KANGAROO LAKE

DOOR COUNTY, WISCONSIN

WISCONSIN DEPARTMENT OF NATURAL RESOURCES LAKE PLANNING GRANT.

SPL-342-14 2014-2016

TITLE: KANGAROO LAKE SHORELINE PRESERVATION & RESTORATION PLAN.

REPORT: HARDSTEM BULRUSH (Schoenoplectus acutus) INTRODUCTION AND GROWTH IN KANGAROO LAKE.

by

Paul G. Mahlberg and Sherrill Eichler

Supported by the Kangaroo Lake Association

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PARTICIPANTS AND BULRUSH PLANTING LOCATIONS (Map 1, arrows).

Landowner sites.

Bezold, George	7211 State Hwy 57
Chiarelli, Luke	7649 Elm Point Road
Ehlers, Todd and Cindy	7097 Old Dam Road
Fritz, Don	7714 West Kangaroo Lake Road
Haig, Nari and Mark Huber	7135 Old Dam Road
Hoffman, Liz and David	7425 State Highway 57
Hoffmann, Leon and Susan	7399 State Highway 57
Ikeda, Jennifer and Michael	7436 West Kangaroo Lake Road
Johnson, Al and Cynthia	7459 State Hwy 57
Kohel, Donna and Larry	7463 South Kangaroo Lake Road
Leach, John and Kathy	7481 South Kangaroo Lake Road
Mahlberg, Paul G. and Marilyn	7694 West Kangaroo Lake Road
Nelson, Bill and Carol	7628 Elm Point Road
Renier, Chris and Julie	3027 Windsong Lane
Schneider, Tom and Jane	7612 West Kangaroo Lake Road
Wienkers, Kevin and Cindy	7099 Bauer's Old Dam Road
Williamson, Howard and Patty	7501 South Kangaroo Lake Road

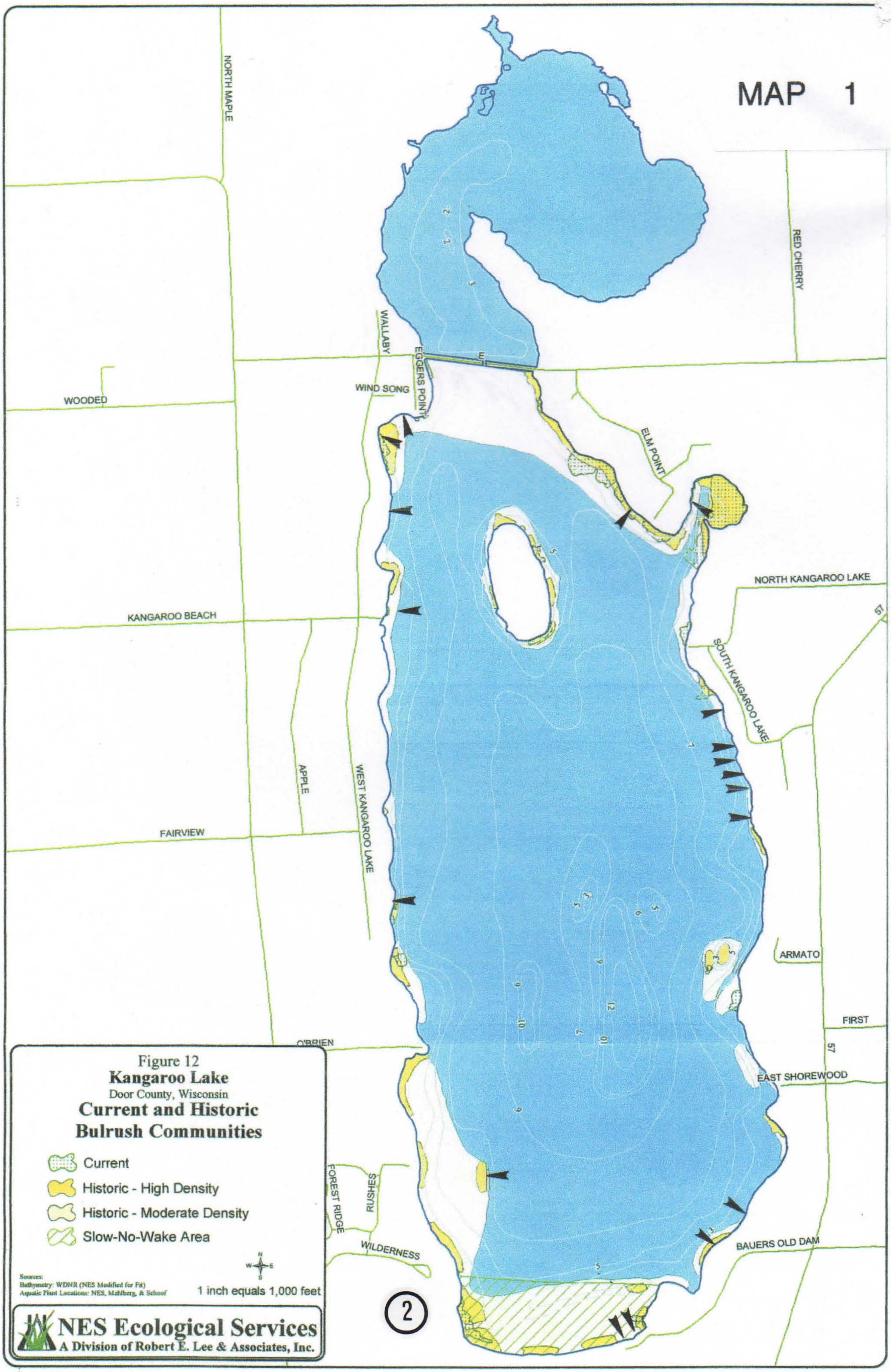
Other participants assisting in planting, recording and/or assembling data:

Eichler, Sherrill and Al	3059 Fairview Road
Hage, Eric and Denise	7774 Wallaby Lane

Additional planting site. Rushes Reef (Map. 1, arrows).

Site of rhizome planting. Mahlberg, Paul G. and Marilyn

MAP 1


NORTH MAPLE
RED CHERRY
WALLABY
EGGERS POINT
WIND SONG
WOODED
ELM POINT
NORTH KANGAROO LAKE
SOUTH KANGAROO LAKE
KANGAROO BEACH
57
APPLE
WEST KANGAROO LAKE
FAIRVIEW
ARMATO
FIRST
O'BRIEN
EAST SHOREWOOD
FOREST RIDGE
RUSHES
WILDERNESS
BAUERS OLD DAM
Figure 12
Kangaroo Lake
Door County, Wisconsin
Current and Historic
Bulrush Communities
Current
Historic - High Density
Historic - Moderate Density
Slow-No-Wake Area
Sources:
Bathymetry: WDNR (NES Modified for Fit)
Aquatic Plant Locations: NES, Mahlberg, & Schoof
1 inch equals 1,000 feet
NES Ecological Services
A Division of Robert E. Lee & Associates, Inc.
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INTRODUCTION.

Hardstem bulrush (Schoenoplectus acutus) is an abundant emergent plant in wetland communities (Borman et al, 1997; Gleason and Cronquist, 1991; Tilley, 2012). It is a source for wildlife food, nesting area for aquatic organisms, fish and other animals, and contributes to moderating storm erosion along lakeshores. Its abundance and visibility in the north lobe serves as a visual comparison for observers when viewing this plant in both lake basins (Figs. 1, 2).

Growth of hardstem bulrushes in the south lobe of lake has been observed and recorded to be under stress, and extensive populations of these plants historically have decreased or disappeared both in deep water and along the lake shoreline (Map 1; Onterra, 2008).

The goal of this project is to experimentally reintroduce seedling hardstem bulrushes at many locations along the lakeshore, and on an offshore reef site where this species formerly grew. In this program landowners are helping in planting, observing, recording and protecting the conditions of their plants over a multiyear period with the objective to determine the desirable long-term conditions for establishing new bulrush populations. Bulrushes are being planted in conjunction with our fishsticks program in that seedling bulrushes were planted among fishsticks as well as among native shoreline plants to provide protection from animals foraging seedling plants.

Plugs of several adult bulrush rhizomes collected from Kangaroo Lake also were planted. Rhizomes represent the principal form of reproduction for bulrushes in the lake. Information on their growth and developmental pattern will be useful, when compared with that of seedlings, so as to evaluate the potential for re-vegetation purposes.

Several new observations related to bulrush seasonal growth and plant structure were observed during this study and are reported here to broaden our understanding of its ecology. This information will help us and others assess growth of this plant under field conditions in this as well as other lakes.

Historically bulrushes were observed in the study areas. Although the basis for their disappearance along the shoreline is not known, this study may provide pertinent information that will enable us to re-establish new populations at many locations. Our participants will gather new information on growth of these plants not only during this grant period but for future years as well and enable us expand these planting to other areas of the lake.

MATERIALS AND METHODS.

Seedlings. Seedlings, 1-, and 2-year greenhouse-grown plants in 3-in. pots, purchased from Agrecol and Transplant Companies, were planted at 17 homeowner sites around the lake (Map 1, arrows). Plants possessed a primary root system and a

Figure 1. Hardstem bulrush populastion north of causeway growing in water several feet deep.

Figure 2. Buirush population at south end of lake. Many stems have been decapitated.

short rhizomatous shoot with 3-4 blade-like leaves 18-24 in. long. Shore structure at different locations included marl, sand, gravel or rock. Water depth at planting sites included shoreline (1-in. or less water), or water 4-, 8-, 16-, or 24-in. deep. Plants were spaced about 6-in. apart. Planted seedlings were surrounded with 3 rocks to avoid them being washed out by wave action during period that plants established roots in the substrate.

Seedlings were planted along the shoreline among fishsticks (2015, 2016, 2017) at those locations where present as well as among shoreline plants to provide protection to bulrushes from foraging geese or other animals (Figs. 1, 2).

Planting periods included August 2014 (year 1), August 2015 (year 2), and May-early June 2016 (year 3), and May-early June for new partners in 2017 (spring year 4). Eight seedlings were planted at each location in year 1, five plants in year 2, and 5 plants in year 3 (Table 1). Seedlings also will be planted at new fishstick locations in year 2017. Locations were marked by GPS. Sites were examined 24-36 hours after planting to check plant survival. Subsequent plant growth was evaluated by increase in number of stems, size and shape of leaves.

Rushes Reef. Seedlings, three sets of 8 plants, were planted (year 1) at three locations on Rushes Reef, two sets in 18-in. water and one set in 8-in. water, during August (2014). All plants were surrounded with several stones to avoid their being washed out by wave action and enable plants to root (Map 1, arrow). Locations were marked by GPS, and sites checked within 24-hrs. for plant survival.

Rhizome plugs. Several (5) plugs were collected from along the causeway. No such plugs were commercially available. (A DNR permit is required to remove bulrushes from the lake.) These plugs, cut into approximately 4-inch round pieces, were planted at Mahlberg shore in June 2013 to establish them as rooted plants for use in the 2014-2017 program. Each plug contained at least one developed horizontal rhizome shoot and several upright round stems.

Only the rhizome planted at the shoreline (1-in. water) survived for use in this study. It rooted and produced several vertical stems during year 2013. This rhizome was employed in subsequent studies (2014-2017). Routine measurements included horizontal rhizome length, number of upright round stems, height of stems, time of floral stem appearance, and duration of stem growth during each year of program.

Horizontal rhizome segment. Botanically, a rhizome is a modified shoot. A segment consisted of one robust horizontal shoot with a tip meristem that enabled it to grow along the lake bottom. A rhizome tip can grow rapidly--one to several feet a year--and develop adventitious roots along its lower surface that anchor it firmly to the lake bottom. New, specialized shoot buds develop at nodes along the upper surface of this growing rhizome. Each bud will form one or several vestigial leaves, followed by a upright round stem that will grow above the water surface to form a tall stem that characterizes a bulrush. Most upright stems are vegetative, but some will form flowers and seeds. The horizontal rhizome is perennial, and forms new upright stems every year. In contrast, upright stems are annual growths, and die each fall; they typically break off the rhizome by tissue decay or are cut off by lake ice movement in winter.

Buds on horizontal rhizome. Many specialized buds form along this rhizome during its growth. Each bud develops an intercalary meristem (group of dividing cells) that initiates formation of an upright stem. The uppermost of these meristem cells progressively elongate and begin to differentiate into maturing tissues, including epidermis, vascular and cortical parenchyma of a stem.

Continued meristem activity in the bud, and formation of maturing tissues in the new elongating stem, result in elevating the maturing portion of a new stem above the water surface. Thus, maturing tissues of a developing green stem are at its tip, and are most distant from its meristem in the bud (exactly opposite of a typical stem familiar to us). Total height of an upright stem is determined by duration of intercalary meristem activity in a bud. Upright stems can grow several feet in height. It is unknown how the plant controls stem height.

This intercalary meristem produces both vegetative and flowering stems during a growing season. Because flowers are positioned at a matured tip of a stem high above the water, those young flowers most probably were initiated in the intercalary meristem prior to stem emergence above the water surface. Flower formation is triggered by the impact of changing pattern in the daily duration of light-period/dark-period (photoperiod) during each day. The critical photoperiod that induces the production of flowers in bulrush is unknown and requires further study.

Specifically, in 2016, the horizontal 14-ft. long rhizome produced 50 tall stems during the period May through early July. The latter 5 of these stems formed flowers in July. Then, three additional short stems appeared immediately after the floral stems. These three emerged only 1-, 2- and 4-in. respectively, above the water surface whereupon they ceased further growth during remainder of the summer to fall period.

Bulrush growth and day-length. Bulrush growth and stem development are day-length dependent. Vegetative stems are formed during the spring period of long-days/short-nights (Hammiverse Lectures, 2012) whereas as the daily light/dark ratio changes floral stems are formed. Although each new stem is derived from an intercalary meristem of one of the many bud along the horizontal rhizome the critical light/dark ratio controlling each growth phase remains to be determined from experimental studies on this plant.

Figure 3. Seedlings in gravel shore under evergreen shoreline trees. First-year planting at Bezold.

Figure 4. Seedlings in stony shore under native deciduous trees. Second-year growth at Ehlers.

OBSERVATIONS.

Seedlings. Most successful seedling growth occurred in 2016 when seedlings were planted at the shoreline, and when planted early in the growing season during late May and June. Desired substrates included sand and/or gravel. The most robust plants included those at Leach and Schneider. Plants developed multiple leaves and, at Leach where plants formed the first observed robust round stems, some leaves grew 24 inches or more in height. Further observations by participants should determine the presence and growth of horizontal rhizomes and development of additional round stems during development in 2017 and later years. Seedlings also developed well at Bezold, Ehlers, Hoffman, Ikeda, Nelson and Wienkers but no round stems were noted on the plants (Figs. 3, 4, 5, 6).

The rocky and more precipitous shorelines at Johnson, Mahlberg and Williamson afforded less successful seedling survival in 2014.

Seedlings planted at all locations during August 2014 in 12-18 in. water remained green throughout the summer but developed few or no new leaves. These plants died during the 2015 winter. As Liz Hoffman noted, these plants simply drowned.

Seedlings planted in August (2015) in 4-12 in. of water likewise remained green for the summer and fall, but did not show robust growth. At several locations plants in shallower water survived and produced additional leaves. These surviving plants from 2015 were observed in spring of 2016 (Table 1). When we planted new seedlings in 2016 at the shoreline they were placed in proximity to the 2015 plants (Table 1). Thus, the seedling population in spring of 2016 included plants from years 2015 and 2016. Most plants remained small but well rooted and established. Our participants should observe and record whether all these plants survived into 2017, and into future years, and record if, and when, any plants form horizontal rhizomes.

Seedling growth at most locations remained confined to the area where they were planted (Figs. 7, 8). No robust rhizomes were evident on plants during observation periods, nor did plants produce rhizomes that grew directionally toward deeper water of the lake. Many plants died. Our participants should continue to observe and record when plants develop rhizomes that grow into deeper water.

Seedling plants produced a number of new stems. Early season stems were vegetative, but in July after the summer solstice (June 20) plants produced flowering stems. Our participants should observe and record, including dates, when their plants produce vegetative as contrasted with floral stems. And, whether any new vegetative stems appeared, and grew, after the development of floral stems on a given rhizome. We want to determine whether the times of appearance of vegetative as contrasted with floral stems are responding to light/dark photoperiod conditions.

Table 1. Seedling Survival During 3-year Period.

Participant	Year 1 Submerged	Year 2 Shoreline	Year 3 Shoreline
Bezold	-	-	5/5
Ehlers	0/8	5/5	4/5
Hoffman	0/8	0/5	3/5
Ikeda	0/8	5/5	5/5
Johnson	0/8	0/5	5/5
Kohel	0/8	-	-
Leach	-	-	5/5
Mahlberg	0/8	-	-
Nelson	0/8	3/5	6/6
Renier	0/8	0/5	4/5
Schneider site S	0/8	0/5	5/5
Schneider site N	0/8	2/5	4/5
Wienkers	0/8	5/5	5/5
Williamson	0/8	0/5	3/5

0/0, survivors among number planted.
-- , none planted.

Rushes Reef. All seedlings on Rushes Reef disappeared at the three sites within 24 hours. No residual traces of plants were evident at any site. While observing the plant loss on the reef, a flock of 50 or more geese were observed about 75 yards from the reef. Geese have been observed swimming on the reef area during an earlier observation period.

Rhizome segment growth. Rhizome segments, when planted at the shoreline, are very effective for establishing a new plant clone in difficult lake bottom terrain. The following data are from the rhizome segment that was established at Mahlberg in 2013 (see "c" in Material and Methods), and that grew during the reporting period 2014-2017.

Rhizome growth was initiated in May (2014), the first year for our program. It grew 2.5-ft. along the lake bottom to a water depth of 20 inches, and produced 24 robust round stems during the growing season. Stem growth was initiated in May when the first new stem tips became evident on the rhizome region near the shoreline. Subsequently the other stems arose toward the rhizome tip. All stems produced by rhizomes are round in shape. The last four of the 20 stems to form during the stem-growing period became floral stems.

In year 2 (2015), this rhizome grew an additional 4.5-ft. along lake bottom into deeper water, its tip resting in lake bottom substrate 27 inches under water. The

Figure 5. Round stems on seedling, 2016, along Leach's shoreline.

Figure 6. Robust seedlings with tall stems at Schneider shoreline.

Figure 7. Seedlings on stony shore adjacent to fishstick among shore shrubs at Hoffman.

Figure 8. Robust seedlings packed among rocks adjacent to fishstick at Ikeda shoreline

intercalary meristem of each bud along the rhizome length gave rise to 38 stems. Some of these stems grew to a height of 54-in. above water surface, and also extended down under water an additional 27-in. to each of their respective intercalary meristems on the rhizome. Several late-forming stems (4) of the growing season gave rise to flowers. The rhizome produced no additional stems after appearance of the floral stems.

During year 3 (2016) this rhizome tip grew an additional 7 feet (total length, 14 feet in three years) along the lake bottom to a water depth of 31 inches. Intercalary meristems of buds along this rhizome produced 52 stems during the 2016 growth period (Fig. 9). The tip also formed a fork during its growth, each fork over 1.5-ft. long (Fig. 10). These stems arose from buds along the entire rhizome length. Some stems were recorded as tall as 60-in. above the water surface, plus an additional 31 inches down through the water to the rhizome on the lake bottom.

The 52 stems included 44 non-floral, 5 floral and 3 short stems, as described elsewhere, during the growing season (Fig. 8). Non-floral stems formed during the early growth period of May and June. The five floral stems formed during the later growth period of July. These stems formed flowers within a few days of each other. Flower clusters arose near the stem tip and were subtended by a short leaf-like bract that projected at a sllght angle from the vertical stem axis. Floral stem formation appeared to trigger cessation of new stem development on a rhizome.

Further trials with rhizome segments planted under diverse shoreline conditions are desirable to determine their effectiveness for establishing robust clones in the lake.

DISCUSSION.

Seedlings. Seedlings can be successfully grown when planted at the shoreline at some but not all locations selected for this study. For success seedlings should be planted early in the growing season during May and June. Acceptable substrates included loam, sand and gravel, rather than rocks/stones. Under optimal growth conditions year-old seedlings may begin to form round stems that typify bulrushes. Round stem development also is indicative that buds with intercalary meristems had begun to develop on the supporting horizontal rhizome.

Successful development of young bulrushes from seedlings may require their formation of horizontal rhizomes that grow from the shoreline into deeper water. No 1- or 2-yr. seedlings showed development of such mature rhizomes. Continued on-going observations by our participants during next several years should identify when such rhizomes appear on seedling plants. Rhizome development may be essential for plant survival during the initial years of growth.

Rhizome segments. Seasonal rhizome growth of several feet, and development of numerous vegetative and floral stems was impressive on the observed rhizome segment. Yet it is unclear if a rhizome extending from the shoreline into several feet of water remains dependent upon attachment to its shoreline host for annual growth. Studies of this growth process are necessary to understand this growth phenomenon into deep water. Historically in Kangaroo Lake, bulrush clones grew in water depths of 5 feet or more, and several hundred feet from any shoreline.

Stem development on rhizome segments. Photoperiodism impacts stem formation and the occurrence of flowering in bulrush. Stems that developed during the increasing-light/decreasing-dark period of the spring growing season, May-June, were vegetative stems. However, in late June-early July (post-summer solstice of June 20) only floral stems were formed. Absence of subsequent stem formation suggests stem initiation and growth may be a response to the daily decreasing light-period/increasing dark-period following summer solstice. No information is available in the literature on this phenomenon for bulrush. Studies on photoperiodism in bulrush are most relevant to determine the critical light-period/dark-period conditions that control vegetative and floral stem development in this plant.

Hardstem bulrush is a native plant in marshes and lakes in our area. It should be possible to obtain plants from local property owners for use in studies in Kangaroo Lake. It is important to clean and remove possible invasive species from the segments before planting them in the lake.

Predators. Animals including birds. Animal predation, perhaps geese, may have been responsible for foraging and pulling out the seedlings on Rushes Reef. Presence of our participants at planting sites is interpreted to help thwart marauding geese from foraging on planted bulrushes along the shoreline of our participants.

Goose and ducks populations occupy the least disturbed lake area at the south end where they forage for food, rest and socialize. Deer wade into shallow water among bulrushes and may feed upon them. Chewed pieces of bulrush rhizomes dug from the lake bottom also have been observed along this shoreline and indicate possible presence of muskrat in the area.

Geese forage on bulrush populations throughout the lake. Foraging activity can be recognized by a characteristic diagonal cut on a stem 8- to 16-in., or more, above the waterline (Fig. 11). Partially cut stems with a fragment dangling from the stem, which is indicative of goose activity, may be evident among plants. Large numbers of stems can be affected in a population. Damaged stem stubs have not been observed to grow or repair during remainder of a growing season. Further studies on how such damage affects survival of a bulrush clone are necessary.

Stem arch formation. Both vegetative and floral stems develop a curved shape along the top 1/2 of their axis late in the summer/fall period (Fig. 12). Shape modification of robust green stems may reflect differential cell wall elongation around

Figure 9. Production of numerous stems on rhizome during 2016 at Mahlberg.

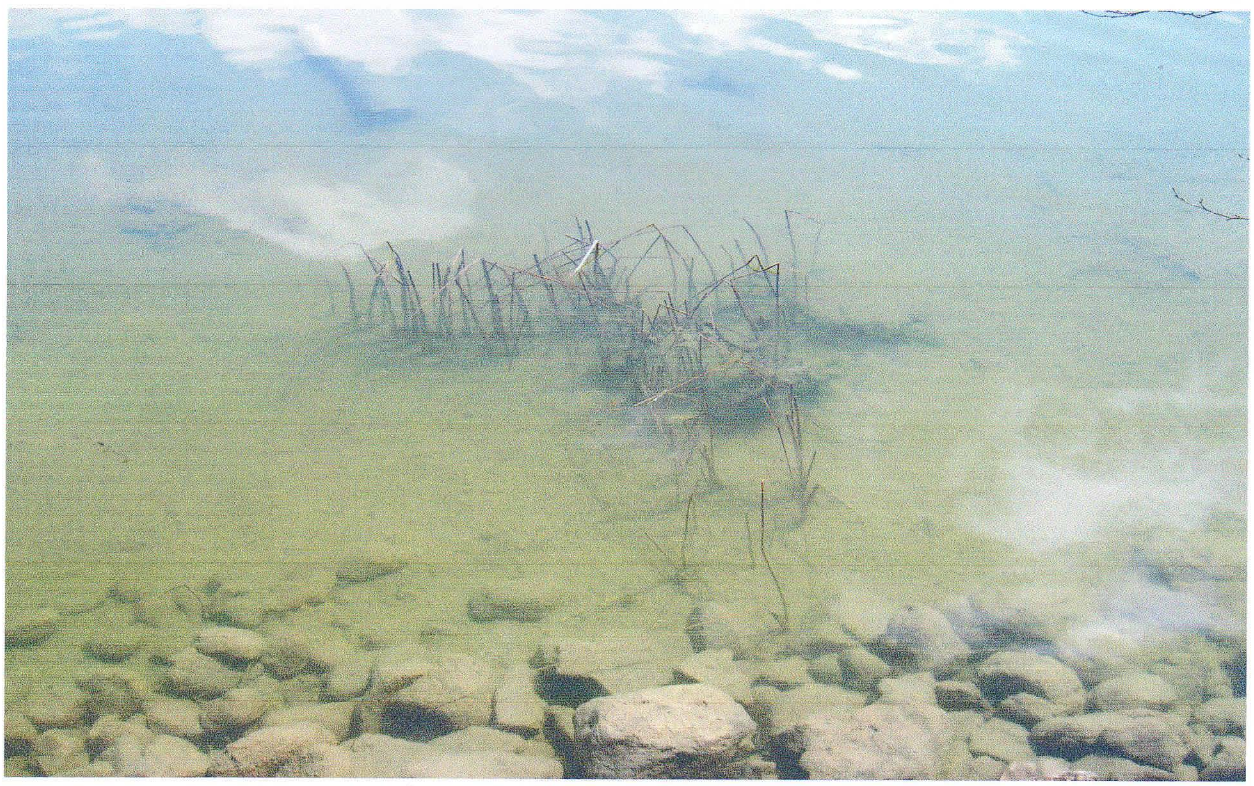

Figure 10. Rhizome rooted in lake bottom. Note forked growing tip. Initial inplant in foreground . Mahlberg.

Figure 11. Bulrush population at south end showing signs of having been foraged by geese.

Figure 12. Arching character of bulrush develops on both vegetative and floral stems during late summer.

the axis to facilitate curvature development of entire stem. As a result the tip region curves in excess of 45° bending it to nearly touch the water surface. Stem tips retain the arched shape as they continue to age into winter (Fig. 12).

Arch formation may be a selection response to reduce potential storm damage to tall stems. A further selection trend for arching of floral shoots in particular may aid seed dispersal in that seeds hanging near water surface would aid for self-distribution as well as be more available to birds and animals to passively carry off for distribution than seeds on upright tall plants. Curiously, a majority of curved stems are oriented in a similar direction.

Anatomical and morphogenetic studies of cell length and shape across the diameter of a stem are relevant for determining the basis of stem arching. Further studies will identify whether all, or only some, bulrush populations show stem arching, and if other species or related genera also evolved and display this trait.

KLA. The Lake Association should consider establishing a bulrush website that includes names of current participants, and other lake members desiring to join the group, to discuss questions and topics about bulrushes, and sources of seedlings and rhizome segments so as to continue this planting program into the future. Information from such discussions also can be presented in our Newsletter.

SUMMARY.

Bulrush seedlings and rhizome segment(s) can be established by planting them at a shoreline location of marl, sand or gravel in approximately 1-inch or less water. Plants must be planted during early spring period, May to mid-June, for maximum survival and establishment of root and shoot systems. Some seedlings formed round stems during the first year of growth, but no seedlings developed a major rhizome that grew into deeper water. Rhizome segments were effective for establishing new bulrush clones. Vegetative stem growth and flower stem formation appeared to be controlled by photoperiod. Little or no further development of vegetative stems occurred following floral stem development and flowering. Human proximity and that of brushy plants afforded some protection to seedlings and rhizome(s) from foraging animals. Decapitated stems cease further growth. Studies are necessary to determine factors that control stem arch formation and its evolutionary role in bulrush life history. Our Association should establish a bulrush website for interested participants to continue this bulrush planting program for Kangaroo Lake.

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