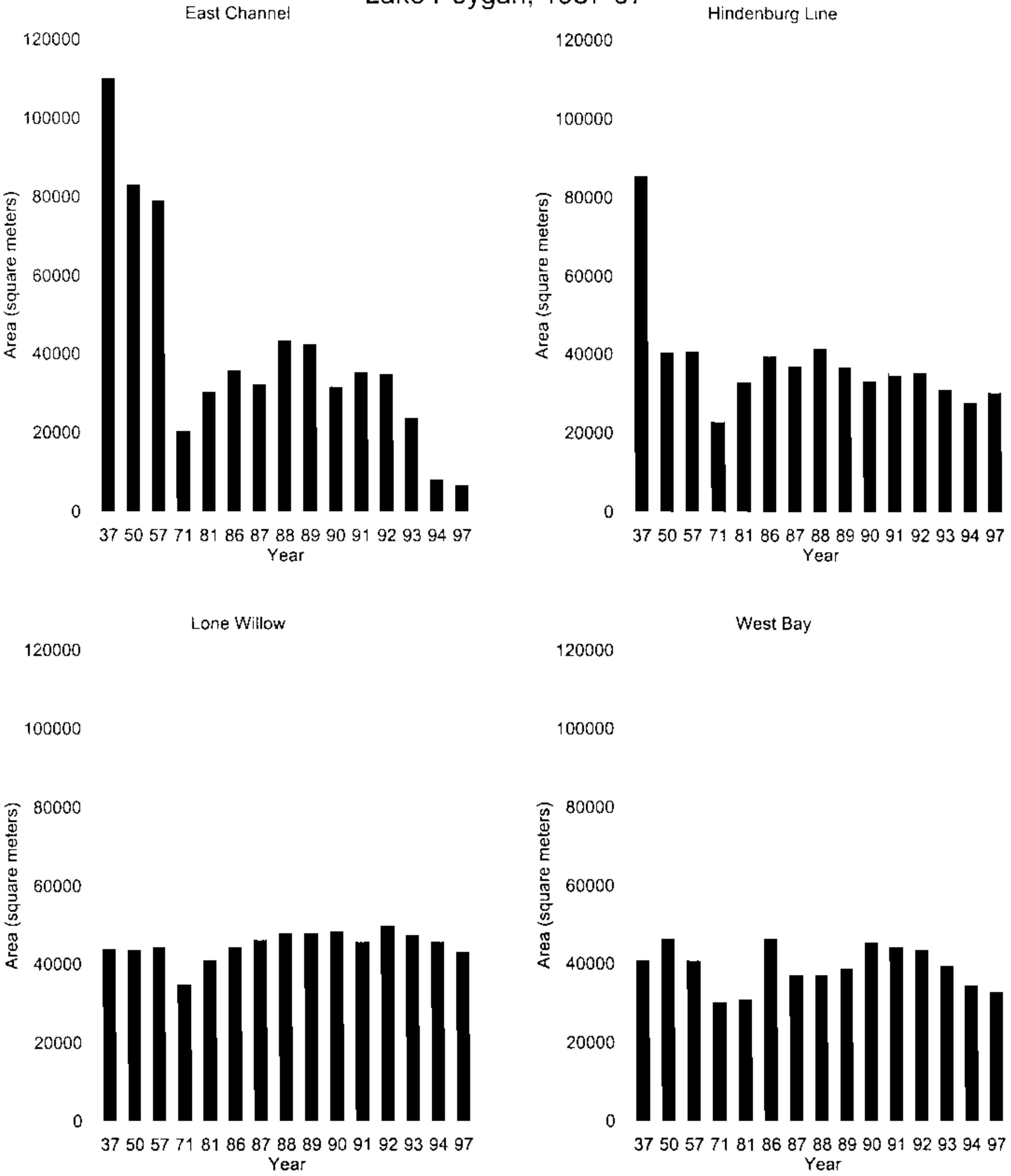


Fig. 2c TOTAL AREA OF REED STANDS

Lake Winneconne, 1937-1999

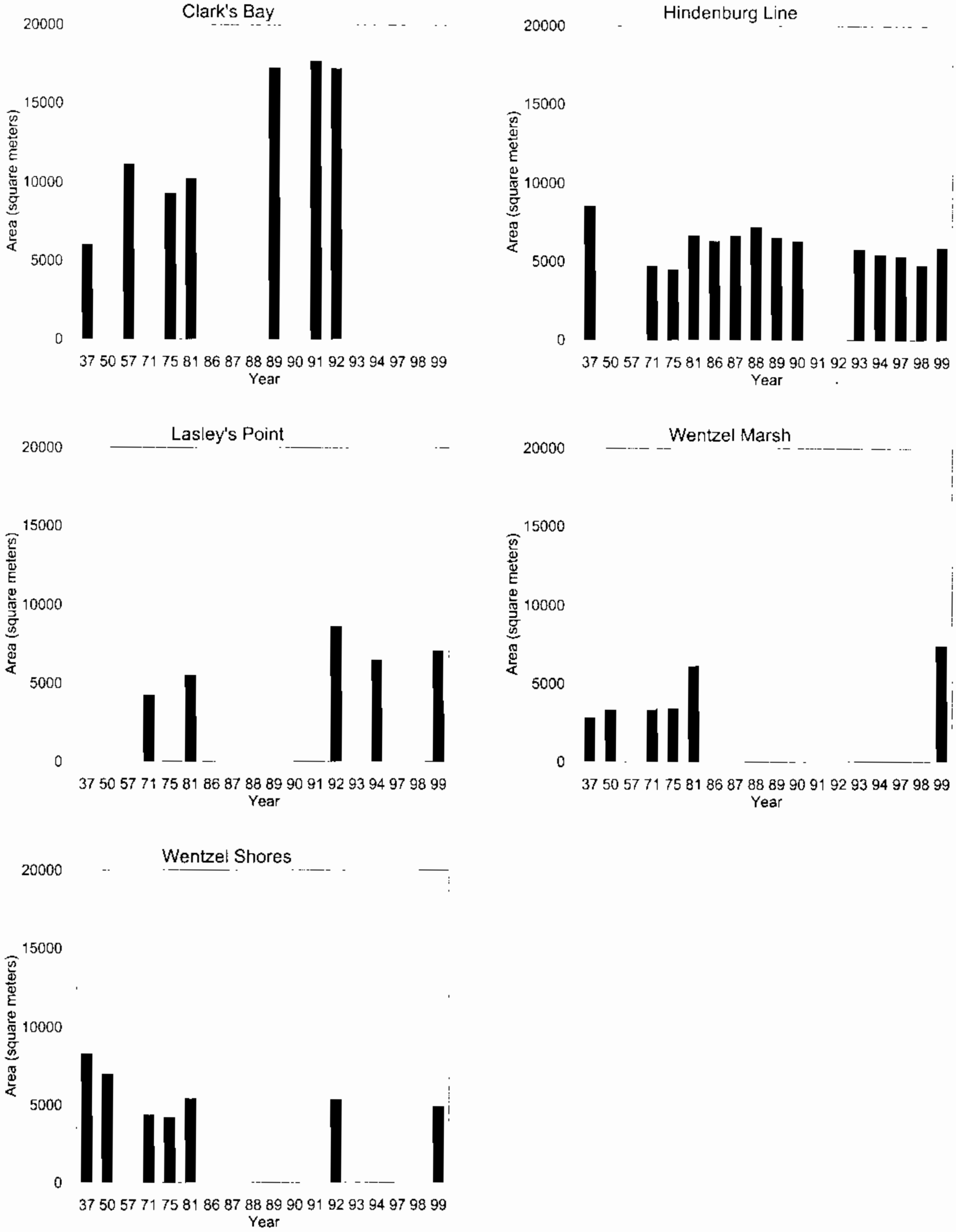


Fig.3a PERIMETER OF COMMON REED STANDS

Lake Butte des Morts, 1950-99

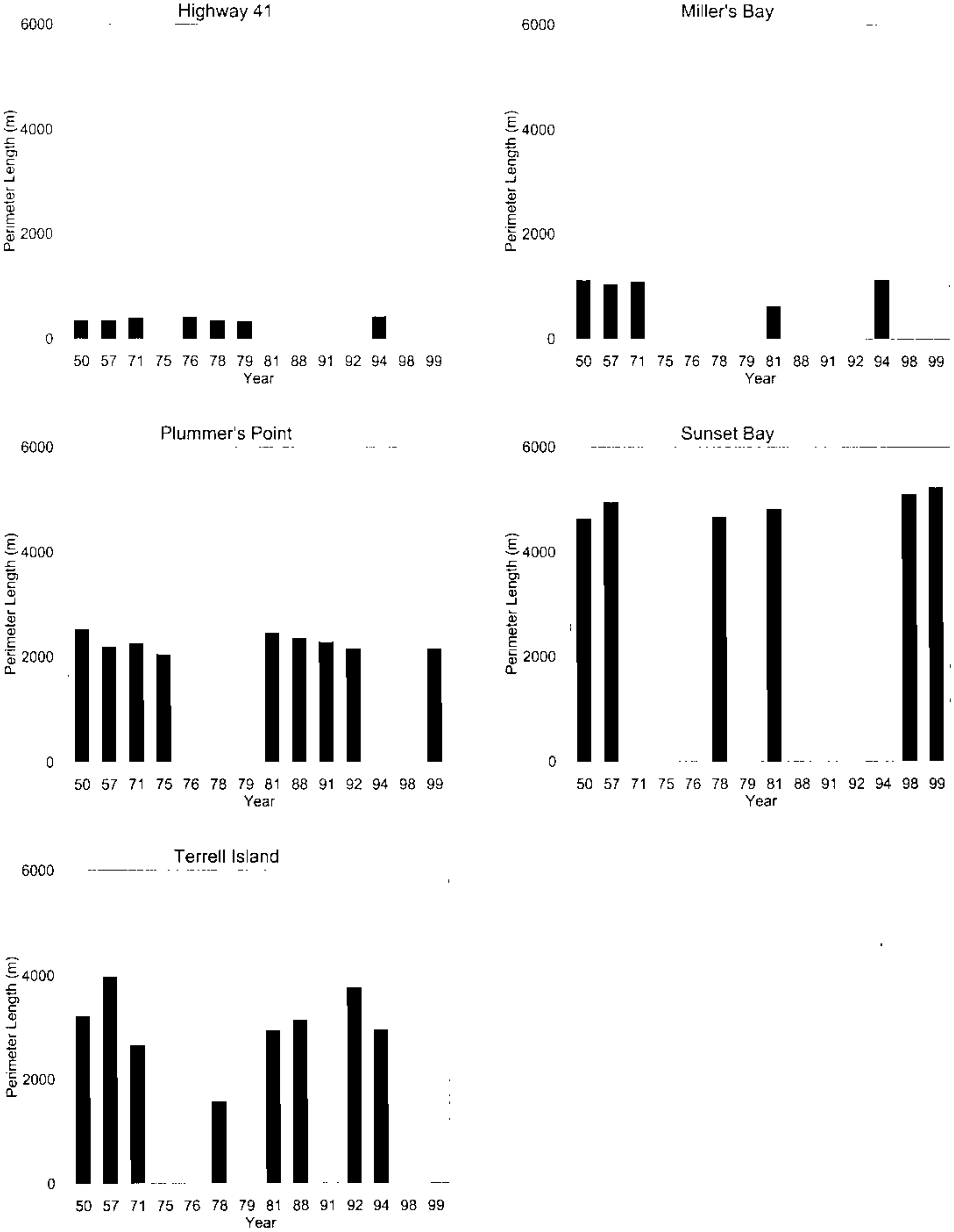


Fig.3b PERIMETER OF COMMON REED STANDS

Lake Poygan, 1937-97

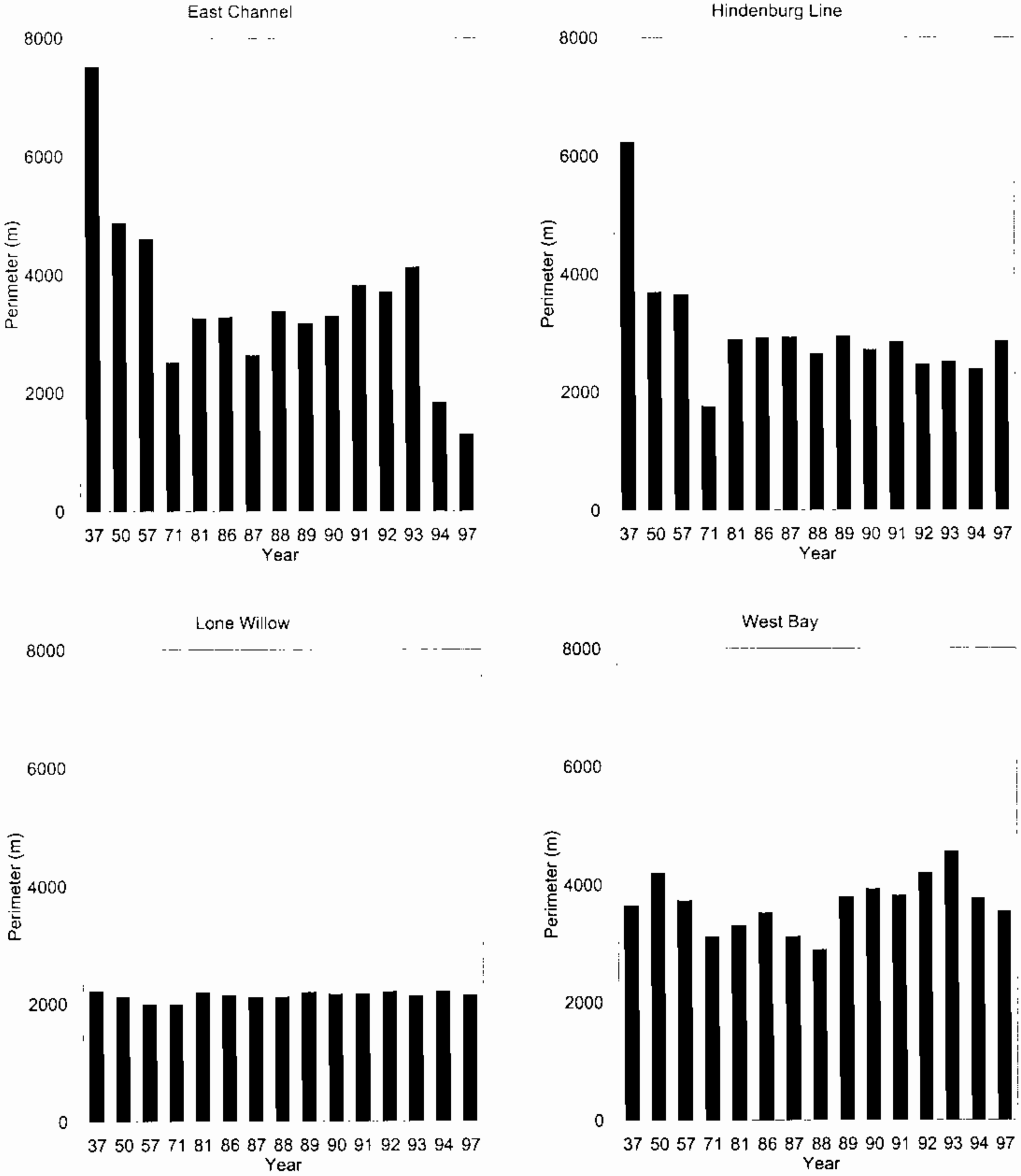


Fig.3c PERIMETER OF COMMON REED STANDS
Lake Winneconne, 1937-99

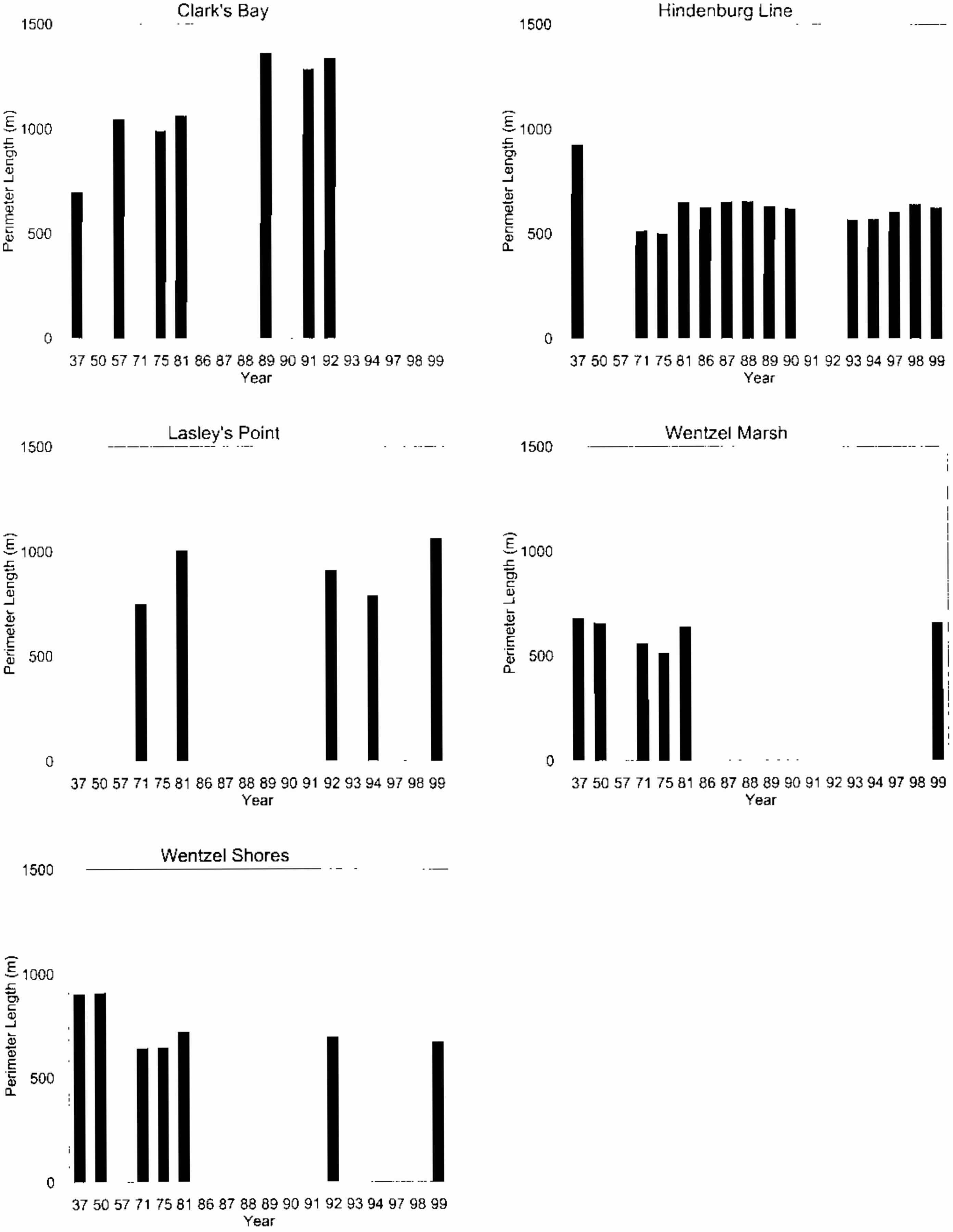
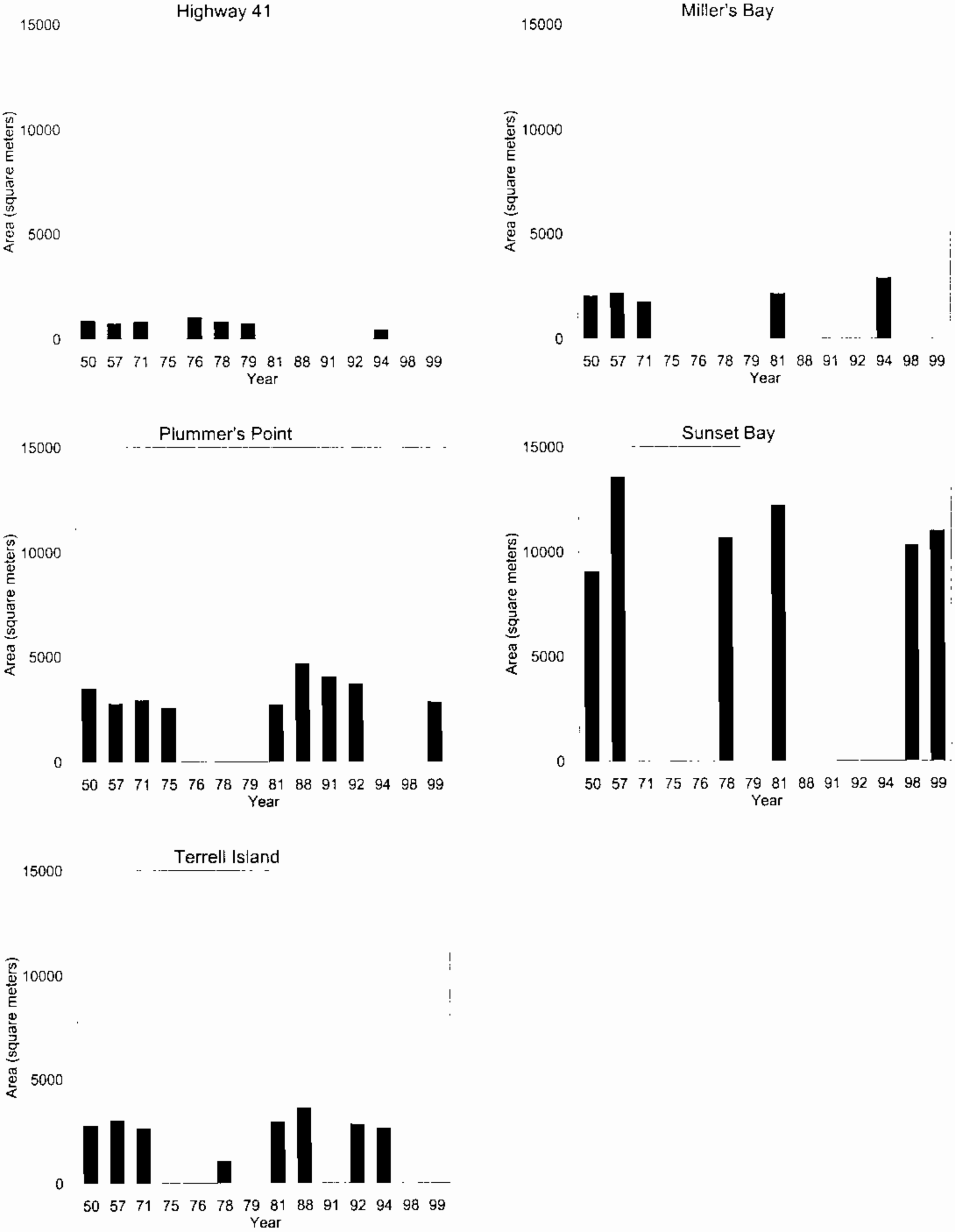


Fig. 4a AVERAGE SIZE OF REED PATCHES

Lake Butte des Morts, 1950-99



Highway 41

Miller's Bay

Plummer's Point

Sunset Bay

Terrell Island

Fig. 4b AVERAGE SIZE OF REED PATCHES

Lake Poygan, 1937-97

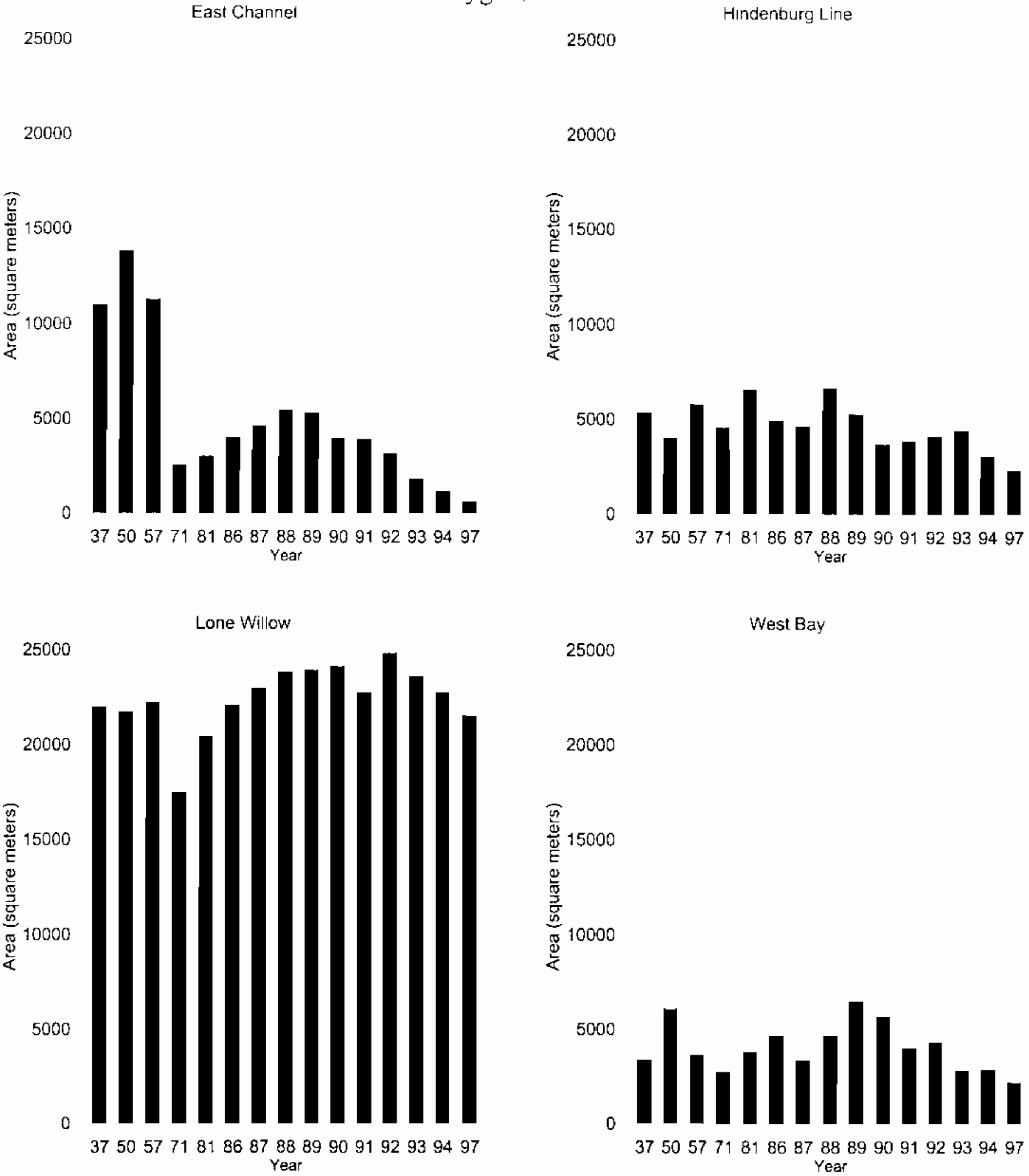


Fig. 4c AVERAGE SIZE OF REED PATCHES

Lake Winneconne, 1937-99

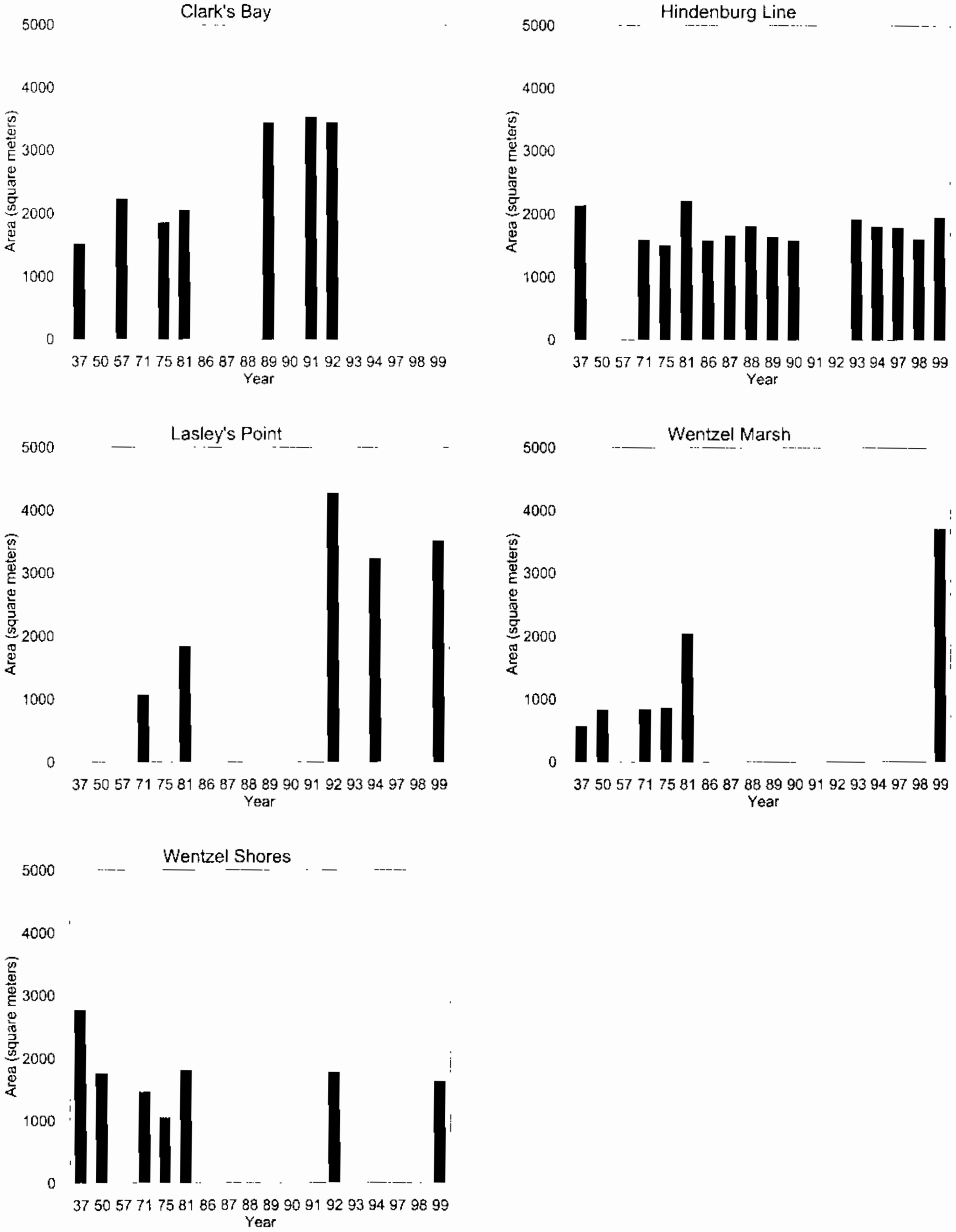


Fig. 5a AVERAGE PERIMETER OF PATCHES

Lake Butte des Morts, 1950-99

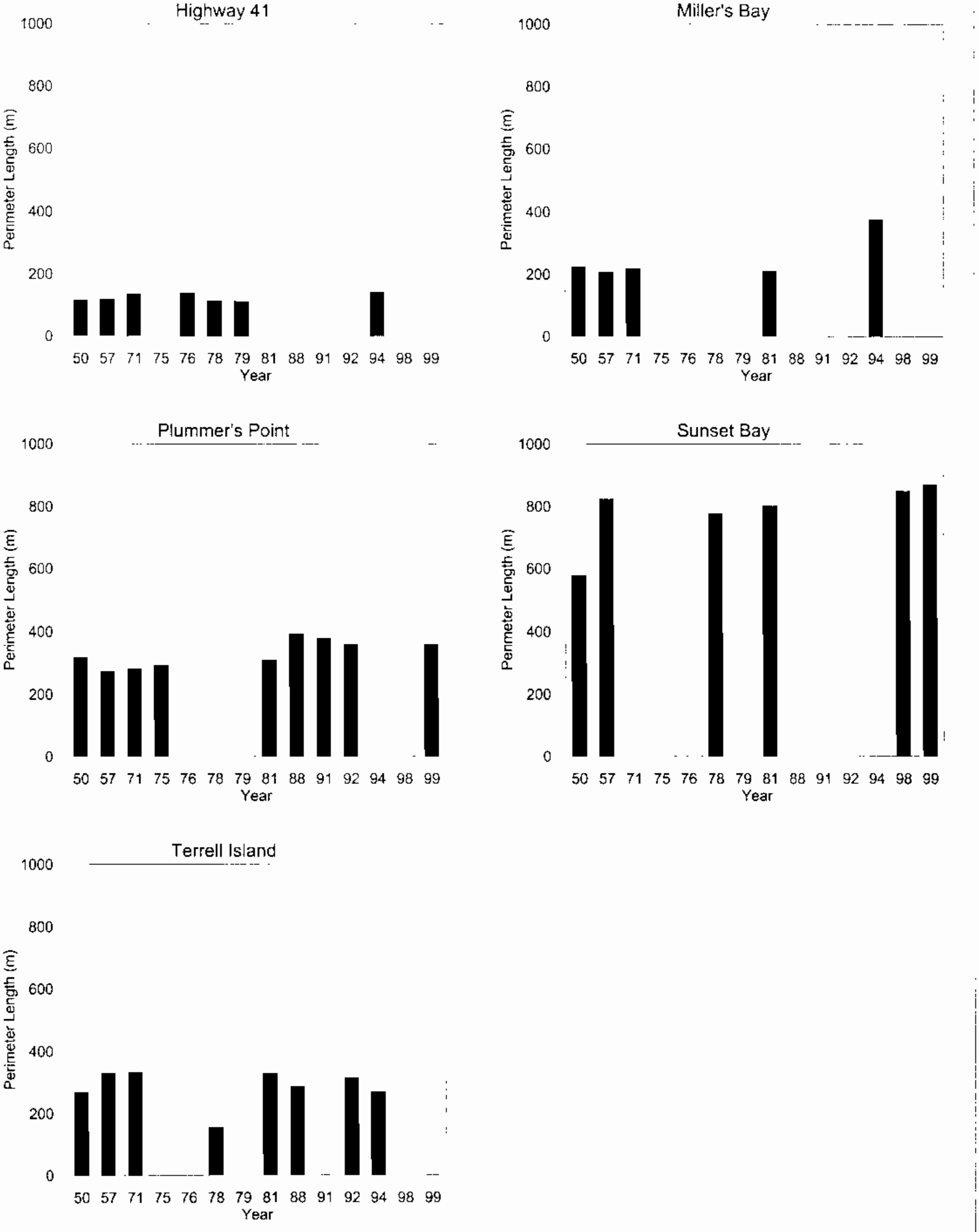


Fig. 5b AVERAGE PERIMETER OF PATCHES

Lake Poygan, 1937-97

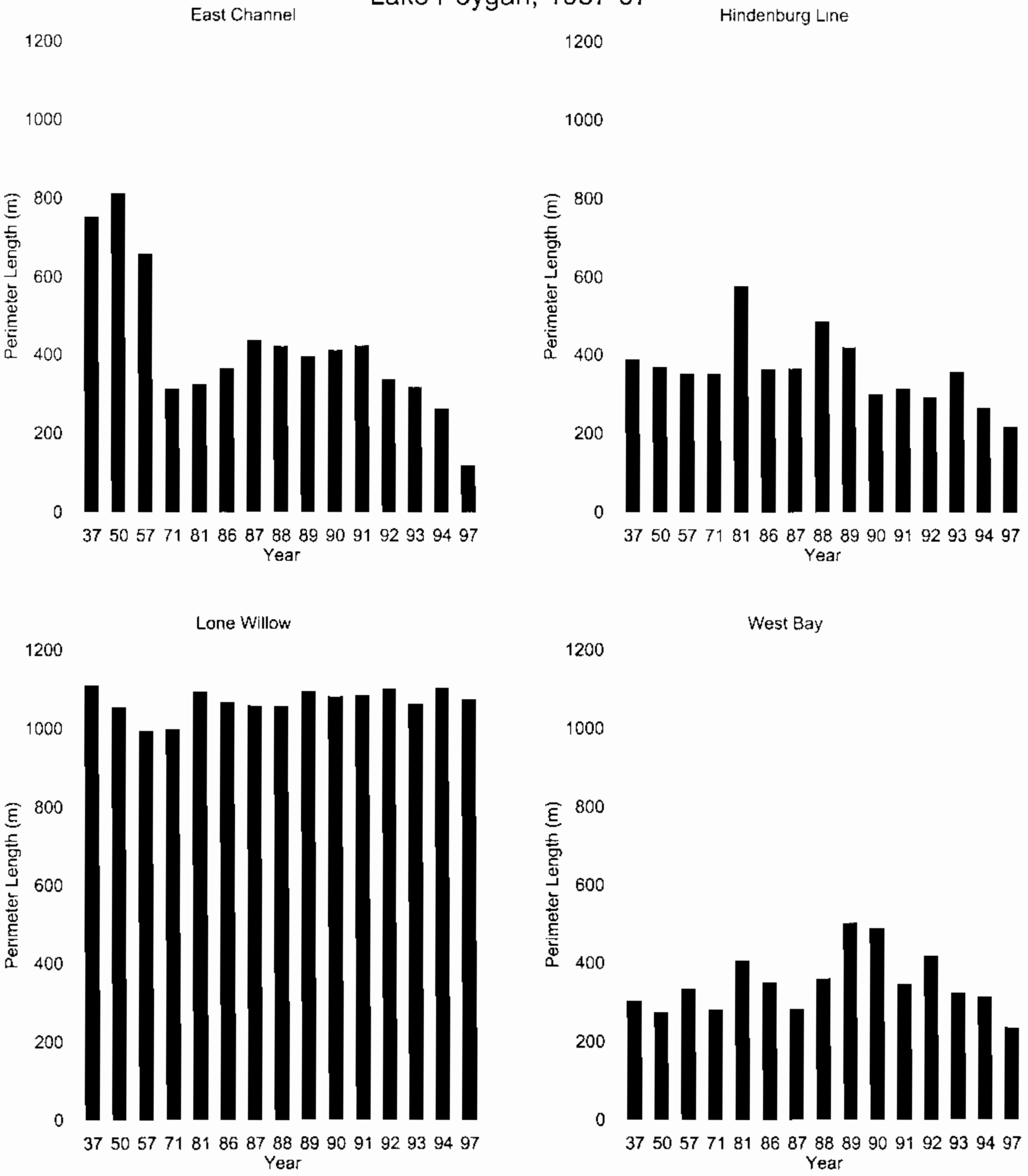


Fig. 5c AVERAGE PERIMETER OF PATCHES

Lake Winneconne, 1937-99

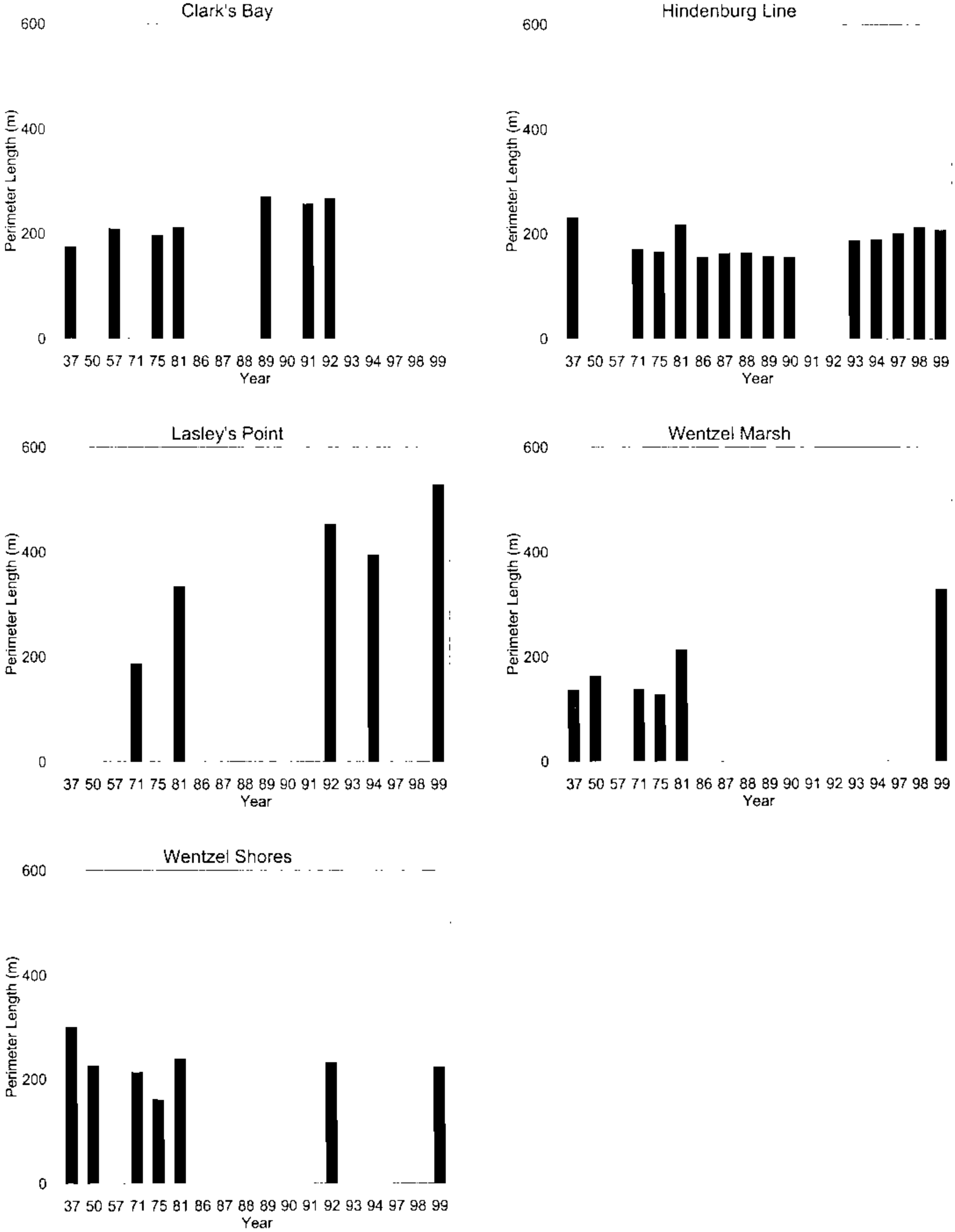


Fig. 6a PATCHES OF COMMON REED STANDS

Lake Butte des Morts, 1950-99

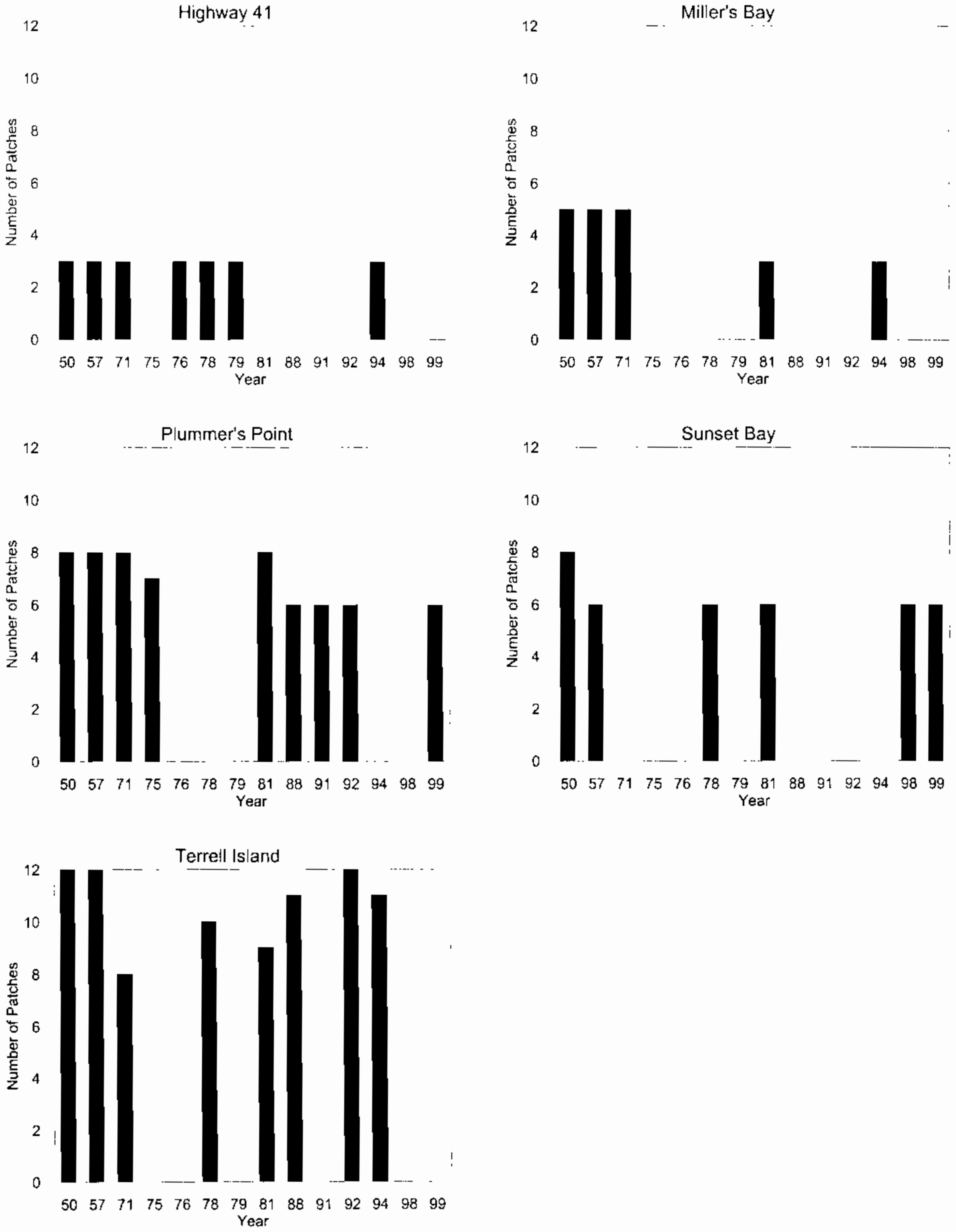
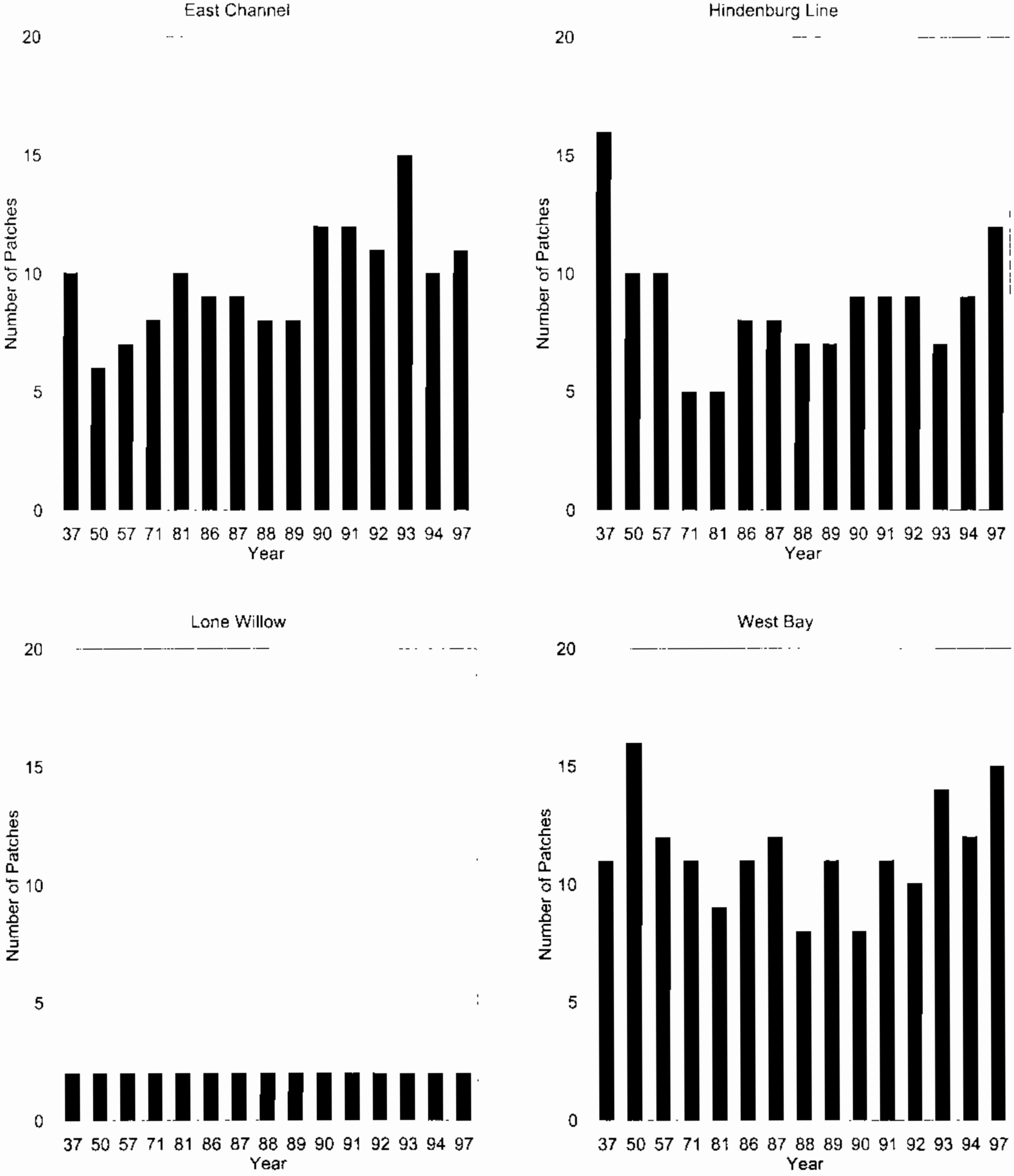


Fig. 6b PATCHES OF COMMON REED STANDS

Lake Poygan, 1937-97



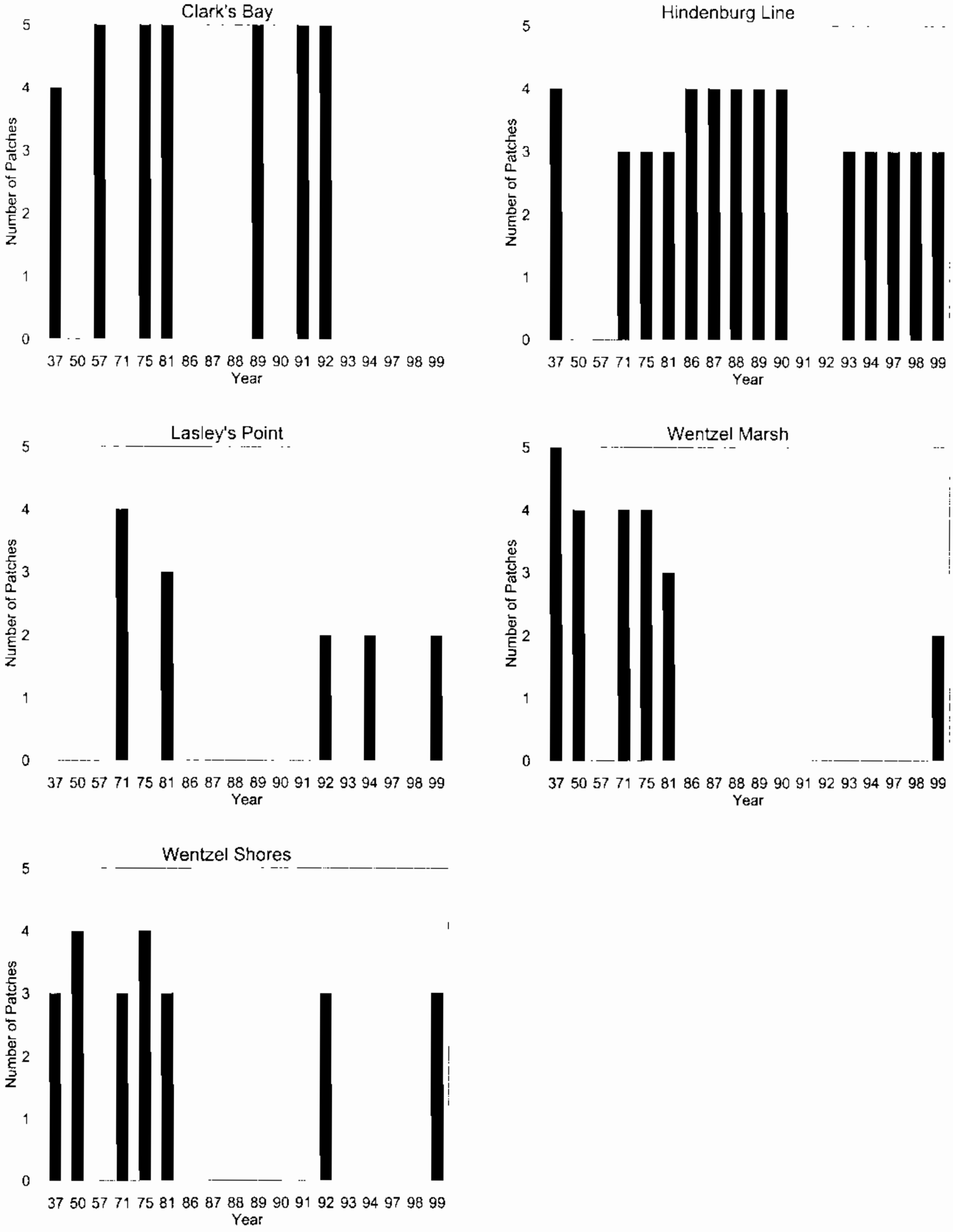


Fig. 6c PATCHES OF COMMON REED STANDS

Lake Winneconne, 1937-99

Fig. 7a PERIMETER/AREA RATIOS

Lake Butte des Morts, 1950-99

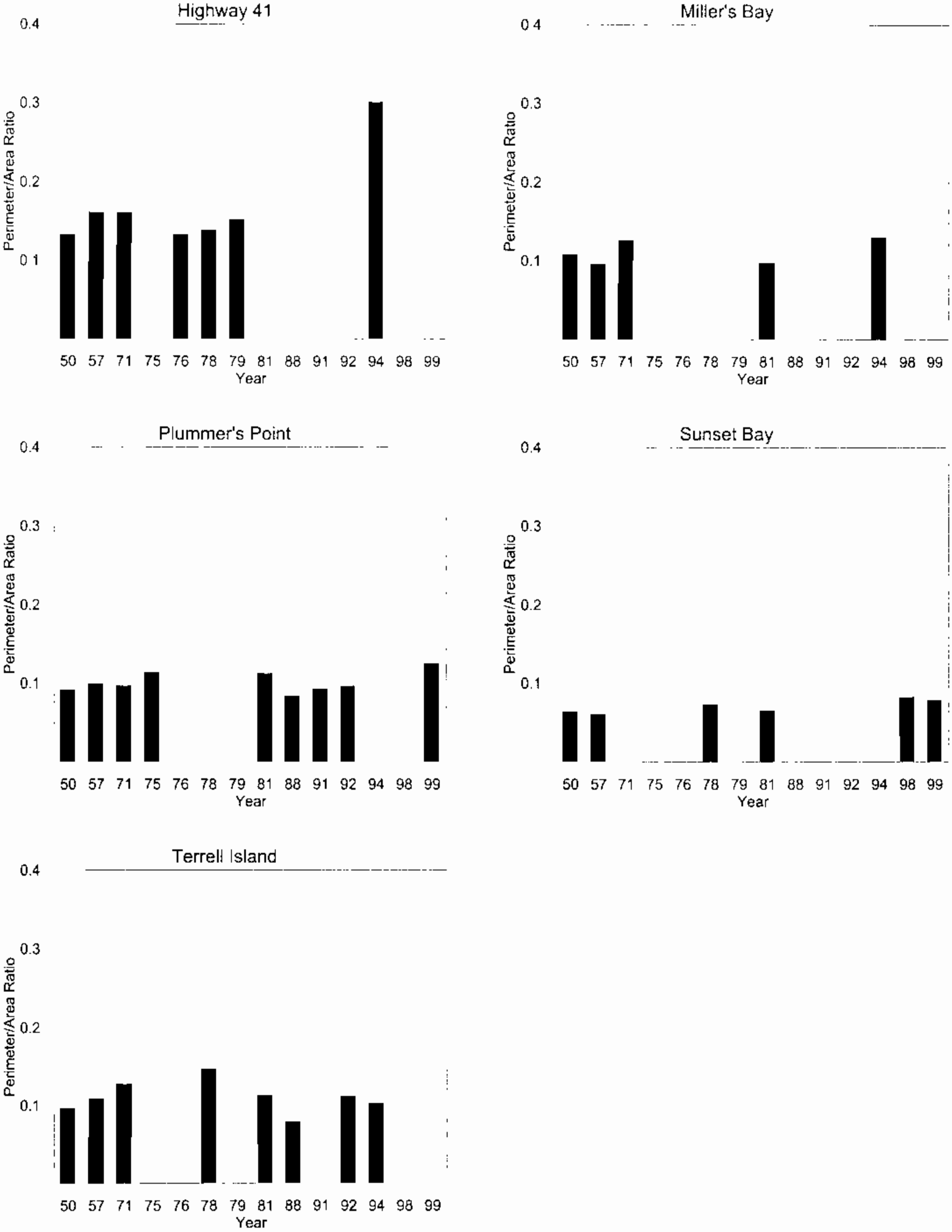


Fig. 7b PERIMETER/AREA RATIOS

Lake Poygan, 1937-97

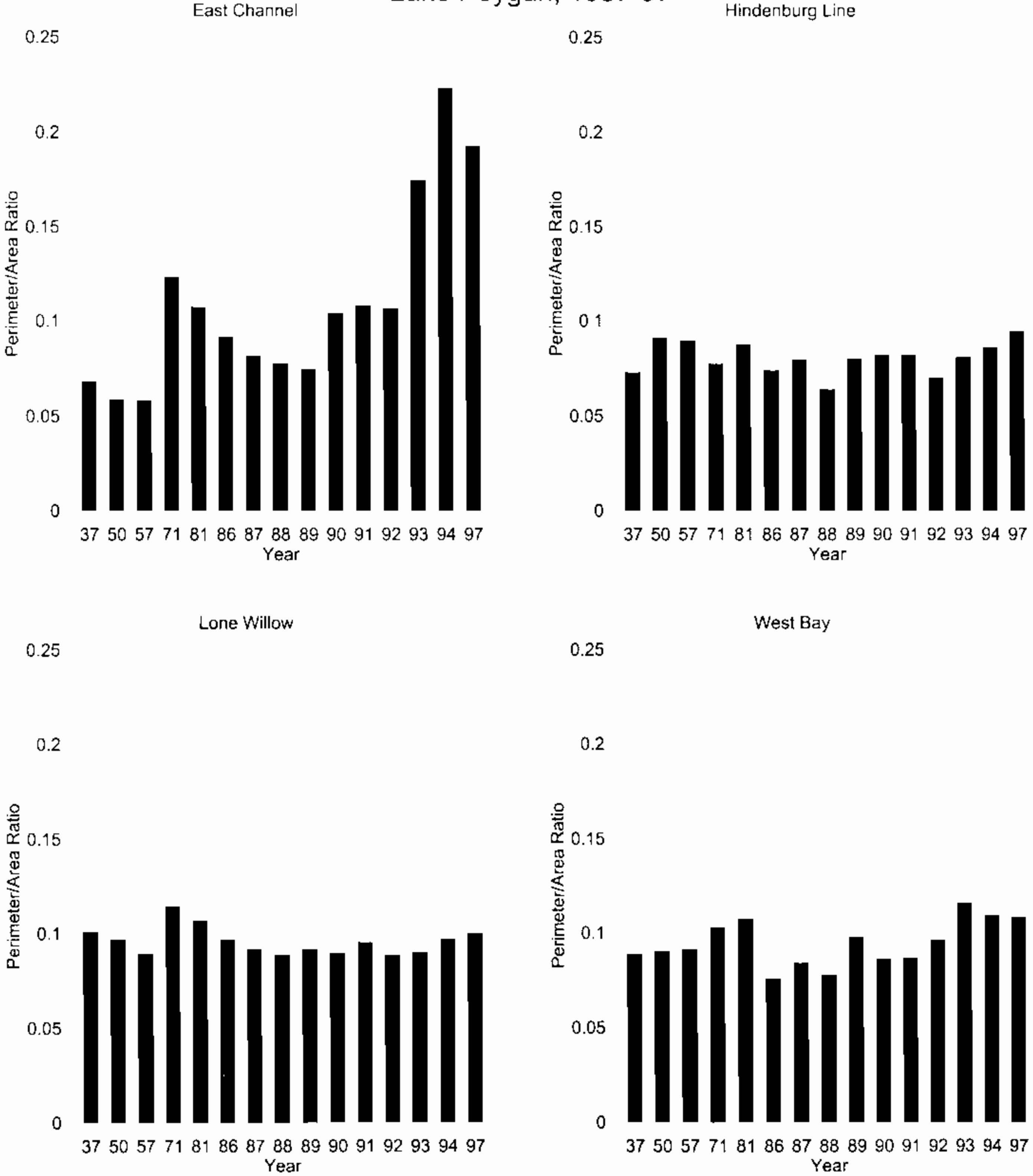


Fig. 7c PERIMETER/AREA RATIOS

Lake Winneconne, 1937-99

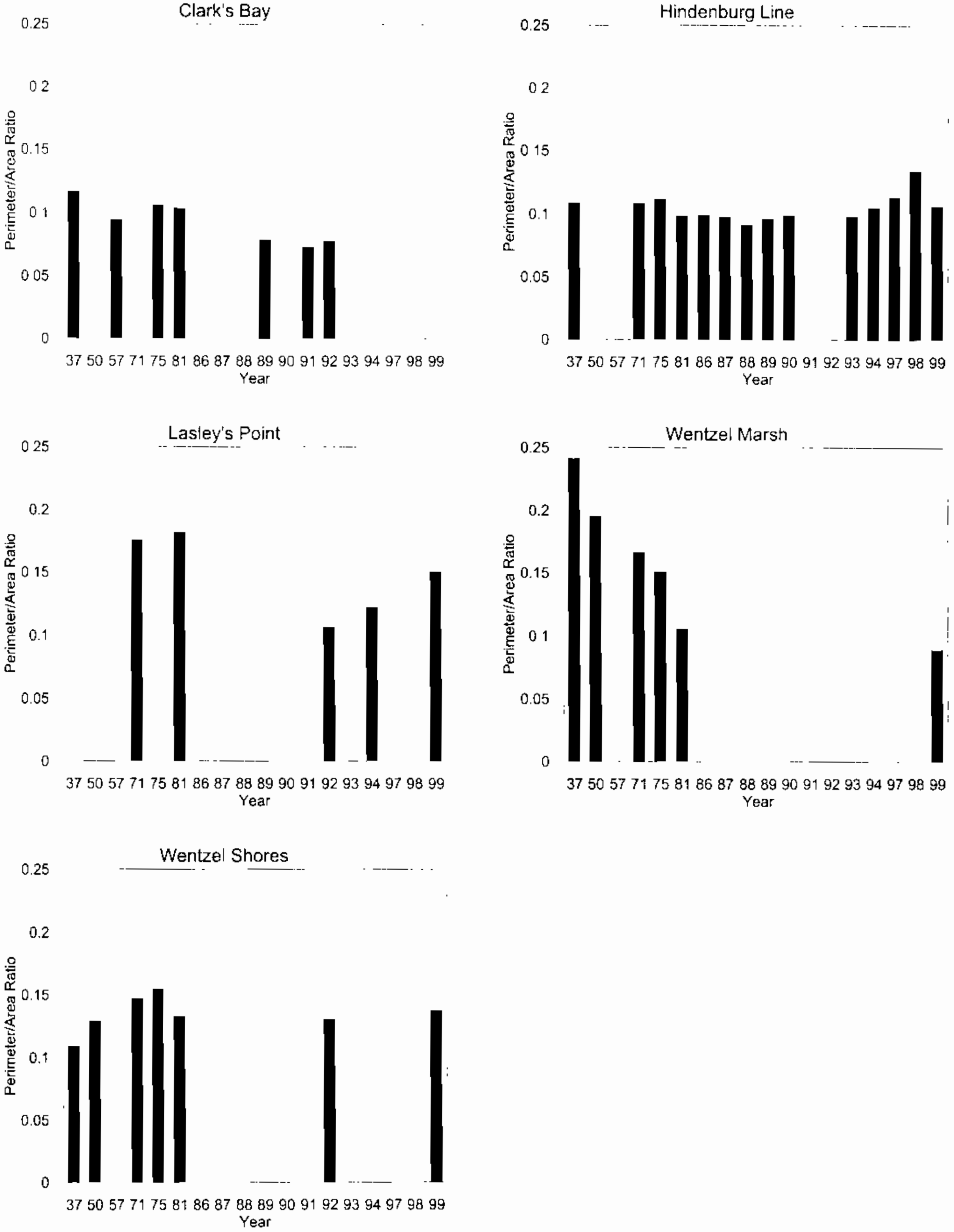


Fig. 8a SIZE OF LARGEST REED PATCH

Lake Butte des Morts, 1950-99

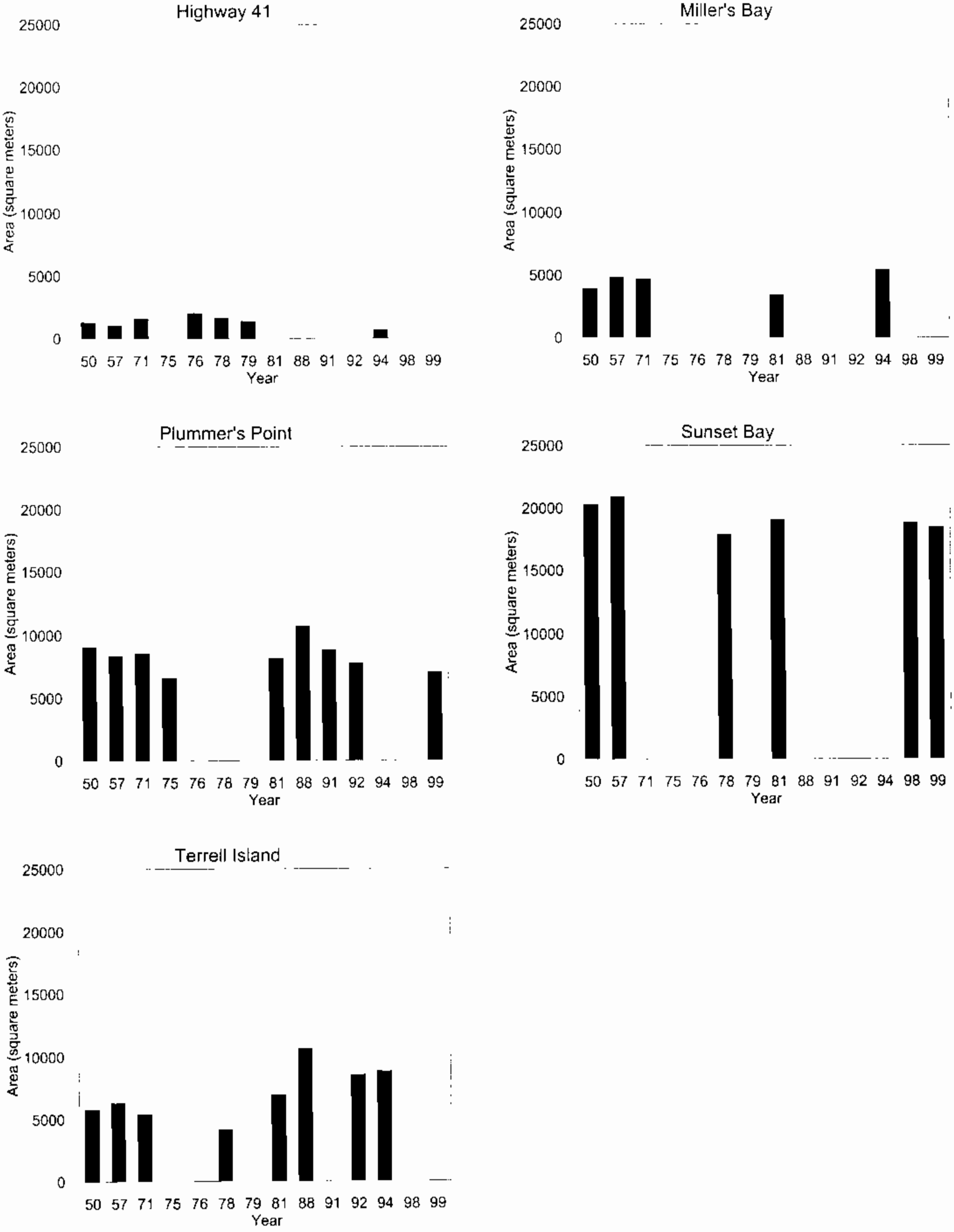


Fig. 8b SIZE OF LARGEST REED PATCH

Lake Poygan, 1937-97

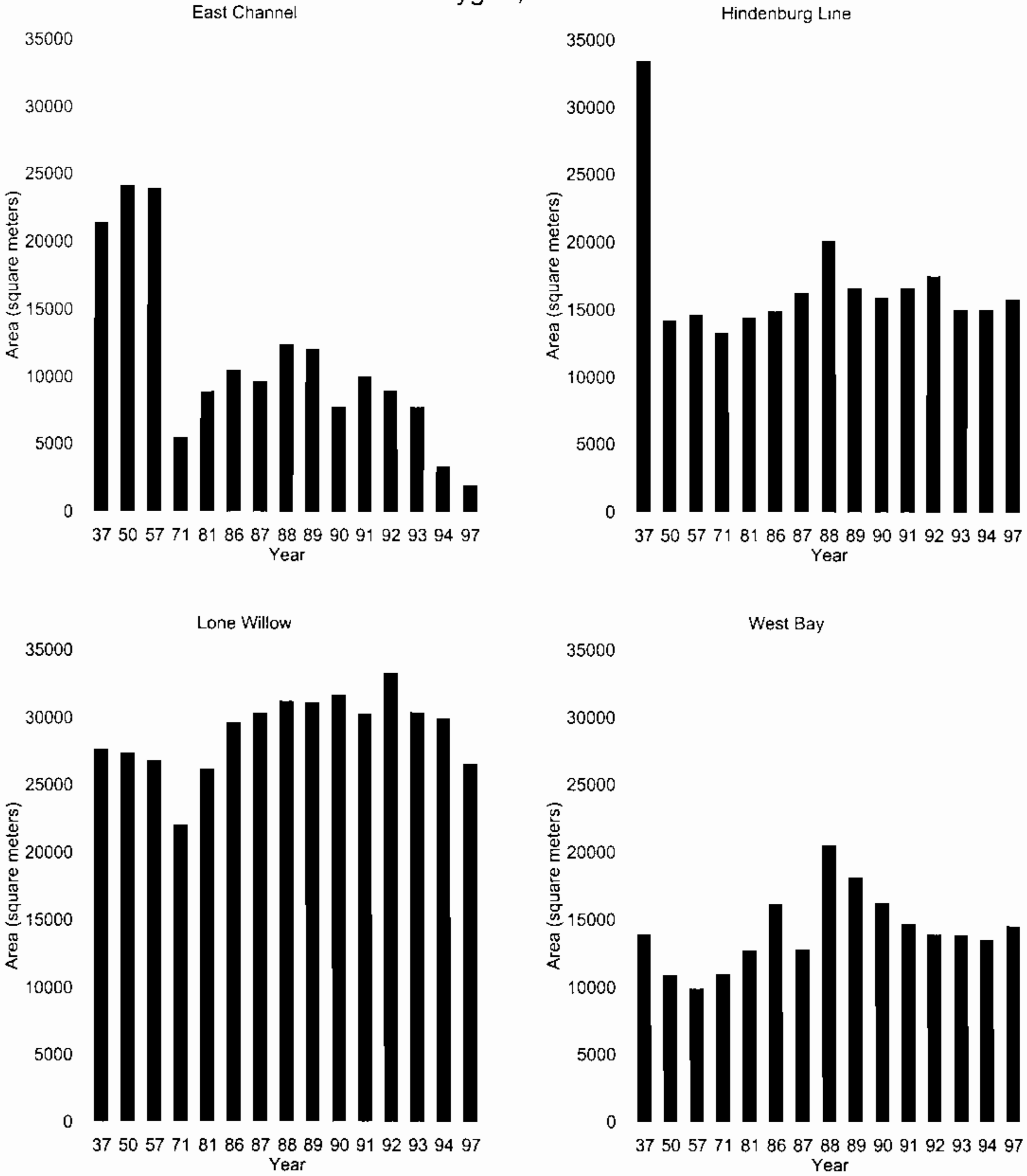


Fig. 8c SIZE OF LARGEST REED PATCH

Lake Winneconne, 1937-99

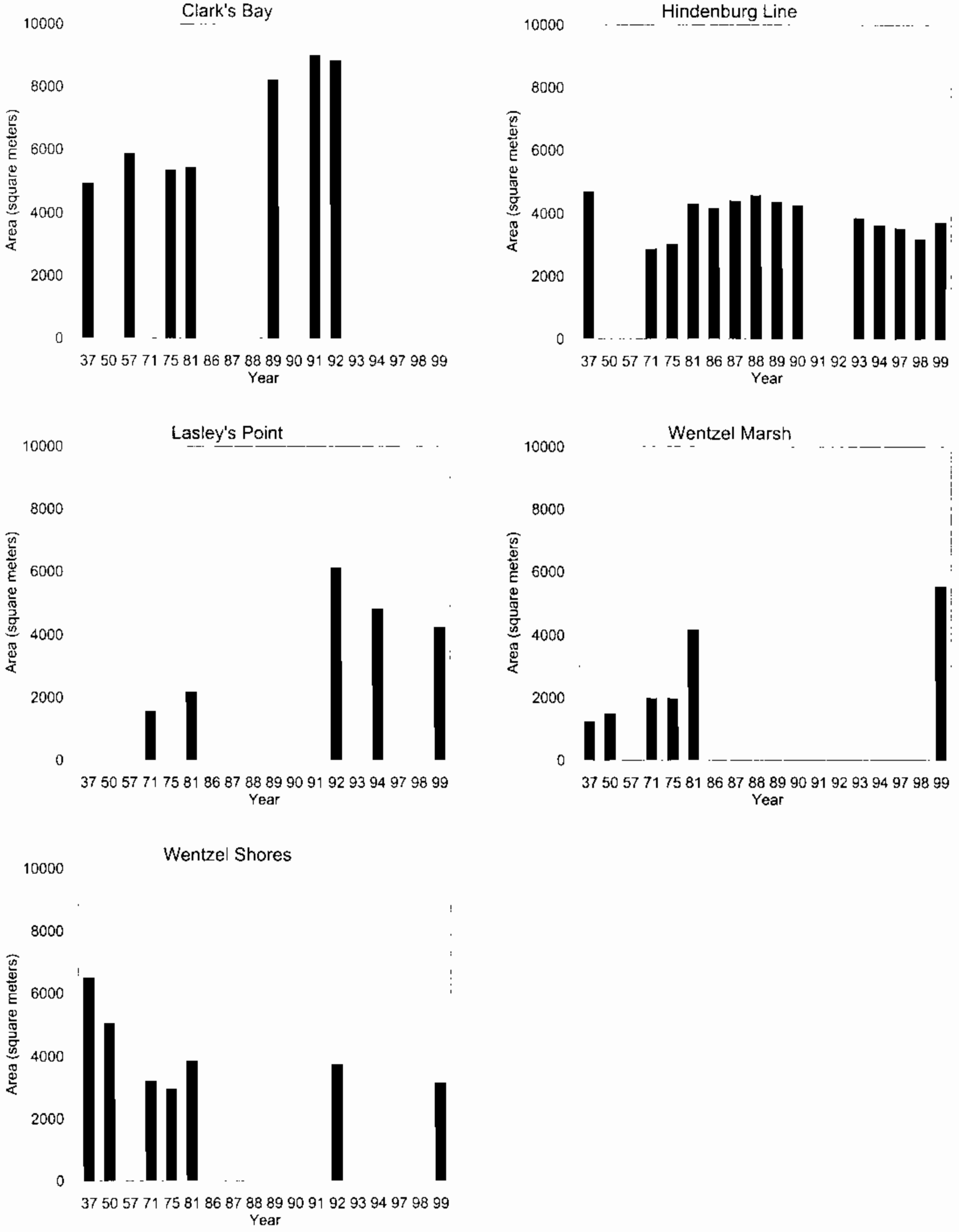


Fig. 9a PERIMETER OF LARGEST PATCH

Lake Butte des Morts, 1950-99

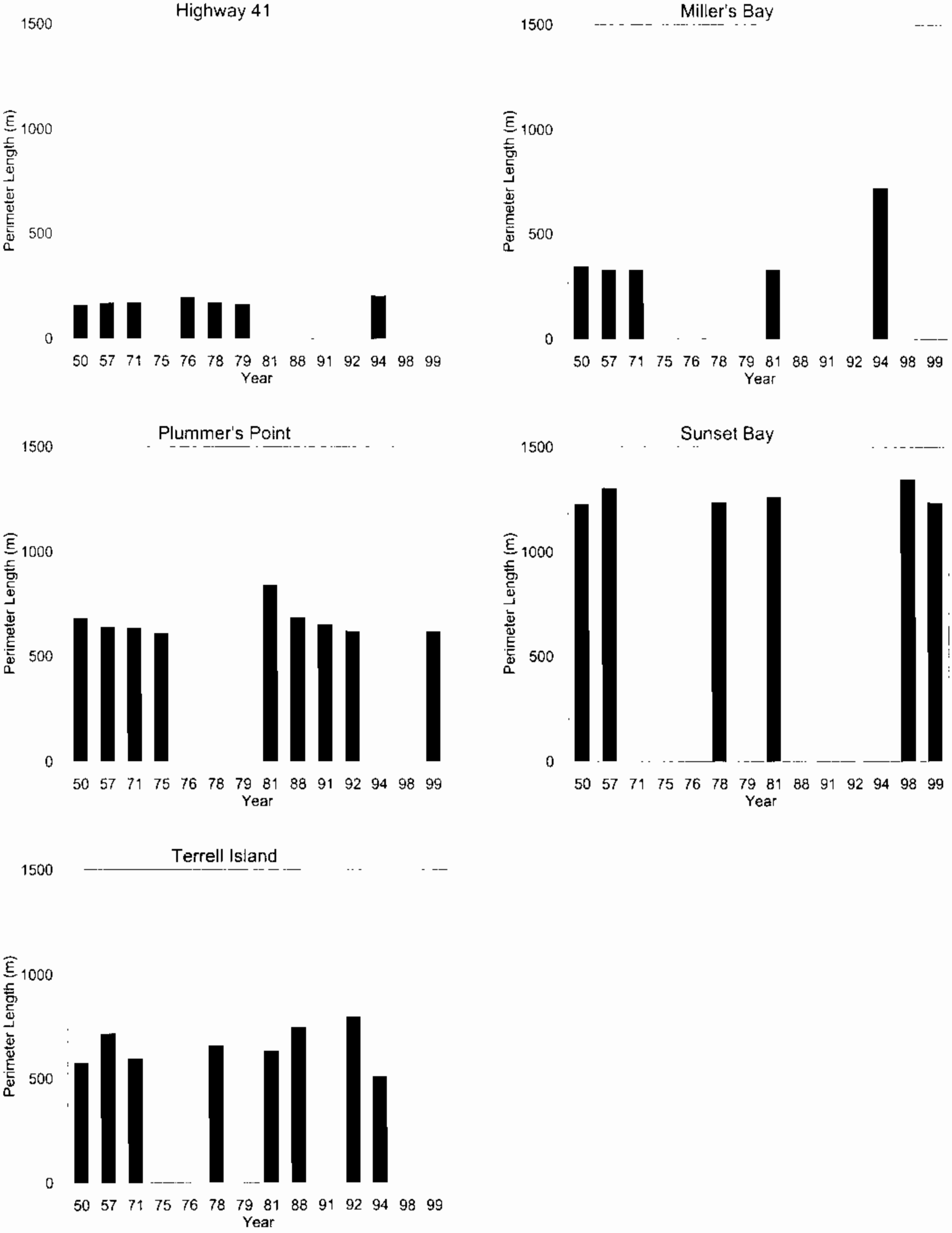
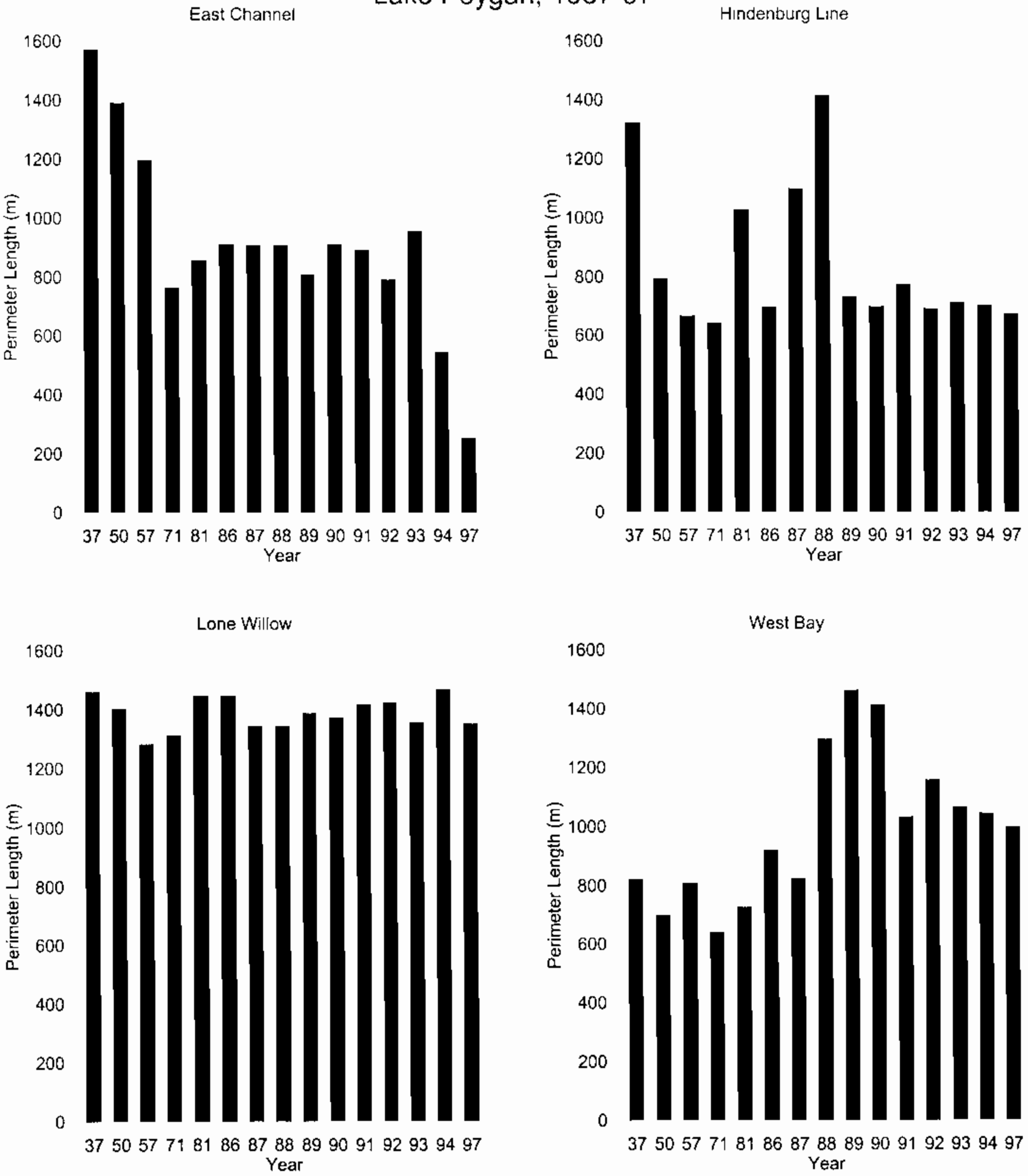


Fig. 9b PERIMETER OF LARGEST PATCH

Lake Poygan, 1937-97



East Channel

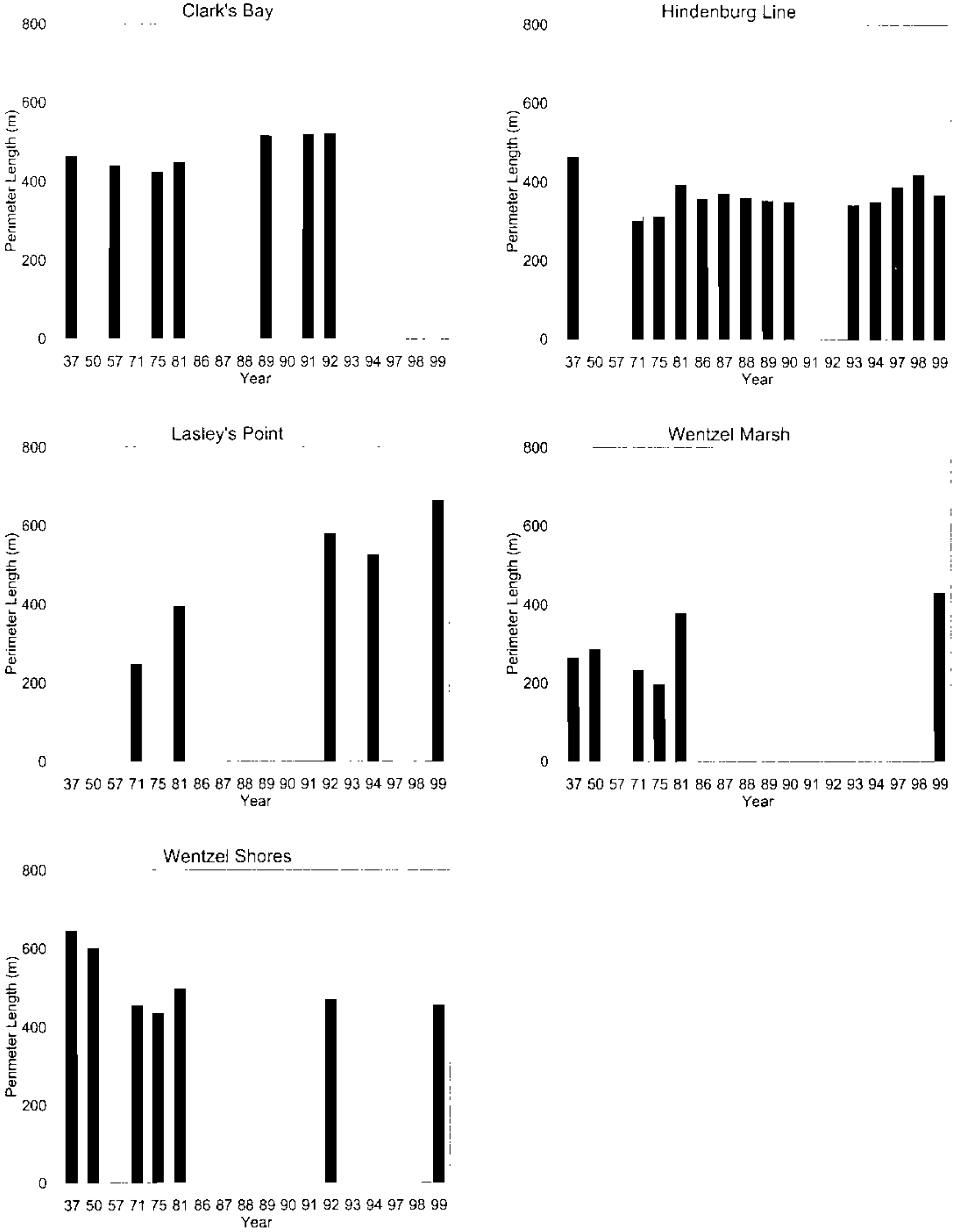
Hindenburg Line

Lone Willow

West Bay

Fig. 9c PERIMETER OF LARGEST PATCH

Lake Winneconne, 1937-99



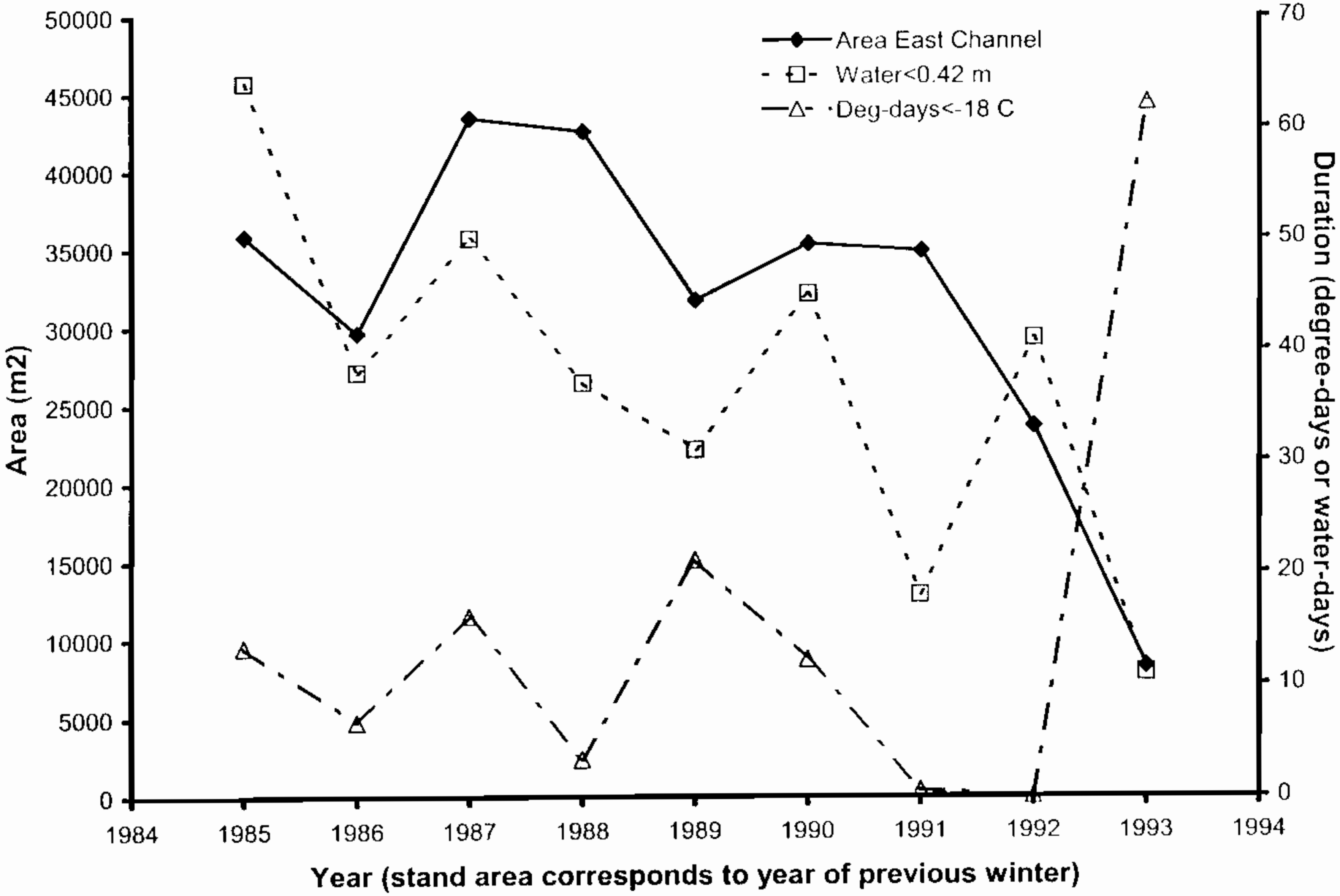


Fig. 10 Effect of Low Winter Temperatures and Low Water Levels on the East Channel Common Reed Stand, 1984-1998

Fig. 11 Median Daily Water Levels
Winnebago Pool Lakes (1968-97)

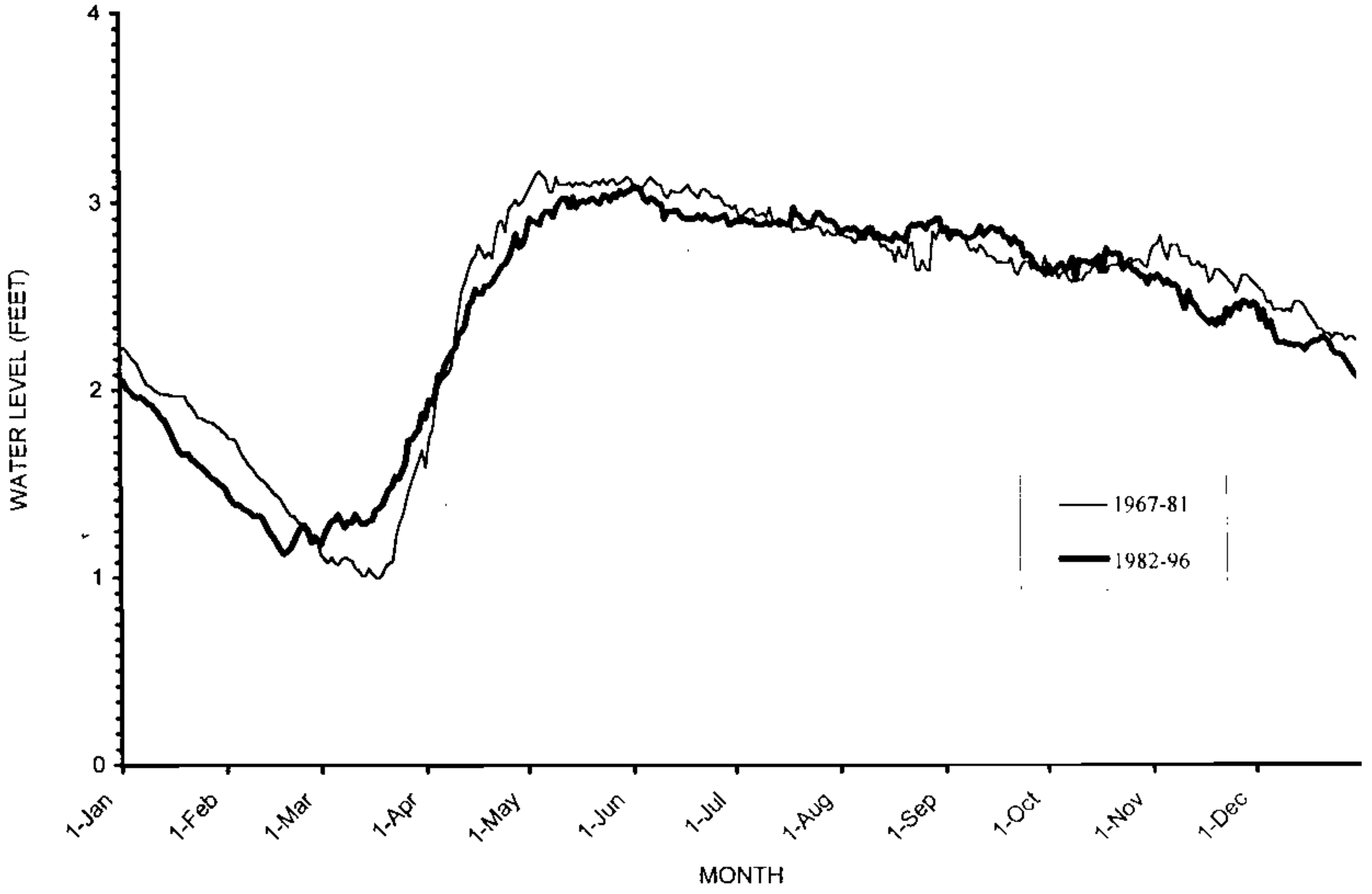


Table 6. Survey Respondent Profile.

CHARACTERISTICS	(%)
Affiliation of respondents	
Shoreline resident	31
Audubon Society	13
Butte des Morts Conservation Club	16
Lake Poygan Sportsman's Club	14
Tri-County Powerboat Alliance	16
Winnebago County/WDNR official	10
Shoreline location of respondents	
Lake Winnebago	3
Lake Butte des Morts	16
Lake Winneconne	11
Lake Poygan	23
Fox River	3
Wolf River	4
Length of residence on shoreline	
less than 5 yrs.	14
5 - 15 yrs.	34
16 - 25 yrs.	25
over 25 yrs.	28
Proximity of Non-Riparians to Upper Winnebago Pool Lakes	
less than 1 mile	23
1-10 miles	43
11-20 miles	17
over 20 miles	17
Age of respondents:	
20 or under:	0.5
21 - 40:	19
41 - 60:	51
61 or over:	29
Level of education of respondents	
completed grade 8:	1
completed high school:	45
completed community college/trade school:	17
completed university:	25
completed post graduate studies:	12
Total 1999 pre-tax income	
less than $25000	7
$25,000 - $50,000	26
$50,001 - $75,000	37
$75,001 - $100,000	13
more than $100,000	17

- all values expressed as % of respondents

Table 7. Use and Awareness of Upper Winnebago Pool Lakes and Canebeds.

	(%)
Use of Upper Winnebago Pool Lakes	
fishing	66
hunting	29
boating	74
snowmobiling	19
nature-watching	54
swimming	46
shoreline resident	40
other uses	3
do not use	2
Have Seen Upper Winnebago Pool Lakes Canebeds	
yes	90
no	4
don't know	6
Use of Upper Winnebago Pool Lakes Canebeds	
nature-watching	31
fishing	52
hunting	25
other uses	6
do not use	26
Awareness of Age of Canebeds	
less than 10 years	3
11-25 years	3
26-50 years	7
51-75 years	8
76-100 years	13
over 100 years	66

- all values expressed as % of respondents

Table 8. Perceptions and Attitudes About Functions of Canebeds

QUESTION					
	SA	**AS**	**DS**	**SD**	**DK**
Canebeds provide scenic beauty.	67	27	3	1	2
Canebeds improve water quality.	76	16	2	0	6
Canebeds protect shorelines from wave erosion.	56	31	7	3	3
Canebeds are important fish habitat.	87	9	1	1	2
Canebeds are important wildlife habitat.	83	13	2	0	2
Canebeds are important fishing areas.	71	19	5	1	4
Canebeds are important waterfowl hunting areas.	65	24	5	2	4
Canebeds are important fur-trapping areas.	16	17	16	14	37

- all values expressed as % of respondents
SA - strongly agree DS - disagree somewhat DK - don't know
AS - agree somewhat SD - strongly disagree

Table 9. Perceptions and Attitudes About Impacts to Canebeds.

QUESTION					
	SA	**AS**	**DS**	**SD**	**DK**
High water levels have negatively impacted the canebeds.	47	21	9	3	20
Low water levels have negatively impacted the canebeds.	18	21	15	19	27
Water pollution has negatively impacted the canebeds.	34	35	10	7	14
Driving recreational vehicles (i.e. snowmobiles, ATVs, etc.) through the canebeds in winter has negatively impacted the canebeds.	51	22	10	8	9
Pleasure boating in the canebeds has negatively impacted the canebeds.	71	14	4	6	4
Pleasure boating near the canebeds has negatively impacted the canebeds.	38	31	17	7	7
Jet skiing in the canebeds has negatively impacted the canebeds.	73	15	4	4	4
Jet skiing near the canebeds has negatively impacted the canebeds.	44	29	15	5	7
Fishing in the canebeds has negatively impacted the canebeds.	33	30	17	12	7
Fishing near the canebeds has negatively impacted the canebeds.	6	20	31	33	10
Waterfowl hunting in the canebeds has negatively impacted the canebeds.	15	32	24	18	11

- all values expressed as % of respondents
SA - strongly agree DS - disagree somewhat DK - don't know
AS - agree somewhat SD - strongly disagree

Table 10. Perceptions and Attitudes About Management of Canebeds on the Upper Winnebago Pool Lakes.

QUESTION	SA	AS	DS	SD	DK
Attempts should be made to create new canebeds where they do not presently exist.	39	30	13	4	13
Existing canebeds should be protected and restored.	85	13	2	0	0
More information about the Upper Winnebago Pool canebeds needs to be presented to the public.	76	23	1	1	0
Public awareness campaigns are needed to explain and prevent damage posed by human activities to canebeds.	77	19	3	0	1
Management of canebeds is largely dependent on public support.	51	32	9	1	7
Boats should be prohibited from entering canebeds	74	15	6	2	3

	YES	NO
Seasons when restrictions should be placed on boats entering the canebeds:		
Spring	35	
Summer	33	
Fall	12	
All Seasons	52	
None	5	
Respondents in favor of manipulating water levels to protect canebeds	69	31

- all values expressed as % of respondents
SA - strongly agree DS - disagree somewhat DK - don't know
AS - agree somewhat SD - strongly disagree

Additional comments on surveys

Audubon society:

- Save the remaining few canebeds.
- At a state level, the DNR and our legislative reps. Need to set a state priority for saving and restoring cane-beds in Wisconsin. The public must be involved in becoming aware of this as a conservation necessity.
- Rules for Canebeds. 1) Preservation and restoration must take precedence over human use/activity. 2) Our conservation leaders (DNR board) DNR secretary, must set saving and restoring cane beds as a state priority. 3) All media sources must be involved in educating the public on this matter.

Butte des Morts Conservation Club:

- I believe water levels and non-point runoff have a tremendous effect on all water plants and needs to be seriously examined.
- We have felt the cane beds have been affected over the years by freeze-downs then rising water in the spring.

Poygan Sportsman's Club:

- Please protect canebeds!
- Need breakwalls on west and southwest sides of beds.

Tri-County Powerboat Alliance:

- I feel the loss of the cane beds is due primarily to a changing environment and not caused by boating, snowmobiling, fishing, etc. I've watched these changes since I first used the lakes when I was 13 years old—I'm 64 now.

Shoreline residents:

- These can beds should have no use made of them in any season—duck hunters may use blinds outside the cane beds—closed to fishermen completely. We need a new management agency for water level control and water should be stabilized from season to season—level control in winter should depend on prediction of water anticipated in the snow pack. The Corp of Engineers has proven they do not know how to manage water. Please do something to protect this resource.
- High water and storms float out "bogs," small pieces. The water was far more polluted when we bought [our land] and there were more beds. Mother Nature? Humans are a part of it—not strangers. We are too shallow now. Propaganda is all we really get [in reference to public awareness campaign question #E.3). Management means man's interference in the environment purposefully from that authoritarianism and total restrictions—then why pay taxes on what can't be used.

- Tournament fishing should be stopped in all weed beds.
- I would like to see more improvement in the water quality. Find the sources of pollution such as some areas on the shoreline still aren't sewered and many times have failing septic systems. Perhaps curtailing jet skiing—certain areas only; speed; and hours of the day. Having known Lake Poygan as a seasonal then permanent shoreline resident in excess of 70 years, find it disheartening to have lost the water clarity.
- I feel a class attendance on using ? should be attended before driving a boat. Large boats ruin the cane beds in our upper lakes. They run close to cane beds and the smaller fishing boats run through the cane beds. We have no weed beds in the lake due to boat traffic through weed beds.
- A prime marsh habitat is in severe danger of being washed out near my house (west side of Lake Winneconne between Wentzel Shore Road and Lakeshore Road). I think priority should be given to preserving existing habitat before new areas are attempted to be established or rebuilt.
- I would like to see additional information in the local paper and the Wisconsin Outdoor Journal, etc. Speakers should appear at the area fishing clubs.
- The cane beds in Lake Poygan (central portion and N. edge) cannot withstand the wave action and moving ice action. Both are entirely acts of nature! The N. shoreline—east and west of the mouth of the river should be protected by riprap!
- Do not lower the water level to save the cane beds. Raise the water level 4-6 inches.
- I think a cable should go around the beds (2 within 200 yards of my house) that are almost extinct.
- Think this covers it. Am an avid duck hunter from 1937. Can still rememeber rafts of cans and scaup on lake—now wild rice and wild celery all are gone.
- I think we have to keep boats out of cane beds in spring and summer when you can't actually see where the cane starts and stops. Also water levels have to remain higher in spring so that the ice doesn't tear out the roots. These are major reasons the cane beds have deteriorated so much over the past 15 years.
- Boaters, shore owners, myself included <u>need</u> levels of water at or slightly higher than current levels. This means <u>NEW</u> canebeds in shallow water NOT regaining what has already been lost—a wasted fight.
- In my opinion the following is what has been hurting the cane beds the most. 1) Ice damage caused by lowering the winter/spring water level too much, when ice goes out it takes cane with it. (Note: Lone Willow hasn't changed much in 70 years because it doesn't freeze very much around there). 2) Fishermen/jet skiis, boaters going in cane beds during the spring and summer growing season. It created large holes in some cane beds. (Note: This has gotten better since the signs have gone up around the cane beds)—public awareness. 3) Water levels in the late spring (after fish are done spawning) are kept too high for the pleasure boaters. This does not allow the weed growth. One would think that lower water levels would help the cane beds germinated with some new growth. (Note: On the north end of the Hindenberg line it seems like the cane is re-germinating in spots. It is very shallow in that area and some of the cane is very thick. Or allow an experiment on growing new cane beds. In general, the cane beds are most sensitive during spring/summer growing season. I do not believe for a minute that the cane is negatively impacted in the fall during waterfowl season. Again note: Lone Willow cane has been hunted as hard if not harder than the rest of the cane beds and it has not changed much for 70 years. If in fact Lone Willow did change a little it has been on the west end where all the

boats park in the summer. That cannot be good for new growth or existing cane! I hope my opinion is helpful.

- In 1957 my parents bought a small cottage on Lake Winneconne when I was only 6 years old. In 1996 I tore the cottage down and built a permanent residence that my family and myself now live in. Over the past 43 years I watched the cane beds and all the other lake vegetation change drastically. In the 50s and 60s most lake shore residents had to cut channels through the vegetation that grew along the shore in order to get their boats into the lakes. All that vegetation is now gone. I've use the cane beds to fish and hunt out of since the early 60s, and they are only a small portion of what they were in the 60s. I think there are lots of reasons as to why the canebeds have disappeared over the years, but I think the main reason is from ice piling up on the shallow canebeds pulling them out by the roots. There are some very large holes on the west side of the cane bed known as Lone Willow, which could only have been caused from the ice. As I'm writing this letter I can look over the lake and there is a very large pile of ice that piled up from the strong winds on April 8th on top of the cane beds known as the Hindenberg line. About 12 years ago. Ron Bruch from the DNR had meetings around the lake talking about some break walls that were planned for Lakes Poygan and Winneconne. I think if the break walls would be installed in the lakes it would be a good start to the restoration of the cane beds and some of the other vegetation that once filled the lakes. Another reason the cane beds have been disappearing is the large boats that run through the cane beds in early summer before the cane beds are high enough to see. If break walls were installed it would define them better and force the boaters to go around them.
- Who determines how the manipulating is done? Do you know how high or low water levels affect them? Which is best? [in response to question #D5]
- At what cost to other areas of the lake/river and what would be the possible repercussions of doing so. I cannot really answer yes without more information [#D5 response].