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A SUMMARY OF SUBMERGED AQUATIC VEGETATION (SAV) STATUS WITHIN THE LOWER ST. JOHNS RIVER: 1996 – 2007

A Summary of Submerged Aquatic Vegetation (SAV) Status Within the Lower St. Johns River: 1996 – 2007

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EXECUTIVE SUMMARY

The St. Johns River is a 500-km long, north-flowing, blackwater river located within the upper eastern extent of peninsular Florida, USA. The lower 161 km of the St. Johns River includes the St. Johns estuary and a tidal, freshwater reach that, collectively, are called the Lower St. Johns River (LSJR). From approximately river mile 27 to the upper extent of the LSJR, are approximately 2140 acres of submerged aquatic vegetation (SAV). SAV routinely seen within the LSJR include eleven species of freshwater and brackish angiosperms and macroalgae. The dominant species of SAV in terms of latitudinal distribution, within-bed distribution, and coverage, is *Vallisneria americana* or tapegrass. SAV, most notably seagrasses have not been found in the mesohaline and polyhaline sections from river mile 25 to the mouth in part due to the absence of littoral shelves. Extremes in light attenuation most likely exclude seagrasses while extremes in salinity exclude brackish and freshwater species of SAV.

SAV habitat is crucial to the preservation of a fully-functional ecosystem providing refuge, food, habitat, and nursery sites for an assemblage of aquatic organisms. In addition, SAV adds oxygen to the water column in the littoral zones, reduces sediment suspension and shoreline erosion, and assimilates nutrients that might otherwise be used by bloom-forming algae or epiphytic algae. SAV has also been established as an important biological indicator of river ecosystem health.

There are two main stressors that limit SAV distribution and abundance within the LSJR: light attenuation and salinity. High color, planktonic algae blooms and suspended solids, increase the level of light attenuation within the water column. SAV declines have been recorded in the upper reach of the LSJR corresponding to increases in color and suspended solids following above normal precipitation events. Extreme examples of this occur in the basin where SAV beds have cycled from barren to lush meadows corresponding to increases and decreases in precipitation, respectively. The effects of salinity on SAV has been documented during two droughts, which occurred from 1999 – 2001 and from 2006 – 2008. Some sections of the lower reach of the river were completely denuded after prolonged exposure to high salinities. Other stressors to the SAV include proliferation of phytoplankton, epiphytic and floating macroalgae. These algae can shade the SAV and also interrupt gas exchange. Finally, tropical storms and hurricanes not only

increase light attenuation by increasing color and suspended solids in the system, they can also remove SAV through physical scouring of the littoral zone.

Below is a summary of changes in SAV coverage, ecozone and depth distribution, and species diversity within the lower St. Johns River basin (LSJRB) from 1996 through 2007. Data were collected annually at 75 fixed transect sites within the LSJRB and quarterly or monthly from at minimum 7 sites. During the survey period from 1998 – 2007, SAV occurred from river mile 27, near the confluence of Fishweir Creek in Duval County, to the most upstream reach of the LSJR (river mile 100). SAV meadows extended from approximately 2 m to 357 m from shore and colonized to a mean maximum depth of 0.79 m. The most recent estimate of SAV coverage within the mainstem LSJR is 2,140 acres (using 2003 & 2004 data) (Dobberfuhl and Hart 2006). The nine year mean (1998, 2000 – 2007) of total linear coverage for the vegetated lacustrine sections (ecozones 1 & 2) was 53.37 m ± 2.43 (mean ± SE) while mean total linear coverage in the freshwater riverine reach (Ecozone 3) was 4.30 m ± 0.50. Extremely short beds in Ecozone 3 appear to be due to conditions other than water quality and that are not found in ecozones 1 & 2. The basin-wide mean for total linear coverage for 2007 was 31.04 m ± 5.07 m (mean ± S.E.) as compared to the greatest mean total which occurred in 1998 (57.01 m ± 4.33 m) and 2004 (57.08 m ± 8.57 m). The lowest occurred in 2000 (29.53 m ± 3.96 m) and 2005 (30.52 m ± 5.06 m). A nine-year mean showed the distribution of the dominant species, *Vallisneria americana*, had a within-bed coverage of 63 %, appeared on 84% of all transects surveyed, and was most often (>90%) associated with the deep-water edge of the SAV meadow. *Vallisneria americana* grows to a maximum water depth of 0.77 m. Two other dominant species included *Najas guadalupensis* and *Ruppia maritima*. They accounted for 16% and 10%, respectively, of total cover.

Basin-wide, large declines in SAV occurred during the drought periods (1999 – 2001 and 2006 – 2008) and following the hurricanes of September 2004. In both instances, recovery from these events has not occurred in the downstream section corresponding to the portion of the river flowing through Jacksonville. Since the droughts of 1999, approximately 4 river miles of SAV have been lost and have not returned while in other, upstream sections SAV has regained its former abundance and distribution. While the initial loss of SAV is due to natural events, the inability of SAV to rebound in the highly urban sections of Jacksonville with corresponding degraded water quality appears to be linked to high light attenuation that creates an additive impediment to SAV recovery. Another example of the additive deleterious effect of multiple stressors is demonstrated by the findings of Gallegos (2005). While the light attenuating colored dissolved organic matter (CDOM), or color, of the LSJR is mostly of natural origin, the two other factors that have been found to increase light attenuation, chlorophyll-a and total suspended solids (TSS), are often anthropogenic. Thus, as decisions related to aquatic habitat protection are made, issues such as increased development and surface water withdrawal should be closely examined as to their potential exacerbation of stressors to SAV, both natural and anthropogenic, that already exist in the LSJR.

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Over the past ten years this program has relied on the assistance of a volunteer force to collect the data associated with the SAV monitoring. This report is dedicated to the WAV volunteers who have donated not only their time to the SAV Monitoring Project but have contributed the use of their boats, provided lunches, and assisted in recruiting new volunteers. It is also in recognition of the property owners who have granted land access permission to the study sites. Andrew Chapman of GreenWater Laboratories conducted all algal identification and provided consultation on all algae-related projects, for which I am grateful. I would also like to extend my gratitude to the SJRWMD Lower St. Johns River Basin Program for funding this project and for providing assistance with data collection. Finally, I would like to thank Dean Dobberfuhl, Lori Morris, and Alicia Steinmetz for their careful review of this paper.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

INTRODUCTION

The Lower St. Johns River

The St. Johns River is a 500-km long, north-flowing, blackwater river located within the upper eastern extent of peninsular Florida, USA. The lower 161 km of the St. Johns River includes the St. Johns estuary and a tidal, freshwater reach that, collectively, are called the Lower St. Johns River (LSJR) (Figure 1). The extent and amplitude of the tide fluctuates daily and seasonally predominantly due to wind driven events (Cera unpublished data 2004). The LSJR is generally divided into four ecozones, or sections, based on salinity regimes and water residence times. Each is characterized as follows, beginning at the most upstream reach of the system: the confluence of the Ocklawaha River to Palatka is freshwater riverine; Palatka to the confluence of Julington Creek is freshwater lacustrine; Julington Creek to downtown Jacksonville at the Fuller Warren bridge is oligohaline lacustrine and from downtown Jacksonville to the mouth of the river is mesohaline to polyhaline riverine. The salinity demarcations change according to seasonal fluctuations in precipitation (McGrail et al. 1998) and extreme climatic events such as drought, which occurred, from 1999 through 2002 and again in 2006 through 2007.

SAV Habitat and its Importance

Along the shores of the predominantly broad (5 km) and shallow (2.9-m mean depth) LSJR are hundreds of kilometers of potential littoral shelves (water depth < 1 m), many of which are populated by meadows of submerged aquatic vegetation (SAV) (Bartram 1791, DeMort 1991, Sagan 2001). SAV meadows have been found only in the upper three ecozones of the LSJR corresponding to the freshwater riverine (Ecozone 3), freshwater lacustrine (Ecozone 2) and the oligohaline lacustrine (Ecozone 1) sections. SAV has not been found in the most downstream, mesohaline/polyhaline reach of the river. Most recent estimates from high resolution aerial photography of SAV coverage within the mainstem LSJR indicate 2,140 acres (Dobberfuhl and Hart 2006).

The dominant species, relative to distribution and abundance within the LSJR, is *Vallisneria americana* alternatively referred to as eelgrass, tapegrass, or wild celery. Other SAV routinely seen within the LSJR include ten species of freshwater and brackish angiosperms and macroalgae. These include baby tears (*Micranthemum sp.*), coontail (*Ceratophyllum demersum*), dwarf arrowhead (*Sagittaria subulata*), horned pondweed (*Zannichellia palustris*), hydrilla (*Hydrilla verticillata*), muskgrass (charophytes), spikerush (*Eleocharis sp.*), southern naiad (*Najas guadalupensis),* slender pondweed (*Potamogeton pusillus*), and widgeon grass (*Ruppia maritima*) (Sagan 2003a, Sagan 2005). In addition, *Potamogeton illinoensis* and *Potamogeton pectinatus* have been found infrequently and at low coverage throughout the study period. Earlier surveys reported *Egeria densa* (DeMort 1991) within the LSJR, but it has not been observed during the study period. Photographs of these plants as well as distinctive (comparative) descriptions of their morphology can be found in "A Guide to Measuring Submerged Aquatic Vegetation in the Lower St. Johns River" (Appendix A).

This assemblage of SAV provides food and habitat for ecologically and economically important aquatic organisms. Many of these organisms, such as largemouth bass, catfish and blue crab are of substantial recreational and commercial value within the lower basin (Watkins 1995). SAV grazers include blue crabs (*Callinectes sapidis*) (Zieman 1982), invertebrates (Lodge 1991, Newman 1991), fish (Agami and Waisel 1988), and the endangered West Indian manatee *(Trichechus manatus*) (White et al. 2002). Waterfowl, many species of which are routinely seen on the LSJR, are known to consume both vegetative as well as reproductive structures of SAV including those of *Najas guadalupensis*, *Ruppia maritima,* and *Vallisneria americana* (Korschgen and Green 1988, Miller 1987, Kantraud 1991).

SAV also provides substrata, habitat, and refugia for a variety of invertebrates and vertebrates. Macroinvertebrates routinely observed associated with SAV leaves, stems, or roots include: chironomid larvae, bryozoans, hydroids, freshwater sponges, aquatic moth larvae, leeches, limpets, snails and bivalves (Sagan 1999). Macrobenthic monitoring in the LSJR, which included samples from within SAV beds, resulted in the collection of a total of 146 taxa (Mason 1998). Samples taken at 9 sites with SAV in the LSJR yielded more than 18,000 macroinvertebrates and 14,000 small-sized fish (Jordan 2000).

Studies within seagrass beds (review by Orth et al. 1984) and in SAV habitats in tidal freshwater rivers (Thorp et al. 1997) have shown that vertebrate and invertebrate communities are found at significantly higher densities and have higher diversity in SAV habitat than nearby unvegetated sites. Studies conducted by Jordan (2000) in the LSJR between May 1996 and August 1997 support these findings. Jordan found that small-sized fish (< 100 mm), predatory fish (including largemouth bass), and rainwater killifish associated with SAV habitat were between three and forty-three times more abundant than in unvegetated habitat. Species diversity for small-sized fish was twice that of unvegetated sites. Invertebrates, including grass shrimp and damselfly larvae, also had significantly greater densities in SAV habitat than in nearby sand flats.

Clearly, quality SAV habitat is crucial to the maintenance of a fully-functional ecosystem providing refuge, food, habitat, and nursery sites for an assemblage of aquatic organisms. In addition, SAV adds oxygen to the water column in the littoral zones, reduces sediment suspension and shoreline erosion, and takes up nutrients that might otherwise be used by bloom-forming algae or epiphytic algae. SAV has also been established as an important biological indicator of river ecosystem health. SAV distribution, diversity, and abundance are used as the major biological indicator of water quality, specifically water clarity and nutrient levels, in the Chesapeake Bay (Dennison et al. 1993).

Stressors to SAV

Many abiotic and biotic stressors to SAV exist in the LSJR ecosystem. Light attenuation is thought to be an important factor limiting SAV distribution and abundance throughout the LSJR and is one of the most commonly cited factors affecting SAV distribution in other systems as well (Dennison 1987, Duarte 1991, Stevenson et al. 1993, Kenworthy and Fonseca 1996). High color, planktonic algae blooms and suspended solids, increase the level of light attenuation within the water column and often characterize the LSJR (Aldridge et al. 1998, Gallegos 2005). Dense and persistent macroalgal blooms and epiphyte growth, as have been quantified in the LSJR (Chapman et al. 1999, Sagan 2003b), not only attenuate light reaching SAV photosynthetic surfaces but such fouling can also reduce nutrient exchange between SAV foliage and the water column (Sand-Jensen 1977, Kiorboe 1980, review by Orth and van Montfrans 1984, Ozimek et al. 1991, Tomasko and Lapointe 1991, Harden 1994, Lapointe et al. 1994). Throughout the decade-plus long study, extremes of climatic events have occurred which have negatively affected SAV. A three-year drought occurred from 1999 – 2001; drought-induced increases in salinity had deleterious effects on the SAV in the lower reach of the river and in other systems as well (Sagan 2002, Cho and Porrier 2005, Sagan 2007). In September 2001, a tropical storm swept through the LSJR and in 2004 three hurricanes (Frances, Ivan, and Jeanne) passed through northeast Florida. In both instances, physical scouring of the SAV bed as well as increased light attenuation resulting from increases in color, turbidity and total suspended solids (TSS), caused declines in SAV. At this writing, LSJRB is in the midst of another drought that began in 2006. Finally, absence of SAV beds due to boat dock shading has been identified as a growing concern within the LSJR (Steinmetz et al. 2004).

The following report summarizes changes in SAV coverage, ecozone and depth distribution, and species diversity within the lower St. Johns River basin (LSJRB) from 1996 through 2007. Representative data are derived from two complementary datasets. One dataset is from seasonal and monthly surveys at permanent monitoring sites; the other, from annual basin-wide surveys. Also included, is a review of related research depicting effects of abiotic and biotic variables as well as natural and anthropogenic stressors to SAV in the LSJRB and in other systems. In addition, a discussion of future stressors is presented.

MATERIALS AND METHODS

Changes in coverage and distribution of SAV within the LSJRB (Figure 1) were assessed across a twelve-year period and included data from 1996 through 2007. Two data sets were used for the analyses, permanent monitoring station data and groundtruthing data. The intended purpose of SAV groundtruthing was to act as field verification of aerial photography surveys of SAV. However, it has provided a basin-wide data set complementary to SAV permanent monitoring station data.

Data collection methods for each data set include recording SAV species coverage. The permanent monitoring station data set also includes SAV canopy height. It should be noted that a different method was used to ascertain SAV species coverage for each data set. SAV coverage at permanent monitoring stations was ascertained by recording SAV presence or absence at 1-m intervals along a transect. Those data are reported as SAV percent occurrence. SAV coverage at groundtruthing sites was ascertained by recording at continuous intervals, the intercept length of each species along the transect; the method is commonly called the line-intercept method. Those data are reported as SAV foliar coverage in meters. A full description of transect locations, data collection methods, and analyses is provided below.

SAV Permanent Monitoring Stations (PMN) and Water Quality Monitoring

<u>SAV Monitoring</u>

a. Historical SAV Monitoring

Table 1 summarizes the data collection schedule since 1995 for SAV monitoring as well as water quality monitoring at SAV permanent monitoring stations. The SJRWMD began the SAV monitoring project in fall 1995 and collected SAV line-intercept and biomass data at 12 stations within the LSJRB from fall 1995 through fall 1996. Since fall 1997 only SAV presence/absence and canopy height data have been collected at each site but beginning in fall 2001 line-intercept data collection was collected again and continued as of this writing. In spring 2000, the number of stations at which data were collected was increased to 20. Nineteen of these stations were located within the lower basin of the St. Johns River. The last station to be added was located in Lake George (Figure 1). The stations are listed below in decreasing latitudinal order. Point La Vista (PLV), Saddler Point (SDP), Bolles School (BOL), Mulberry Cove (MUC), Buckman (BUC), and Moccasin Slough (MOC), were located in Ecozone 1 and were located from approximately twenty-five to thirty-eight miles from the mouth of the LSJR. Fleming Island (FLE), Hallowes Cove (HAC), Orangedale (ORD), Bayard Point (BAY), Ferriera Point (FRP), Scratch Ankle (SCA), Federal Point (FDP), Rice Creek (RIC), and Mullis Dock (MUD) were located in Ecozone 2 and were located between forty-three and seventy-eight river miles from the mouth of the LSJR. Browns Landing (BRL) was located within Ecozone 3 near river mile eighty-five. The southernmost station (Lake George (LKG)) was located in Lake George (a widened section of the St. Johns River). Doctors Lake (DRL), Old Bull Bay (OBB), and Crescent Lake (CRL) were located in major water bodies flowing into the St. Johns River. DRL was located in Doctors Lake, an oligohaline lake flowing into the Ecozone 1 reach of the LSJR just north of MOC. OBB was located in Julington Creek which discharges into Ecozone 1 of the LSJR near river mile thirty-nine. CRL was located in Crescent Lake, a freshwater lake discharging into the Ecozone 3 reach of the LSJR via Dunns Creek.

b. Current Site Locations and Descriptions

As of 2007, SAV data were collected at eight permanent monitoring sites within the LSJR (Figure 2). Data at these sites have been collected continuously since 1996, with the exception of Orangedale; data were not collected between 2001 and 2005. The eight sites include, in decreasing latitudinal order, BOL, BUC, MOC, DRL, ORD, SCA, RIC and CRL. BOL, BUC, and MOC were located in the oligohaline – mesohaline ecozone of the river (Ecozone 1) and were approximately thirty, thirty-five and forty river miles, respectively, from the mouth of the SJR. ORD, SCA and RIC were located in the freshwater ecozone (Ecozone 2) and were approximately fifty, sixty, and seventy-five river miles, respectively, from the mouth of the SJR. DRL and CRL were located in major water bodies flowing into the St. Johns River. A summary of each site is included which describes access requirements, latitude and longitude coordinates, maximum bed length, species diversity, and sampling frequency (Table 1).

c. Frequency of Data Collection

SAV surveys at each permanent monitoring station were scheduled to occur during four seasons: winter (January – March), spring (April – June), summer (July – September) and fall (October – December). Quarterly surveys of sites occurred within one month of each season when possible (February, May, August, and November) to ensure consistency with previous sampling dates and consistent spacing across the year. Special effort was made to complete summer and fall monitoring during early August and early November, respectively. Hurricane activity in recent years has occurred in early September and surveys, if left until later in the season, could be impeded by adverse weather conditions. Similarly, in the fall, high precipitation levels combined with northeast winds create increased water depths at sites, which make sampling impossible, and in some areas, due to sewage treatment system overflow, unsafe. Thus, fall sampling was started immediately in late October/early November to allow for frequent cancellations due to adverse weather conditions. Data collection at the sites monitored monthly, Buckman and Rice Creek, occurred approximately on the 24th and 5th of each month, respectively, to coincide with previous monitoring dates.

d. Rationale and Data Collection Methods

Rationale

As described above, the data collection methods currently used by the SJRWMD have provided scientifically rigorous data with which the relationship between water quality and SAV has been explored. It is appropriate to first address why traditional methods of SAV quantification were not used in the LSJR. The dark, turbid waters of the St. Johns River reduce visibility of SAV. Depending on the season and light attenuation levels, SAV was not visible even when viewed in shallow water (< 10 cm) or underwater by a masked diver. During the fall, water depths were at their greatest (bed-wide mean depth = 0.67 m ± 0.25 (mean ± STD)), further impeding visibility (Sagan 2004a).

Even if visibility constraints were not an issue (ex. during low, low tides during winter months), LSJR SAV density and plant morphology (Figures 4a and 4b) was such that in-site determinations of 1) individual plant cover (per m^2) or 2) shoot counts could not be conducted. For instance, many nearshore plants, including the second-most dominant species, *Najas guadalupensis*, produce clonal shoots immediately adjacent to the parent plant through dozens of adventitious roots. Thus, conducting shoot counts would be widely subjective. In addition, many plants (*C. demersum*, *H. verticillata*, *N. guadalupensis*, *Micranthemum* sp.) concentrate foliage at the surface of the water. Even *Vallisneria* takes on a canopy-type architecture during low tides when up to one third of the plant leaves may be layed over onto the surface of the water. Thus, designating a cover category per species according to the Blaun-Blanquet method was not possible, nor was attempting to count shoots within a gridded quadrat to achieve density values.

Data Collection Methods

At each PMN site, five transects were placed perpendicular to the shore starting from the shoreline and extended towards the river channel. Transects were positioned parallel to each other at a distance of 0, 12, 25, 38, or 50 m from a stationary benchmark which was present at each site (Figures 5). Data were collected at 1-m intervals along each transect. In addition, data were collected along fixed transect locations from which discrete changes in SAV parameters such as canopy height, cover, bed length, and maximum water depth distribution, could be compared from sampling event to sampling event. This provided an especially fine temporal comparison at those sites at which monthly monitoring occurred. The use of fixed transects has provided a dataset from which rigorous statistical analyses has been achieved in other systems such as the Indian River Lagoon (Morris et al. 2000).

At 1-m intervals along each of the 5 transects, presence or absence of SAV within a 25 cm x 25-cm quadrat was noted. If SAV was present, the representative canopy height of each species was recorded, along with water depth, to the nearest centimeter. In addition, total SAV cover estimates within the quadrat were made using the following categories: 0 = bare (0% cover), 1 = sparse (1% - 32% cover), 2 = moderate (33% - 65% cover), 3 = heavy (66% - 100% cover). Sediment within the quadrat was qualitatively characterized as follows: 1 = sandy, 2 = mucky-sand, 3 = muck. Other substrates were also present and included riprap, clay, or humic material; these were noted as 0 = "other" in the database. Data collection continued along the transect to the last occurrence of SAV.

Along an additional five, randomly positioned transects, linear cover of all SAV species was recorded. Linear cover was obtained by recording the length of tape intercepted by each species and by bare ground along the entire length of the SAV bed (Figure 6). If not visible through the water column, SAV was removed at 5 cm-increments along the transect to ensure detection of all species. Interception of the tape included both interception by the plant and aerial interception of SAV foliage perpendicular to the tape.

<u>Water Quality Monitoring</u>

Table 1 summarizes the data collection schedule since 1995 for water quality monitoring at SAV monitoring sites. In October 1997, SJRWMD began biweekly water quality sampling. Water quality samples were collected at sites corresponding to the SAV PMN sites. These samples were collected at the outer edge of the SAV bed as well as in the river channel. Biweekly sampling was not coordinated with tidal flow and therefore occurred across all tide regimes. Water quality data chosen for representation included those factors that affect or are indicative of light attenuation: chlorophyll a (Chl-a), color, light attenuation coefficient (K_d), total suspended solids (TSS) and turbidity. K_d values were generated with an optical properties model which uses turbidity, color, and Chl-a values obtained from each site (Gallegos, 2005). K_d was generated using a basin-wide mean bed depth of 0.50 m. In addition, salinity was also included because increased levels during drought years have been shown to adversely affect SAV.

Groundtruthing

Site Locations and Frequency of Data Collection

Seventy-five groundtruthing sites were located at the most downstream extent of the sampling area near river kilometer 43 (mile 27) and extended upstream to river kilometer 161 (mile 100) (Figures 3a – 3c). Data collection was conducted on an annual basis and has been collected every year since 1998 (with the exception of 1999). Groundtruthing transects were initially randomly selected. The original transects were than revisited annually. In previous years, data collection occurred between June 1 and August 1.

Data Collection Methods

At each site a benchmark post was installed to mark the shoreline position. To delineate each transect, a survey tape was positioned perpendicular to the shore starting from the shoreline benchmark post and extended towards the river channel to the deep-water edge of the SAV bed. Along each transect, the length of tape intercepted by each species and by bare ground was recorded to the last occurrence of SAV. Interception of the tape included both interception by the plant and aerial interception of SAV foliage perpendicular to the tape as described for PMN sites.

In addition, water depth, sediment characterization, and species canopy height was recorded at regular intervals along each transect sites (Figure 5). SAV bed lengths varied considerably throughout the LSJR, therefore specific interval lengths were determined on-site for each transect. Intervals were equal to 10% of the current SAV bed length. For instance, intervals corresponding to a 100-m long bed will be at 10-m, 20-m, 30-m, 40-m, ……. 100m. Interval lengths were never less than 1 m or greater than 20 m. The last interval corresponded to the deep-water edge of the SAV bed. In addition, field notes were taken as described for the PMN sites. Finally, GIS coordinates were collected at the nearshore benchmark and at the deep-water edge of the SAV bed at each location and saved under a data filename as directed by the SJRWMD. Data from all 75 sites were entered into the SJRWMD SAV database.

RESULTS

Basin-wide Distribution and Abundance of SAV

SAV Distribution and Abundance within the LSJR Mainstem and Crescent Lake

The information below was derived from the annual basin-wide groundtruthing surveys. As described in the methods, data were collected during the growing seasons in 1998 and 2000-2007. During the survey period (1998 – 2007), SAV occurred from river mile 27, near the confluence of Fishweir Creek, to the most upstream reach of the LSJR (river mile 100) (Figure 2). SAV meadows extended from approximately 2 m to 357 m from shore (Figure 7) and colonized to a mean maximum depth of 0.79 m (Sagan 2007). Extreme differences in bed length were controlled primarily by bathymetry. The most recent estimate of aerial coverage within the mainstem LSJR is 2,140 acres (using 2003 & 2004 data) (Dobberfuhl and Hart 2006). The basin-wide mean for total linear coverage for 2007 was 31.04 m ± 5.07 m (mean ± S.E.) as compared to the greatest mean total which occurred in 1998 (57.01 m ± 4.33 m) and 2004 (57.08 m ± 8.57 m). The lowest occurred in 2000 (29.53 m ± 3.96 m) and 2005 (30.52 m ± 5.06 m). A nine year mean (1998, 2000 – 2007) of total linear coverage within the lacustrine sections (ecozones 1 & 2) was 53.37 m ± 2.43 (mean ± SE) while total linear coverage in the freshwater riverine reach (Ecozone 3) was 4.30 m ± 0.50 (Data not shown). This great difference in coverage between Ecozone 3 and the other sections highlights substantial differences in habitat conditions other than water quality which will be described in the discussion.

SAV, most notably seagrasses, were not present in the mesohaline and polyhaline sections from river mile 25 to the mouth (DeMort 1991, SJRWMD observation). Brody (1994) provides a number of plausible reasons for this absence including temperature extremes, which would not support *Thalassia* or *Zostera* and light attenuation levels that are too high for *Halodule*. In addition, the salinity extremes in these sections exceed those thresholds of tolerance for the freshwater and brackish species routinely seen in the vegetated stretch. Also, in many sections of the mesohaline and polyhaline sections, light attenuation is very high and littoral shelves are scarce as much of that section has been dredged and bulkheaded.

An analysis of annual basin-wide surveys collected from 1998 through 2007 found *Vallisneria* was the dominant species basin-wide (Sagan 2007). *Vallisneria* appeared on 84% of the transects with SAV and accounted for 63% of the total SAV cover. Two other dominant species included *Najas guadalupensis* and *Ruppia maritima*. They accounted for 16% and 10%, respectively, of total cover. Year-round maximum water depth for *Najas guadalupensis* was 0.68 m ± 0.24 (Mean ± STD). *N. guadalupensis* often co-occurred with *V. americana* within the SAV bed but often at a much reduced percent cover (Sagan 2004a). The presence of Ruppia is noteworthy as it was the only halophyte found. Year-round maximum water depth for *R. maritima* was 0.53 m ± 0.21 (Mean ± STD). *R. maritima* had the most restricted distribution, inhabiting the shallowest near-shore third to half of the bed and with cover usually below 50%. The exception to this trend was *R. maritima* distribution at BOL where its distribution mirrored that of *N. guadalupensis*. More conspicuous was the limited latitudinal distribution of *R. maritima*. This species had the greatest cover and bed-wide distribution at BOL but both cover and distribution decreased with each upstream site until *R. maritima* was only marginally present at RIC and not present at all at CRL. The remaining species of SAV individually accounted for < 2% of total SAV but collectively make up 10% of total SAV.

<u>Basin-wide Distribution and Biology of *Vallisneria americana*</u>

Distribution

Vallisneria americana, the dominant species, had the greatest latitudinal distribution of any LSJRB species; it has been found throughout the survey area starting at river mile 26 within the oligohaline/mesohaline reach and upstream to river mile 100. As described above it has the greatest within-bed coverage, occurring in mixed near-shore zones along with *N. guadalupensis*, *R. maritima*, and other near-shore species while it dominated the outer and deep-water sections of the bed (Figures 16 – 22). It was the species most often associated with the deep-water edge of the SAV meadow (>90%) (Sagan 2003a, Sagan 2004a). In a study of data collected across both drought and normal precipitation (2000 – 2004) conditions, a comparison between *Najas*, *Ruppia*, and *Vallisneria*, showed that *Vallisneria* occurred at significantly deeper water depths (year-round maximum water depth = 0.77 m ± 0.20; mean ± STD) (Sagan 2004a). Recent estimates within the freshwater section of LSJR and Crescent Lake show that *Vallisneria* was found where light within the water column was only 9% of ambient light (Dobberfuhl 2007). It was often found in monospecific meadows presumably under light conditions that did not support the growth of other species. In contrast to many studies (Barko et al. 1991) that suggest *Hydrilla* can out compete *Vallisneria* in low light conditions, we have observed at those locations where *Hydrilla* and *Vallisneria* co-occur, *Vallisneria* dominates, to the exclusion of *Hydrilla*, the deep-water section of the bed (Sagan 2005). This may be related to the quality of water column light (orange to red wavelengths, 600 – 700 nm) characteristic of highly colored and turbid systems like the LSJR (Kirk 1994).

Reproduction

Many thorough papers exist that describe the life history of *Vallisneria* and should be referred to for an extensive overview of the species (Lowden 1982, Korschgen and Green 1988, Dawes and Lawrence 1989, Smart and Dorman 1993, Catling et al. 1994, Ferasol et al. 1995, Biernacki and Lovett-Doust 1997, Lokker et al. 1997, Blanch et al. 1998, Doyle 2001, Grimshaw et al. 2002). The information here is listed in order to give a unique description of *Vallisneria americana* as it exists in the LSJR.

Vallisneria is a dioecious plant and both male and female flowers have been seen throughout the LSJR and during all months of the year (personal observation). Other systems in southern climates have shown nearly year-round flower production; Bortone and Turpin (2000) found male and female flowers in the Caloosahatchee River from July – December. Fruits were also routinely seen in the LSJRB in conjunction with flowers.

Colonization of a denuded site by *Vallisneria* seeds has been documented in the LSJRB (Sagan 2004b) and provided an exceptional opportunity to record the growth pattern of this species. A seed bank study was conducted at a barren study site (CRL) in Crescent Lake in 2004. While germination of *Vallisneria* seeds from sediment samples from the site were occurring in laboratory growth chambers there was a concurrent reestablishment of *Vallisneria* at the study site. Many observations lead to the conclusion that in situ reestablishment was from seeds as opposed to propagules. The size of both the above-ground foliage and roots of the *Vallisneria* plants observed recolonizing CRL2 was small – the same size as those observed germinating in laboratory settings. In addition, *Vallisneria* recovering from leaf senescence has a disproportionate leaf to root size; the new leaves sprouting from existing root stock are disproportionately small relative to the root mass (personal observation). Further, no vegetative propagules (turions or root stock) were found during in any of the sediment samples or during recent quarterly surveys of the site. Also, while *Vallisneria* plants colonized adjacent areas through rhizomatous expansion in the near-shore section, plants appeared, which were not the result of vegetative propagation, in the deep-water sections of the study site. Most notably, single *Vallisneria* plants that were not present in earlier surveys colonized the deep-water sections of the bed. In addition, on one occasion a seed coat was still found attached to a *Vallisneria* plant in the field.

The initial frequency of occurrence of *Vallisneria* after this resurgence was 4% and average leaf length was 3 cm. Two and five months later, *Vallisneria* coverage increased to 50% and to 56%, respectively. At this point, average *Vallisneria* leaf length was 4 cm. As of fall 2004 sampling, the site was once again devoid of plants presumably because of deeper and darker water resulting from increased precipitation during the fall.

While SAV did not grow to maturity during the seed bank study, previous recolonization of CRL was documented which can complete the description of *Vallisneria* growth from seed to mature plant. In October 1998, the first record of SAV was detected at the study site. During the first 12 months of recovery at Crescent Lake, *Vallisneria* coverage increased throughout the study plot (Figure 32). By May 1999, small plants (< 0.05 m) expanded laterally by multiple rhizomes (personal observation) resulting in an occurrence frequency of 64.0% and a bed which extended 66 m from shore. By Fall 2000, canopy height increased to more than seven times the mean height of the previous fall while occurrence frequency and bed length (91.0% and 92 m, respectively) remained unchanged. *Vallisneria* leaves during this time were tall and thin. As of

May 2001, the site consisted of a dense, virtually monospecific stand of *Vallisneria* that had grown to the height of the water column (mean = 0.32 m). *Vallisneria* produced fruits each sampling visit starting in spring 2000 through Spring 2002 with the exception of fall 2001 and winter 2002. SAV resurgence at Crescent Lake was highly correlated with decline in color (Sagan 2002).

Unlike northern populations of this species that senesce during the winter months, *Vallisneria* in the LSJR grows throughout the year (Figures 8 – 15) . Other "evergreen" *Vallisneria* populations have been reported in other southern climates as well (Dawes and Lawrence 1989, Smart and Dorman 1993, Bortone and Turpin 2000). In temperate climates in the United States and Canada, spring regeneration occurs through sprouting of new growth from overwintering propagules, called tubers (Rybicki and Carter 1986, Catling et al. 1994, Kimber et al. 1995b, Korschgen et al. 1997, Lokker et al. 1997, McFarland and Rogers 1998, Rybicki and Carter 2002, Capers 2003). However, tuber production has not been noted in the LSJR or in other southern populations in which *Vallisneria* grows throughout the year such as Texas (Smart and Dorman 1993) or in Central Florida (Dawes and Lawrence 1989). Thus, *Vallisneria* in the LSJRB must rely on whole plant export, vegetative growth or germination from seed banks in order to recolonize barren or impoverished beds.

Distribution and Abundance of SAV by Ecozone and Site

<u>SAV Ecozone Descriptions</u>

A summary of annual changes in coverage relative to ecozone is shown in Table 3 for 1998 through 2007. Data was obtained from annual surveys which are conducted between June through August of each year. Ecozone 3 had greatly reduced bed lengths (Figure 7) and coverage as compared to ecozones 1 and 2. SAV beds in Ecozone 3 extended, on average, only 12.39 m from shore and mean total coverage did not exceed 9.05 m. Ecozone 1 has shown the greatest variability in coverage and bed length. Total SAV coverage ranged from 19.30 m in 2007 to 98.64 m in 1998. Ecozone 2 coverage ranged from 32.04 m in 2005 to 71.69 m in 2004. The distance from which SAV extended from shore (bed length) ranged from 57.5 m to 93.5 m in

Ecozone 1 as compared to 45.36 m to 68.55 m in Ecozone 2. The greatest declines in Ecozone 1 corresponded to drought years while the greatest declines in Ecozone 2 occurred after the hurricanes in 2004. *Vallisneria americana* coverage within both ecozones followed the same annual trends as total SAV coverage.

SAV PMN Site-specific Descriptions

As of 2007, SAV data were collected at eight permanent monitoring sites within the LSJR (Figure 2). Data at these sites have been collected continuously since 1996, with the exception of Orangedale; data were not collected between 2001 and 2005. The eight sites include, in decreasing latitudinal order, BOL, BUC, MOC, DRL, ORD, SCA, RIC and CRL. BOL, BUC, and MOC were located in the oligohaline – mesohaline ecozone of the river (Ecozone 1) and were approximately thirty, thirty-five, and forty river miles, respectively, from the mouth of the SJR. ORD, SCA and RIC were located in the freshwater ecozone (Ecozone 2) and were approximately fifty, sixty, and seventy-five river miles, respectively, from the mouth of the SJR. DRL and CRL were located in major water bodies flowing into the St. Johns River. A summary of each site is included which describes access requirements, latitude and longitude coordinates, maximum bed length, species diversity, and sampling frequency (Table 1).Table 2 provides a summary of the surveying frequency, type of data collected, and frequency of associated water quality monitoring. Figures 8 – 15 depict mean percent occurrence of each species and total SAV for each site and date; species are arranged in order of total SAV, *Vallisneria*, *Najas*, *Ruppia* (the most dominant species), and the remaining species in alphabetical order. Bar graphs are patterned to reflect the season in which the data was collected: Winter is depicted with diagonal stripes, Spring is solid, Summer is horizontal stripes, and Fall is solid black. Figures 16 – 22 depict water depth distribution for each dominant species for each winter, spring, summer, and fall seasons; this data represent a mean taken from four years of data (Sagan 2004a). Figures 23 – 32 depict mean bed length and mean maximum canopy height for all sites and dates.

Since surveying began, a variety of epifauna, SAV-associated algae (both epiphytes and detached/drift algae), and aquatic organisms have been observed at these site. It is beyond the scope of this project to quantify these species or describe any seasonal or water quality trends affecting their appearance or abundance. Most notably absent is any description of fish; this is because this researcher is not adept at fish identification or “on the fly” observations of moving vertebrates. The Florida Fish and Wildlife Conservation Commission has conducted ecozone surveys of fish species and abundance since 2004. Macroinvertebrate surveys associated with each SAV site has been conducted since 2003. Also, a monthly survey of the epiphytes associated with *Vallisneria* at the PMN SAV sites was conducted by the University of North Florida from March 2005 through August 2006. Similarly, a monthly, basin-wide survey of epiphytes and detached algae were conducted by Chapman and coworkers in 1999 and a quantification of epiphytes and detached algae at the Buckman site were conducted by Sagan (2003b).

Bolles School (BOL)

The site was located in front of the property of a private school in a highly urbanized section of Duval County on the eastern bank of the river (7400 San Jose Blvd., Jacksonville, Florida 32217). The steep banks of the site were dominated by *Gleditsia* sp. and Kudzu. Shoreline consisted of concrete rip-rap; shell fragments were littered throughout study plot. Sediment throughout the study plot shifted from predominantly mucky-sand (89.0% ± 8.3%) in fall 1999 (Sagan 1999) to mostly sand (98.7% ± 1.4%) in spring 2000 (Sagan 2000) during the 1999 – 2001 drought. At this writing, mucky sediments still characterize the first 10 m of the study plot but sediments associated with the SAV meadow were mostly sandy.

Incremental data associated with this site have been collected since March 1996. Species that have been present with regular frequency at the site include *Najas*, *Ruppia*, *Vallisneria*, and *Zannichellia* (Figures 8a and 8b). *Vallisneria* was the dominant species at this site with a maximum percent occurrence of 88% ± 3% in September 1997. In contrast it was absent from the site in August 2007. The maximum percent occurrence seen for Najas was 9% ± 2% and occurred in September 1997. *Najas* was routinely absent during periods of high salinity. The maximum percent occurrence seen for *Ruppia* was 30% ± 4% and occurred in May 1999 and was absent during winter 2004 and fall 2004 through spring 2005. Charophytes and *Potamogeton pusillus* were present infrequently and at low occurrence before 2000 and 1999, respectively.

Ceratophyllum appeared just once in November 2004. The mean maximum bed length at this site was 94 m ± 1 m (mean ± SE) and occurred in September 1997; the minimum bed length occurred in August 2007 and was 17 m ± 4 m (Figure 23). Mean maximum canopy height was 0.37 m ± 0.01 m in August 2004; minimum canopy height was 0.05 m ± 0.002 m for all sampling dates in 2000 and the first half of 2001 and again in May of 2007 (Figure 23).

The following is a summary of the organisms that have been observed at this site. Sparse to heavy epiphytes that have been observed include *Enteromorpha, Lyngbya* sp., *Rhizoclonium* sp., the red algae, *Caloglossa* sp., and *Polysiphonia* sp. Flocculent blue-green algae have been seen on varying occasions in sparse to heavy densities throughout the study plot. Rocks at the site have been covered in diatoms, primarily *Navicula* spp. but also some *Nitzschia* spp. Green sediment was observed, indicating microalgal-sediment associations. Epifauna that have been observed included barnacles, *M. leucophaeta*, insect cases (unidentified), chironomid larvae, sponges, olive nerite snails (*Neritina* sp.*)*, and snail egg cases. *M. leucophaeta* was also often associated with the root systems of SAV. Bivalves, most likely the brackish water clam *Rangia cuneata*, were associated with the sediment. Numerous comb jellies (*Beroe* sp.) have been observed throughout the outer half of the SAV bed and associated with high salinity periods. Atlantic sting rays (*Dasyatis sabina*), and Blue crabs (*Callinectes sapidis*) were seen frequently at the site. Manatees have been observed at this site following seasonal trends as described by White and coworkers (2002). On one occasion five manatees were observed feeding outside the study plot for two hours in approximately 0.8 m of water within a *Vallisneria* and *Ruppia* bed. SAV in this area after feeding was reduced to approximately 5 cm leaf stubs but with rootstock intact.

Buckman (BUC)

The site was located in front of private residential property in a highly urbanized section of Duval County. It was located on the eastern bank of the river, upstream from the Buckman Bridge (Interstate 295). The study plot shoreline was bisected by an undeveloped property upstream and a developed residential property downstream (11138 Scott Mill Rd., Jacksonville, Florida 32223). The shoreline consisted initially of a natural waterfront with a riparian zone of approximately 1 meter followed by turfgrass up to the residence. In 2001, the property owners built a bulkhead along the entire length of the study plot. Dominant emergent species along the undeveloped shore included *Acer rubrum*, *Pinus sp*., *Quercus nigra*, and *Sabal sp*. The study plot sediment composition was predominantly sand throughout (89.2% ± 10.4%) with sediment characterized as mostly mucky-sand toward the last few meters of the SAV bed (Sagan 1999) and remains the same as of this writing.

Incremental data associated with this site have been collected since June 1996. Species that have been present with regular frequency at the site include *Najas*, *Ruppia*, *Vallisneria*, and *Zannichellia* (Figures 9a and 9b). *Vallisneria* was the dominant species at this site with a maximum percent occurrence of 74% ± 2% in September 1997 and minimum (10% ± 2%) occurred in August 2007. The maximum percent occurrence seen for *Najas* was 66% ± 3% and occurred in October 1996. *Najas* was routinely absent during periods of high salinity (2000 – 2001 and 2007). The maximum percent occurrence seen for Ruppia was 18% ± 5% and occurred in June 2002. It was absent during winter 2004 and fall 2004. *Micranthemum* and *Sagittaria* were seen at low occurrence (< 4%) before the 1999 – 2001 but have not reappeared since then. charophytes, *Ceratophyllum*, *Hydrilla* and *Potamogeton pusillus* have been notably absent during periods of high salinity but even when present occurred at a low percent occurrence (< 5%). Exceptions to this were seen for charophytes and *Potamogeton pusillus*. Charophytes were maximum in June 1996 at a percent occurrence of 46% ± 9% and again at 32% ± 2% in July 2005. *Potamogeton pusillus* occurrence was greatest in June 1996 (15% ± 4%). The mean maximum bed length at this site was 86 m ± 2 m (mean ± SE) and occurred in September 1997 and August 2004; the minimum bed length occurred in May 2007 and was 45 m ± 3 m (Figure 24). The greatest mean canopy height occurred in September 1997 and was 0.53 m ± 0.01m; minimum canopy height was 0.03 m ± 0.0 m in August of 2007 (Figure 24).

The following is a summary of the organisms that have been observed at this site. Sparse to heavy epiphytes that have been observed include *Anabaena* sp., *Cladophora glomerata, Enteromorpha* sp., *Lyngbya* sp., *Oedogonium* sp., *Phormidium* sp., *Pithophora* sp., *Polysiphonia* sp., and *Rhizoclonium* sp. Flocculent blue-green algae have been seen on varying occasions in sparse to heavy densities throughout the study plot. Green sediment was observed, indicating microalgal-sediment associations. During summer 2003, large rafts of floating plants such as *Salvinia* sp. and *Lemna* sp. occurred throughout the first third of the bed and appeared concomitantly with a massive macroalgal bloom. Epifauna that have been observed included barnacles, dragonfly nymphs, hydroids, *M. leucophaeta*, insect cases (unidentified), chironomid larvae, gastropods, sponges, olive nerite snails (*Neritina* sp.*)*, and snail egg cases. During June 2003, a dense congregation (15 gastropods per hand sweep) of small (< 0.5 cm) gastropods were congregated on the *Vallisneria* leaves. *M. leucophaeta* was also often associated with the root systems of SAV. Bivalves, most likely the brackish water clam *Rangia cuneata*, were associated with the sediment. Manatees have been observed at this site following seasonal trends as described by White and coworkers (2002). Numerous comb jellies (*Beroe* sp.) have been observed throughout the outer half of the SAV bed and associated with high salinity periods. Atlantic sting rays (*Dasyatis sabina*) and Blue crabs (*Callinectes sapidis*) were seen frequently at the site. During the construction of the bulkhead, two river otters (*Lutra canadensis*) were present at the site.

Moccasin Slough (MOC)

The site was located in front of undeveloped conservation property in Clay County (purchased by Clay County, Florida Department of Environmental Protection, SJRWMD, and the Trust for Public Land). It was located on the western bank of the river, upstream from Doctors Lake Inlet and across from Julington Creek. The shoreline vegetation was dominated by the emergent species *Acer rubrum, Pinus sp*., *Quercus nigra, Sabal sp*. and *Taxodium distichum.* Prior to 2000, a large stand of *Hydrochloa sp.* and *Typha sp*. spanned meter mark 25 m to 50 m across the study plot and extending 36 m into the study plot. In 2000, this had been replaced by a sandy beach and shallow, emergent-free littoral zone from which emerging SAV species were found. Also notable about this site, was a slough running parallel to the shore and extending from approximately 50 m to 90 m from shore. Water depth within this slough ranges from 0.6 m to 0.85 m depending on season (Sagan 2004a). The study plot as a whole shifted from predominantly mucky sediment (50.4%) in spring 1999 to predominantly sand (67.3%) in spring 2000 (Sagan 2000) and has remained predominantly sandy since. However, during high precipitation events that result in increased sediments, TSS, and nutrients, the associated slough becomes increasingly mucky.

Incremental data associated with this site have been collected since March 1996. Species that have been present with regular frequency at the site include charophytes, *Najas*, *Ruppia*, *Vallisneria*, and *Zannichellia* (Figures 10a and 10b). *Vallisneria* was the dominant species at this site with a maximum percent occurrence of 86% ± 2% in March 2004 and minimum (50% ± 4%) occurred in November 2006. The maximum percent occurrence seen for *Najas* was 64% ± 1% and occurred in September 1996. *Najas* was routinely absent or at low occurrence (< 2%) during periods of high salinity (2001- 2002 and 2007). The maximum percent occurrence seen for *Ruppia* was 35% ± 1% and occurred in August 2001. It was absent frequently during 2004 through 2006. *Zannichellia* appears predominantly during the winter and spring months and always at low occurrence (8%). Charophytes were present some seasons in every year except in 2005 and rarely exceeded a 3% occurrence. Data was not available for *Ceratophyllum demersum* from 1998 through August 2002. However the species was present up until 1998; the maximum recorded percent occurrence was 39% ± 1% and occurred in September 1997. *Ceratophyllum* has been associated with the mucky slough as described above and its appearance appears to be directly related to increasing organic content of the sediment in that slough (personal observation). The remaining species (*Eleocharis*, *Micranthemum*, *Potamogeton pusillus*, and *Sagittaria*) were only present during three to six survey events and at occurrences less that 5%. The mean maximum bed length at this site was 170 m ± 3 m (mean ± SE) and occurred in May 1998; the minimum bed length occurred in March 2005 and was 143 m ± 3 m (Figure 26). The greatest mean canopy height occurred in September 1997 and was 0.74 m ± 0.01m; minimum canopy height was 0.04 m ± 0.001 m in August of 2007 (Figure 26).

The following is a summary of the organisms that have been observed at this site. Sparse to heavy epiphytes that have been observed include *Enteromorpha* sp., *Oedogonium* sp., *Phormidium* sp. (which were associated with the sediment and sometimes formed large (> 1m) clumps), *Polysiphonia* sp., and *Rhizoclonium* sp. Flocculent blue-green algae have been seen on varying occasions in sparse to heavy densities throughout the study plot. During summer 2003, large rafts of floating plants such as *Salvinia* sp. and *Lemna* sp., as occurred at the Buckman site, appeared concomitantly with a massive macroalgal bloom. Epifauna that have been observed included barnacles, bryozoans, chironomid larvae, clams (cf. *Rangia* sp.), hydroids, limpets, *M. leucophaeta*, *Neritina* sp., sponge, insect larvae, and snail egg cases. Manatees have been infrequently observed at this site as compared to the Bolles School and Buckman sites. Alligators (*Alligator mississippiensis*) have been regularly observed. Atlantic sting rays (*Dasyatis sabina*) and Blue crabs (*Callinectes sapidis*) were seen frequently at the site. In May 2002, a dense congregation of Atlantic stingrays (*Dasyatis sabina*) was observed in the nearshore area at this site and corresponded to the ovulatory period for this species (Johnson and Snelson 1996). Densities in the nearshore area were estimated to be 0.5 per 1 m^2. Comb jellies (*Beroe* sp.) have been observed infrequently but when present were always associated with high salinity periods.

Doctors Lake (DRL)

The site was located on the southeast shore of Doctors Lake in Clay County, northeast of the confluence of Swimming Pen Creek and the lake. Land immediately abutting the site is undeveloped swampland dominated by *T. distichum*. Other emergent vegetation includes *A. rubrum, Aster sp., Crinum americanum, Cephalanthus occidentalis,* and *Ludwigia sp*. In 1998, *Nymphaea mexicana* densely covered the surface for nearly half of the site but by 2000, the N. mexicana patch was greatly reduced and eventually disappeared. Near shore sediment was mucky with an overlying layer of detrital matter. As for many other sites in section 1, a shift in sediment composition from predominantly mucky-sand (49.8% ± 14.2%) to a predominantly sand (71.4 % ± 20.8%) occurred in spring 2000 (Sagan 2000). Underwater snags were abundant throughout first half of study plot and the sediment was mucky-sand to mucky. Moving farther from shore the sediment changes to sandy with shell fragments.

Incremental data associated with this site have been collected since May 1998. Species that have been present with regular frequency at the site include *Najas*, *Vallisneria*, and *Zannichellia* (Figures 11a and 11b). The site has been barren since November 2005. Vallisneria was the dominant species at this site with a maximum percent occurrence of 62% ± 3% in May 2004. The maximum percent occurrence seen for Najas was 54% ± 3% and occurred in August 2004. *Najas* was routinely absent or at low occurrence (< 2%) during periods of high salinity (2001-

2002 and 2007). *Zannichellia* appeared predominantly during the winter and spring months and at low occurrence (<5%) with the exception of May 2004, when it appeared with a frequency of 20%. *Ruppia* has not been seen since May 2001 and was never above 2% occurrence. The mean maximum bed length at this site was 61 m ± 3 m and occurred in May 2004. The greatest mean canopy height occurred in May 1998 and was 0.38 m ± 0.02m (Figure 27).

The following is a summary of the organisms that have been observed at this site. Sparse to heavy epiphytes that have been observed included *Enteromorpha* sp., *Chaetomorpha* sp., *Lyngbya sp*., and *Phormidium retzii*. Flocculent blue-green algae have been seen on varying occasions in sparse to heavy densities throughout the study plot. Epifauna that have been observed included barnacles, clams (cf. *Rangia* sp.), *M. leucophaeta*, *Neritina* sp., insect larvae, and snail egg cases. Alligators (*Alligator mississippiensis*) were regularly observed before the 1999 – 2001 drought but have not been seen since. Neither Atlantic sting rays (*Dasyatis sabina*) nor Blue crabs (*Callinectes sapidis*) were seen frequently at the site. An osprey nest (*Pandion haliaetus*) was located in a cypress tree just north of the site and has been active since 1998.

Orangedale (ORD)

The site was located on the eastern shore of St. Johns County, north of the Shands Bridge (State Road 16) and one dock upstream of the old Shands Bridge Fishing Pier. The shoreline was residential, covered in turfgrass up to a cement bulkhead. Little emergent vegetation was present along the shoreline. The base of the bulkhead was littered with rip rap. Sediment within the first 10 m was mucky-sand to mucky but thereafter remained sandy to the end of the grassbed. A 3 – 6 m long, mucky slough, which ran parallel to the shore, was present within the first few meters of the near-shore area.

Incremental data associated with this site have been collected since March 1996 through May 2000 and again from August 2006 through August 2007. All eleven species routinely seen in the LSJR were present with regular frequency at the site with the exception of *Hydrilla*; it was present during only one sixth of the survey events (Figure 12). *Vallisneria* was the dominant species at this site with a maximum percent occurrence of 77% ± 1% in July 2007 and minimum

(47% ± 7%) occurred in May 2000. The maximum percent occurrence seen for Najas was 71% ± 7% and occurred in September 1996; minimum percent occurrence was in June 1998 (5% ± 1%). The maximum percent occurrence seen for Ruppia was 7% ± 2% and occurred in July 2007. It was absent during winter and spring 1996 and in 1998. *Ceratophyllum* has been associated with the mucky slough and its occurrence was no greater than 7% (data was not available for *Ceratophyllum* prior to August 2006). were present some seasons in every year except in 2005 and rarely exceeded a 3% occurrence. *Zannichellia* appeared predominantly during the winter and spring months and, during May 2007, exceeded 20%. The remaining species (charophytes, *Eleocharis*, *Hydrilla*, *Micranthemum*, *Potamogeton pusillus*, and *Sagittaria*) were present at a frequency of 6% or less. The mean maximum bed length at this site was 76 m ± 1 m and occurred in October 1997; the minimum bed length occurred in August 2006 and was 57 m ± 3 m (Figure 28). The greatest mean canopy height occurred in October 1997 and was 0.59 m ± 0.01 m; minimum canopy height was 0.15 m ± 0.01 m in May 2007 (Figure 28).

The following is a summary of the organisms that have been observed at this site. Sparse to heavy epiphytes that have been observed included *Enteromorpha* sp., *Chaetomorpha* sp., and *Lyngbya sp*., flocculent blue-green algae have been seen on varying occasions in sparse to heavy densities throughout the study plot. Epifauna that have been observed included barnacles and sponges. Alligators (*Alligator mississippiensis*) were associated with the Typha sp. stand near the fishing pier. Atlantic sting rays (*Dasyatis sabina*) and Blue crabs (*Callinectes sapidis*) were seen, albeit infrequently, at the site. Florida manatee were observed during some of the survey events.

Scratch Ankle (SCA)

The site was located in front of private residential property in a low density rural section of Clay County. It was located on the western bank of the river, abutting swampland and naturalized residential shoreline. Dominant emergent species included *A. rubrum, Aster spp., L. styraciflua, Polygonum sp., P. cordata*, and *T. distichum*. Sediment was predominantly sand (Sagan 2000) with sediment characterized as muck and mucky-sand corresponding to approximately the first third of the study plot and a few muck-filled depressions at approximately 100 m from shore.

Incremental data associated with this site have been collected since March 1996. All eleven species routinely seen in the LSJR were present with regular frequency at the site (Figures 13a and 13b). *Vallisneria* was the dominant species at this site with a maximum percent occurrence of 68% ± 2% in August 2001 and minimum (17% ± 4%) occurred in March 2005. The maximum percent occurrence seen for *Najas* was 47% ± 2% and occurred in May 2002; minimum (1% ± 0.4%) occurred from fall 2004 through winter 2005. The maximum percent occurrence seen for *Ruppia* was 13% ± 2% and occurred in May 2000. It was predominantly absent during 1996 through 1997 and again from summer 2003 through summer 2007. The remaining species occurred at greater frequencies than at other sites within the LSJR and accounted for a diverse near-shore bed that extended approximately 100 m from shore (Figure 4a). Many of these species were absent from the site from fall 2004 through winter 2006. It is worth noting that the exotic invasive, *Hydrilla*, has incrementally expanded at the site since 1996 when the percent occurrence was less than 1%. It peaked to a high of 30% in December 2005 out competing other near-shore native species. The mean maximum bed length at this site was 217 m ± 13 m and occurred in August 2001; the minimum bed length occurred in February 2006 and was 138 m ± 11 m (Figure 29). This site has the longest bed lengths of all the sites; maximum lengths of individual transects ranged from 173 m (transect 1) to 251 m (transect 5). The greatest mean canopy height occurred in November 2001 and was 0.57 m ± 0.01m; minimum canopy height was 0.10 m ± 0.003 m in May of 2005 (Figure 29).

The following is a summary of the organisms that have been observed at this site. Sparse to heavy epiphytes that have been observed included *Cladophora* sp., *Enteromorpha* sp., and *Lyngbya sp*. Flocculent blue-green algae have been seen on varying occasions in sparse to heavy densities throughout the study plot. Epifauna including barnacles, bryozoans, caddis fly larvae, chironomid larvae, fish eggs, leeches, limpets, segmented worms, snail egg cases, and sponge have been observed throughout the SAV bed. Manatees have been infrequently observed at this site as compared to the Bolles School and Buckman sites. Alligators (*Alligator mississippiensis*) have been regularly observed. Atlantic sting rays (*Dasyatis sabina*) and Blue crabs (*Callinectes sapidis*) were seen infrequently at the site. A river otter (*Lutra canadensis*) was present during a few survey dates.

Rice Creek (RIC)

The site was located in front of private, undeveloped property in a low density section of Putnam County (Palatka, Florida). It was located on the western bank of the river, approximately two miles downstream of the confluence of Rice Creek and the river. Rice Creek is used by Georgia Pacific paper plant as an effluent discharge tributary. The shoreline consisted of a natural waterfront with emergent and shoreline vegetation which included *L. styraciflua, Ludwigia spp., Polygonum sp., and Quercus spp., T. distichum, Typha sp.,* and *Vitis spp.* A *Typha sp*. stand existed approximately 40 m from the bench mark of the study plot and extended 15 m from the shore. Sediment was predominantly sand (88.0% ± 14.1 %) with sediment characterized as muck and mucky-sand corresponding to the area within the *Typha* sp. stand (Sagan 1999).

Incremental data associated with this site have been collected since February 1996 when the study plot was barren of SAV. The species routinely seen at this site included *Vallisneria*, *Najas*, charophytes, *Eleocharis*, *Hydrilla*, *Micranthemum*, and *Sagittaria* (Figures 14a – 14c). *Vallisneria* was the dominant species at this site with a maximum percent occurrence of 74% ± 1% in October 2001. It was absent from the site in February 1996 and occurred along less than 1% of increments in most of 2005. The maximum percent occurrence seen for Najas was 54% (n=1 for that date) which occurred in June 2003. It was absent from the site in February 1996 and occurred along less than 1% of increments in most of 2005. The maximum percent occurrence seen for *Ruppia* was 8% ± 2% and occurred in April 2007. It was predominantly absent during 2000 through 2005. The remaining species occurred at low frequencies within the bed (<10%). Specifically, charophytes had a percent occurrence of 10% or less, *Sagittaria* of 5% or less, and *Eleocharis*, *Hydrilla*, and *Micranthemum* of 1% or less. *Ceratophyllum*, *Potamogeton pusillus*, and *Zannichellia* appeared infrequently throughout the eleven-year study period and had percent occurrence of 1% or less. The mean maximum bed length at this site was 91 m ± 3 m and occurred in August 2007; the minimum bed length occurred in May 2005 and was 13 m ± 10 m (Figure 30). The greatest mean canopy height occurred in November 2001 and was 0.42 m ± 0.02 m; minimum canopy height was 0.02 m ± 0.003 m in May of 2005 (Figure 30).

The following is a summary of the organisms that have been observed at this site. Sparse to heavy epiphytes that have been observed included *Lyngbya sp*. Flocculent blue-green algae have been seen on varying occasions in sparse to heavy densities throughout the study plot. Epifauna including bryozoans, chironomid larvae, fish eggs, hydroids, leeches, limpets, segmented worms, snail egg cases, and sponge have been observed throughout the SAV bed. Alligators (*Alligator mississippiensis*) have been regularly observed as have Manatees (SJRWMD personnel observations). Atlantic sting rays (*Dasyatis sabina*) and Blue crabs (*Callinectes sapidis*) were seen infrequently at the site.

Crescent Lake (CRL)

The site was located on the southern shore of an undeveloped, fingerlet (associated with Salt Branch Run) protruding from the eastern shore of Crescent lake (Flagler County, Florida). It was accessible by boat from Shell Bluff Road boat ramp which was located approximately 1.5 miles southeast of the site. Some of the emergent vegetation associated with the site included *Hydrochloa* sp., *Salix* spp. and *Typha* sp. As of this writing the *Typha* stand was greatly reduced as compared to its former cover within the study plot, which ran the width of the plot and extended from 7 m to 21 m from shore. The existence of an even larger stand at the site (prior to 1998) was substantiated by the remains of *Typha* roots that extended the length of the plot and continued from the shore to the end of the grassbed (73 m). *Vallisneria* roots were often associated with *Typha sp*. root husk remains. The sediment was sandy throughout.

Incremental data associated with this site have been collected since May 1998. This site has undergone a cycle of SAV resurgence and decline during the nine-year study period. The site was barren or essentially barren (< 5%) in May 1998, from May 2003 through March 2004, and again, from November 2004 through February 2006 (Figure 15a). During periods in which SAV was present, *Vallisneria* was always present, often as a monospecific meadow, and reached maximum percent occurrence of 74% ± 1% in October 2001. Other species that periodically appeared during recolonization periods included charophytes, *Ceratophyllum*, *Eleocharis*, *Hydrilla*, *Micranthemum*, *Najas*, and *Zannichellia* (Figures 15a and 15b). Najas percent occurrence was greatest from 1999 through summer 2001 when it ranged from 10 % - 20%; it was present during fifteen of the twenty-six survey events during which *Vallisneria* was present. The remaining species, with the exception of charophytes, had occurrences of less than 2%. Charophytes were present during eleven of the twenty-six survey events during which *Vallisneria* was present. Charophytes reached a maximum percent occurrence of 19 % ± 3% in May 2004. The mean maximum bed length at this site was 93 m ± 1 m and occurred in December 1999; SAV was absent during periods as described above (Figure 232). The greatest mean canopy height occurred in September 2001 and was 0.60 m ± 0.01 m; minimum canopy height was 0.02 m ± 0.002 m in November of 2005 (Figure 32).

Although *Hydrilla* was present only marginally at CRL, its expansion was much greater at other sites along the eastern shore. At one of the annual survey sites on the eastern shore, a mixed bed of *Vallisneria* and *Hydrilla* was present in summer 2001. *Vallisneria* was present throughout most of the bed (coverage = 90%) and extended 46 m from shore. *Hydrilla* occupied the near-shore section of the bed (coverage = 38%) and extended 27 m from shore. Although not quantified, this expansion of *Hydrilla* was also noted along much of the shoreline from the boat ramp at Shell Bluff Road toward the study site and was present marginally (< 2%) on the western shore of the lake. *Hydrilla* coverage during 2002 annual surveys was much lower than in 2001. Surveys in 2003 and 2004 found no *Hydrilla* at any study sites within the lake. However, once again in August 2007, although *Hydrilla* was not found at the study site, there were extensive beds along the eastern shore from Shell Bluff Road north.

The following is a summary of the organisms that have been observed at this site. Sparse to heavy epiphytes that have been observed included *Lyngbya sp*. Flocculent blue-green algae have been seen on varying occasions in sparse to heavy densities throughout the study plot. Epifauna including aquatic beetles, bryozoans, chironomid larvae, dragonfly larvae, gastropods, and leeches have been observed throughout the SAV bed. Alligators have been regularly observed. River otter were observed on a few occasions along the eastern lake banks enroute to the site. Florida manatee were observed only twice during the survey events. During spring 2000, a bird colony was located at the site and a site-specific proliferation of filamentous algae was associated with the near-shore area. Algae were most likely proliferating due to the nutrients associated with the copious guano droppings from the bird colony.

DISCUSSION

Annual, seasonal, and monthly surveys of SAV have provided a dataset that describes SAV distribution and coverage throughout the LSJRB. Coupled with water quality monitoring conducted by SJRWMD, these data have helped to establish the physical and biological conditions required for SAV growth and maintenance and to characterize the effect of perturbations on SAV meadows. Differences in SAV coverage, latitudinal and depth distribution, and diversity, as described in this report, appeared to be attributable to variations in water quality, river morphometry, and substrate quality. In addition, distinct individual site characteristics also appeared to shape the SAV habitat. Finally, catastrophic climatic/hydrologic events have dramatically altered SAV habitat. But before a discussion should ensue of how these variables (salinity, shore exposure, light attenuation) drive the distribution, abundance, and growth patterns of the SAV, a general description of the river, its morphometry and water quality trends along its length should be described.

River Morphometry, Adjacent Land Use, and Water Quality

The three ecozones within the LSJR which support SAV include the oligohaline lacustrine reach, the freshwater lacustrine reach, and the freshwater riverine reach (Ecozones 1 – 3, respectively) (Figures 3a-c). Ecozones 1 through 3 are distinct due to river morphometry and salinity concentrations. In addition, variations in land use and population density within the subbasins of these river ecozones affect water quality. In general, the river morphometry in ecozones 1 and 2 are distinct as compared to that in Ecozone 3. Ecozones 1 and 2 are characterized by wide, shallow river expanses, gradually sloping river bottoms with mostly sandy (Sagan 2000) sediments. Ecozone 3 was a narrower, deeper and faster-flowing river with a steeply sloping bottom which was often littered with underwater snags, leaf and twig litter, and other detritus. The potential littoral zone in this ecozone was shorter due to steep drops offs into water which exceeded 1 m depth. In addition, much of the tree canopy in the naturalized sections shaded a large percentage of the potential littoral zone, effectively shading out SAV. Groundtruthing surveys in this river ecozone found the sediment was often mucky, mucky-clay or a thick, spongy peat layer (partially decayed logs) often with an overlying detrital layer. A characterization of the littoral zone sediments in the three ecozones that was conducted in 2003 (Dobberfuhl et al. 2006) supported these field observations. Those sediments from the freshwater riverine section had higher amounts of organic carbon and percent mud as compared to the freshwater and oligohaline lacustrine zones.

In terms of land use, Ecozone 1 was the most highly urbanized. The shoreline was lined by residential property, was mostly bulkheaded, and the immediate shoreline transected by a high density of boat docks (Steinmetz et al. 2001). In addition, the Jacksonville Naval Air Station was located along the western shore from approximately river mile 29 – 33. Degraded water quality in this area results from its proximity to the densely populated, and oldest, sections of Jacksonville which had high incidence of untreated stormwater discharge, leaking sewage infrastructure (old sewage lines and septic tanks), and sewage treatment facilities which dumped nutrient laden effluent into the river. These sources added to the turbidity and eutrophication of this ecozone (Brody 1994, Watkins 1995, McGrail et al. 1998). In addition, this ecozone of the river experienced varying concentrations of salinity that fluctuate daily and seasonally. Ecozone 2 had many miles of natural shoreline, was less affected by fluctuations in salinity (most parts are freshwater), was less densely populated but was bordered by many agricultural and forested lands (McGrail et al. 1998). Large sections of shoreline in Ecozone 3 were abutted by hardwood swampland and the population density was less than that in ecozones 1 or 2.

While water quality profiles for each of these ecozones have been shown to be unique as well (Sagan 2000), it is more instructive to discuss water quality in terms of the latitudinal gradient seen for many of the water quality parameters or by a site by site comparison. Bi-weekly water quality data associated with those permanent monitoring sites (BUC, BOL, MOC, DRL, SCA, RIC, and CRL) that have been surveyed since 1996 were graphed for each site and water quality parameter. Included are salinity and those parameters that attenuate light in the water column or are indicative of light attenuation, specifically, chl-a, color, Kd, TSS, turbidity (Figures 33 - 38). The trends seen in these graphs are characterizations that are supported by other sources (Brody 1994, Department of Environmental Protection water quality monitoring database, Aldridge et al. 1998, McGail et al. 1998). There is limited literature characterizing Ecozone 3. In addition, addressing the effects of water quality on SAV in Ecozone 3 was difficult given the plethora of other variables (i.e. tree shading, unsuitable substrate, underwater shading, reduced littoral zone), which we believe keep SAV abundance and distribution significantly below that in ecozones 1 and 2, independent of water quality conditions. Thus, water quality data only for those sites in ecozones 1 and 2, and for Doctors Lake and Crescent Lake are included.

Some water quality parameters decline or increase along the latitudinal gradient of the river. Specifically, color and salinity show incremental changes from upstream to downstream. As would be expected in a tidal system, salinity values increased from RIC downstream to BOL. CRL, RIC, and SCA were freshwater (0 – 0.5 ppt) with SCA rarely oligohaline; DRL oscillated primarily between freshwater and oligohaline (0.5 – 5 ppt) but salinities increased in the mesohaline range (5 - 18 ppt) during drought conditions (Figure 33). Similarly, MOC, BUC, and BOL oscillated between freshwater and mesohaline (5 – 18 ppt) with increasing incidence of salinities in the polyhaline range (18 – 30 ppt) closer to BOL. Declines in salinity follow a seasonal pattern: low salinity during high precipitation months in the late summer and fall. Salinities were highest during drought events.

Mean chlorophyll-a was highest at DRL (32.95 mg m^{-3}) and was lowest at MOC (10.88 mg m^{-3}) (data not shown). Other than this exception, most sites upstream had mean values greater than twice that of the downstream sites (Figure 34). A basin-wide pattern was difficult to assess as types of nutrient sources (i.e. point or non- point sources) vary within the basin. Presumably, algae growth is spurred by a combination of high nutrients, high residence times, and light. Conversely, as shown by Aldridge and coworkers (1998), high color and the resulting increases in light attenuation decreases chl-a levels.

Color was highest at CRL and RIC; color reached maximum values of 1600 and 800 CPU, respectively, at both sites following high precipitation events (Figure 35). Mean color decreased from CRL towards BOL (CRL > RIC > SCA > MOC > BUC > BOL > DRL) (data not shown) and follows the trend in terms of adjacent land use; a higher percentage of wetlands abut the upstream areas and thus, runoff contains higher levels of tannic acid. In addition, RIC was downstream of Rice Creek, from which pulp mill effluent, which is high in color, was discharged. Mean color of Rice Creek samples taken from the highway 17 bridge was 514 ± 280 CPU (mean ± STD) (SJRWMD data) and was significantly higher ($p < 0.0001$) than the mean color for RIC (195 ± 136 CPU) averaged from between October 1997 through July 2007. All sites showed a color peak ≥ 500 CPU after the 2004 hurricanes.

Mean TSS values for all sites did not appear similar; however, BOL > SCA > DRL. The maximum values were at BUC and CRL (285 mg l^{-1} and 277 mg l^{-1}, respectively) and as low as 51 mg l^{-1} at RIC (Figure 36).

Mean turbidity values ranged from 7.23 NTU at BOL to 5.57 NTU at MOC (BOL > DRL = SCA, RIC > BUC > CRL > MOC. The maximum value was seen at RIC (127.5 NTU) and coincided with the 2004 hurricanes; the remaining sites had maximum values between 27 NTU and 44 NTU (Figure 37).

Mean Kd decreased from CRL towards BOL (CRL > RIC > SCA > DRL ≈ MOC ≈ BUC ≈ BOL) (data not shown) and ranged from 5.56 m^{-1} to 2.93 m^{-1}. The maximum value was at CRL (19.68 m^{-1}) following the 2004 hurricanes (Figure 35). Peaks in light attenuation follow a similar trend for all sites and often correspond to high precipitation events (Ex. Tropical storm in September 2001 and Hurricanes September 2004).

The Status of SAV within the LSJRB

Since 1996, eleven species of SAV have been routinely observed throughout the LSJRB. *Vallisneria* continues to remain the dominant species. It was found at the farthest downstream groundtruthing and permanent monitoring stations in 1998 and was located in the most upstream reaches of the LSJR as well. It was the SAV most often associated with the deep-water edge of the SAV meadow. However, SAV status within the LSJR has declined in some sections of the river. Most notably, within the oligohaline lacustrine reach (Ecozone 1).

As of this writing, SAV within Ecozone 1 was in a state of decline due to high salinities brought on by a recent two-year drought. Thus, it is not instructive to compare current status with earlier years (i.e. 1996 – 1998). What is most telling was the inability of the SAV in certain sections of Ecozone 1 to rebound after the 1999 – 2001 drought. A better comparison would be between annual data from 1998 and 2004 surveys. In 2004, SAV was recovering from the previous drought. For two years previous, salinity levels had dropped and SAV responded with a massive resurgence. In fact, total linear cover for Ecozone 1 was higher than in 1998 (98.64 m ± 19.15 m in 2004 versus 63.28 ± 6.63 m in 1998). However, a comparison of annual survey data for those two years shows that bed length, maximum water depth distribution, and species diversity had decreased while incidences of bare transects had increased. This indicates that, although along some transects an abundance of SAV recolonized denuded areas, it did not recolonize to the same depth or bed length as in 1998 nor with the same diversity of species. Permanent monitoring station data recorded from the summer season supports these trends. At BOL, bed length declined by 20 m between summer 1998 and 2004. Percent occurrence declined from as high as 90% to 60 %. While SAV at the BUC site in 2004 did recolonize to 1998 bed lengths, percent occurrence was lower and many near-shore species have not recolonized to their previous levels or at all. Thus, it appears that bed recovery from adverse water quality events often exceeds three years and as of this writing fully recover had not occurred in Ecozone 1.

Not only was SAV within extant beds not as abundant as in previous years, there was a vast section of the oligohaline reach either not colonized by SAV at all or colonized by biologically insignificant SAV (i.e. the plants were small and infrequent). Specifically, the most downstream section of the study area does not support significant SAV. In contrast, the latest record (1998) of SAV in that area, at a former PMN site along Saddler Point (SDP) (Figure 3a), in combination with anecdotal evidence from residents, suggests that in recent decades there were extensive SAV meadows along Saddler Point. Percent occurrence at the SDP site in April 1998 was 71% ± 4% and was predominantly *Vallisneria*; *Ruppia* was present with a mean occurrence of 3%. The bed extended on average 76 m ± 5 m. Mean maximum canopy height was 0.20 m ± 0.009 m but maximum *Vallisneria* heights were 60 cm. The next time this site was visited in June 2000, no plants were present. Similarly, at a nearby location (Site 2) in 1998, a bed of predominantly *Vallisneria* (linear cover ≅ 33 m) with *Zannichellia* (linear cover ≅ 8 m) existed. In subsequent years during annual surveys (1998 – 2007), little or no SAV was found at adjacent sites to SDP. Similarly, although annual survey sites 6 and 8 (Figure 3a) have had up to 35 m of SAV, the plants were always small (< 8 cm) and the sites often barren. Thus, a section of river, from the confluence of the Ortega River (river mile 27) to river mile 31 that could and has supported SAV was essentially barren. Therefore, it appears that the repeated and sustained droughts have already removed approximately 4 miles of productive littoral habitat. Further, water quality conditions during non-drought periods were not conducive to recolonization.

Ecozone 2 and Crescent Lake, in contrast to Ecozone 1, have shown greater SAV resurgence after dramatic declines. In fact, annual surveys reveal that Ecozone 2 had greater total cover and colonized to a greater depth than it did in 1998. Most telling was that after the hurricanes of 2004, when dramatic declines were seen in this section, which continued into early 2006 due to lingering degraded water quality, this section resurged in an equally dramatic fashion. As compared to 2006 values, maximum water depth and total cover increased by 0.26 m, and 24.0 m, respectively, and as compared to 2005 values, 0.13 m and 33.0 m, respectively. Data from permanent monitoring sites also showed a rapid and expansive resurgence. In a year and a half, bed length at RIC increased 72 m as of this writing. Similarly, total percent occurrence increased from 3% to 76% and total linear cover increased 74 m as of this writing. Scratch Ankle bed length increased 57 m in a year and a half and percent occurrence increased from a low of 26% in March 2005 to 71% in August 2008. Although recent data for ORD exists only since August 2006, bed length at that site increased by 18 m in one year. Crescent Lake has twice, since surveys began, showed a rapid resurgence corresponding to improved water quality, particularly, light attenuation. During both the previous and current drought, the site has increased from totally barren to a lush SAV meadow that extended 90 m from shore, had coverage up to 90%, and supported 45 cm tall *Vallisneria*.

What Variables Affect SAV?

SAV distribution and abundance is controlled by a variety of abiotic and biotic variables. Light attenuation is one of the most commonly cited factors affecting SAV distribution (Dennison 1987, Duarte 1991, Stevenson et al. 1993, Kenworthy and Fonseca 1996). The high color, or colored dissolved organic material (CDOM), of the LSJR coupled with occurrences of planktonic algae blooms and epiphytic algae can reduce light levels reaching SAV and therefore limit the depth distribution of all species. Salinity also plays a significant role in this tidal system, affecting latitudinal distribution of SAV not tolerant to high or fluctuating salinity levels. Finally, physical perturbations, from small to extreme, have been observed to drive changes in SAV status.

1. Drought

During the two drought periods (1999 – 2001 and 2006 – 2007), dramatic declines in SAV coverage were seen in the oligohaline lacustrine section of the river. Both basin-wide data and data from permanent monitoring sites demonstrated the deleterious effects of the high salinities associated with the 1999 – 2001 drought. Basin –wide annual data analyses (Sagan 2002b) demonstrated that SAV cover in section 1 significantly declined in 2000, 2001, and 2002 as compared to1998 cover. An analysis of data corresponding to SAV permanent monitoring site data at BOL, BUC, MOC and corresponding water quality was conducted (Sagan 2002) and found that increasing salinities were significantly correlated with SAV declines. Salinity levels during this period however, were not as high as some experimental treatments to which *Vallisneria* has been exposed and has survived. During these experimental trials, *Vallisneria* was able to withstand exposure as high as 12 ppt over a 21-day period without any significant declines (Twilley & Barko 1990). Differences in extent of exposure to elevated salinity levels may explain the discrepancy between published tolerance levels and declines seen in the LSJRB. SAV in this section of the LSJRB was exposed to salinity levels between 7 ppt and 18 ppt for at least 41 days and for some sites exposure occurred throughout a 55-day period. Mesocosm studies conducted for the SJRWMD by the National Wetlands Research Center (Boustany et al. 2001) supports the assertion that the extent of exposure can exacerbate the deleterious effects of salinity. These researchers found that declines in total biomass, areal productivity, and leaf area index occurred in *Vallisneria* after a 2.5 month exposure to salinities of 8 ppt. Complete loss of aboveground tissue occurred after the same period of exposure to 18 ppt. SJRWMD biweekly water quality data shows salinity levels over 8 ppt for a two to four month period at sites in section 1. Biweekly sampling cannot capture spikes in salinity which often occurs at high tides or due to tidal surges caused by offshore storms. SAV throughout this period then, may have experienced acute exposure to even higher salinities than captured during biweekly sampling. It has been shown that chronic exposure to elevated salinities may not be necessary to cause declines in SAV. Doering (2001) found that after a 1 day exposure to salinities at 18 ppt, *Vallisneria* showed declines relative to controls.

Not only was increasing salinity significantly correlated with SAV declines in the 1998 – 2001 LSJR analysis (Sagan 2002), but increasing TSS was found to be correlated with SAV declines. This poses the question whether attenuation of light by suspended solids in the water column caused declines in SAV. However, the significant increase in cover of *Ruppia*, a halophyte requiring high light environments on par with seagrasses (Orth and Moore 1988, Kantraud 1991), suggested that salinity, not light reduction, was responsible for the decline of SAV in this section. Subsequent water quality analysis using Kd values (Sagan 2003a), found that year-by-year, Kd values (Table 4) in Ecozone 1were actually lower than or equal to values in the freshwater lacustrine section (Ecozone 2) where declines were not seen. It is also likely that other stresses to SAV may have exacerbated the impact of elevated salinity levels. High color, organic and inorganic suspensions in the water column, and periphyton presence on SAV are factors typically responsible for attenuating light to SAV. In fact, Kd values, while lower in Ecozone 1 than in Ecozone 2, were high compared to other systems. These other stressors will be addressed later.

Throughout the hydrologic extremes that have occurred between 1996 and 2007, it has become apparent that water quality changes occur along a gradient within the river. Depending on the hydrologic event of the moment, SAV at the upstream/downstream extremes of the LSJR are usually reacting differently to the resultant water quality changes. For instance, while declines were seen in the oligohaline portion of the river during the 1999 – 2001 drought, the upstream, freshwater portion showed signs of expansion and in fact, significant increases were seen in Crescent Lake (Sagan 2002). Basin-wide analysis of cover, maximum water depth distribution, and mean species number in Ecozone 2 found that all these parameters increased in 2001 relative to 1998 (Sagan 2002). For instance, Total SAV cover in 1998 was 74% ± 5% versus 93% ± 9% in 2001 (Mean ± SE); maximum water depth increased from 0.78 m ± 0.4 m in 1998 to 0.85 m ± 0.05 m in 2001; and mean species number per transect increased from 4 to 5. Significant increases in percent occurrence were seen at Crescent Lake during the 1999 – 2001 drought period and correlated with declines in color (Sagan 2002). Specifically, no SAV was present at the site in spring 1998 but by spring 2001 percent occurrence had increased to over 90%. Yearly mean color preceding SAV spring 1998 surveys was 550 CPU $\pm$ 34 but had decreased to 110 CPU $\pm$ 22 preceding SAV spring 2001 surveys. Subsequent analyses by Gallegos (2005) has shown that of the three main constituents that affect light attenuation, color is the dominant contributor. Thus, while drought conditions greatly reduced the input of tannin-stained runoff from wetlands into the lake and LSJR, it also decreased the amount of freshwater input into the system which allowed salinities to increase in the downstream reach. Because the upstream portion of the LSJR and Crescent Lake are still relatively undeveloped, and instead are flanked by wetlands, these areas receive a higher input of tannin-stained discharge during rain events. Therefore, SAV in the upstream section benefits from reductions in light attenuation during drought periods.

2. Above-Normal Precipitation Periods

Just as below-normal precipitation periods, such as drought, affect the two extremes of the LSJR differently, so too do periods of above-normal precipitation. This "see saw" phenomenon in the river is best illustrated by figure 41. Figure 41 shows monthly SAV linear cover, in meters, for a downstream site, Buckman, and an upstream site, Rice Creek. These two sites are approximately 40 river miles apart (Figure 2). During tropical storms, or any extended high precipitation events, the upstream reach is more severely negatively impacted. For example, in September 2001, a tropical storm occurred which resulted in extremely high river water levels and increased wave action as well as increases in light attenuation due to sediment-laden storm runoff. For example, water levels breached the bulkheads at some sites and left a line of wrack, five meters past the bulkhead. The month after the storm in October 2001, SAV cover at the Rice Creek site was only slightly less than September cover (103.71 m vs 107.60 m). However, a substantial decrease in cover occurred beginning in November (mean cover = 77.43 m) and continued to decline until total cover was half that immediately preceding the storm (Figure 41). Presumably SAV demonstrated a lag effect in responding to deleterious increases in light attenuation due to the storm but ultimately declined as light attenuation increased with increasing color. For instance, color values at the RIC site were on average 65, 235, 400 and 500 CPU for August, September, October, and November 2001, respectively. In contrast, total cover at Buckman showed an immediate and dramatic increase in October 2001, nearly doubling since August 2001 from 22 m to 42 m. Increased precipitation decreased salinity concentrations (4 ppt in August 2001 vs < 1 ppt October through December, Figure 33) in this ecozone allowing SAV to recover despite increases in light attenuation in the area. Light attenuation, although increasing, clearly remained within a range that was not deleterious to SAV, while at the upstream section light attenuation was at deleterious levels.

3. Tropical Storms and Hurricanes

From 1996 through 2007, four dramatic storm events affected SAV within the LSJR. Not only do these events dramatically alter water quality from heavy precipitation but they can also physically damage SAV. In September 2001, a tropical storm caused severe wind damage as described above. In September 2004, three hurricanes passed near Northeast Florida. Frances September 5, Ivan September 15, Jeanne September 26. All temporal comparisons, 1) one-year pre- and post-hurricane, 2) seasons immediately prior to and following the hurricanes, and 3) monthly comparisons, show that SAV loss occurred predominantly along the western shore (Sagan 2006a). These differences appear to be directly attributable to initial physical damage (i.e. wave- and wind-driven scouring, physical abrasion by hurricane debris such as docks and trees) caused by hurricane winds originating out of the east. However, basin-wide, total cover continued to decline six months following the hurricanes to less than half of the pre-hurricane values. A Spearman Rank Correlation was performed to analyze the relationship between water quality parameters on PMN SAV one year preceding the hurricanes through one year after. For this analysis seasonal WQ means from three months preceding SAV data collection were calculated for Chl-a, color, Kd, salinity, turbidity, and TSS and paired with seasonal SAV means (Figures 39 & 40) from fall 2003 through spring 2005 (n=7). Mean water quality data preceding fall SAV sampling, and which included values following the hurricanes, showed dramatic increases in color, Kd, and turbidity as compared to values preceding summer SAV surveys. Color, Kd, and TSS values peaked in the months preceding winter 2005 SAV sampling. Peak mean values for color (337 ± 11 CPU), Kd (5.718 ± 0.193 m-1), and TSS (13.933 ± 2.267 mg l-1) corresponded to the lowest SAV mean cover (46.49 m ± 5.38 m) during the analysis period.

Turbidity peaked in the immediate months following hurricane activity; mean turbidity preceding fall 2004 was 11.149 ± 3.84 NTU. Spearman Rank correlation results found a significant correlation between declines in SAV total cover and increases in color ($R_s = -0.893$; $p = 0.0287$), Kd ($R_s = -0.929$; $p = 0.0229$), turbidity ($R_s = -0.929$; $p = 0.0229$), and TSS ($R_s = -0.857$; $p = 0.0358$). It appears that initial declines in the SAV were due to physical damage that occurred to the SAV beds but further declines were caused by increases in light attenuation that resulted from greater than normal cumulative rainfall and the resulting runoff. The status of SAV one (Sagan 2006a) and two years (Sagan 2006b) after the hurricanes showed SAV had not recovered to its pre-hurricane status.

4. Anthropogenic Stressors to SAV

Eutrophic conditions in the river have given rise to both phytoplankton and SAV-associated macroalgal blooms. In the LSJRB, Chl-a and TSS levels, indicators of eutrophic status, did not meet the minimum levels that support SAV growth (which included *Vallisneria*) determined for the Chesapeake Bay area. For instance, an analysis of LSJR water quality associated with SAV PMN sites (Sagan 2003a), found annual mean Chl-a concentrations for all ecozones were greater than 15 ug/L; the exception was the oligohaline in 1998 and 2001 - 2003. Even in that section Chl-a levels at many individual sites were above the Chesapeake Bay minimum, in the case of DRL, levels were chronically higher (Figure 34). Mean TSS levels were > 19 mg/L for most years in Ecozone 1 and, chronically in DRL (Figure 36). If Chesapeake Bay standards are valid for the LSJRB, SAV is chronically exposed to water quality levels that may cause stress to the system.

Large-scale phytoplankton blooms occurred frequently in the river, varying in distribution and duration (Figure 34). However, two massive phytoplankton blooms should be noted. One occurred from July 1999 through August 1, 1999, during which dense, blue-green algae flocs were carried to the oligohaline portion of the river. A massive fish kill occurred on August 6, 1999 and was attributed to the decomposition of the algal bloom and resulting drops in dissolved oxygen. A second massive algae bloom (*Microcystis aeruginosa)* occurred throughout the LSJR during summer of 2005. Associated with the bloom were algal toxins (microcystin) which exceeded the World Health Organization (WHO) standard (10 ppb) for recreational activities. Toxin concentrations were over 100 ppb at many locations throughout the LSJR, according to St. Johns River Water Management District press releases, and remained above WHO standards in many areas of the river as of this writing.

Not only are algal blooms potentially dangerous, they increase TSS and turbidity and thereby increase light attenuation in the water column. Light attenuation was recorded in the Chesapeake Bay through the duration of a massive phytoplankton bloom. The bloom, which peaked at 65 ug/L, caused a three-fold increase in light attenuation (Gallegos and Jordan 2002). Light attenuation was initially due to chlorophyll; it was later due to suspended solids in the form of lysed algal cell components. USGS mesocosm studies conducted for the SJRWMD investigated the role of nutrients and color on *Vallisneria americana* growth. They found that light attenuation due to phytoplankton growth was equivalent to at least 100 CPU of color (Boustany et al. 2002).

Similarly, eutrophic conditions have given rise to heavy epiphyte abundance on SAV as well as massive macroalgal blooms. Algal mats not only shade SAV but decomposition of the algae can cause anoxic conditions and decouple nutrient cycling exchange between sediments and the water column. Examples of these mats has occurred frequently throughout the study period in the LSJR. In the spring of 1997, heavy mats of detached algae (*Enteromorpha* sp. and *Rhizoclonium* sp.; Chapman et al. 1999) within the littoral zone were assumed to be responsible for SAV loss underneath the mats (Figure 42). At that time, detached algae was sampled (n=3) during the peak of the bloom, in April, and was highest at the Buckman site. Mean algae DW was 153.49 g m^{-2}, however, the 1997 maximum at Buckman was 405.6 g m^{-2}. In addition, detached algal mats (*Cladophora glomerata;* Chapman, personal communication*)* developed at Eagle Point in May 2000 was also assumed to be responsible for SAV loss underneath the mats (Figure 43). Finally, algal mats were associated with the Buckman site in June through August 2003 (Figure 44), and dry weight values were on par or exceeded those from other eutrophic systems; maximum dry weight value was 294.557 g m^{-2} (Sagan 2003b). However, no deleterious effects on SAV were seen. In contrast, heavy filamentous algae mats that developed at the BUC site in April 2006, did have deleterious effects. The mats were dominated by species of green algae, *Rhizoclonium* sp.

and *Enteromorpha* sp. and by May, near-shore algae was mostly absent or was in the form of putrefying mats. Associated with the areas where the algae had been were H_2S-stained sediment corresponding to decreased SAV.

Epiphytes were also routinely seen associated with SAV in the LSJR. Studies from many systems have shown that the presence of epiphytes can be deleterious to SAV (Kiorboe 1980, review by Orth and van Montfrans 1984, Ozimek et al. 1991, Tomasko and Lapointe 1991, Lapointe et al. 1994). Epiphytes, as opposed to phytoplankton, were believed to be primarily responsible for the detrimental shading of SAV in lakes in Great Britain and Denmark (Phillips et al. 1978, Sand-Jensen 1990) and may have an additive deleterious effect when combined with light attenuation caused by phytoplankton (Twilley et al. 1985) or total suspended solids in general (Moore et al. 1996). Many studies have focused on how epiphytes attenuate light reaching SAV (Sand-Jensen 1977, Bulthuis and Woelkerling 1983, Sand-Jensen and Borum 1984, Twilley et al. 1985). This in turn decreases photosynthetic rates of the host plant (Bulthuis and Woelkerling 1983, Sand-Jensen and Borum 1984, Twilley et al. 1985). Epiphytes also reduced nutrient (specifically inorganic carbon) diffusion from the water column to the SAV foliage (Sand-Jensen 1977). Finally, periphyton may increase the drag on SAV, making it more susceptible to damage from wave or wind action (Koch 2001).

In a pilot study within the LSJR (Sagan 2003b), epiphyte dry weight and ash-free dry weight per *Vallisneria* leaf mass were quantified at the Buckman site from July 2003 through September 2003. Maximum DW and AFDW densities per leaf biomass for both near-shore (0.360 g g^{-1} and 0.242 g g^{-1}, respectively) and outer-half (0.400 g g^{-1} and 0.309 g g^{-1}, respectively) bed locations occurred in September. Maximum densities per leaf area showed the same trend (Max. DW = 0.336 mg cm^{-2}). However, epiphyte density at Buckman was much lower than other systems or than has been found to be deleterious to SAV. Twilley and coworkers (1985) found an epiphyte dry weight of 2 mg cm^{-2} and 6 mg cm^{-2}, respectively, blocked 80% of light before it reached the SAV leaf surface. Moore and coworkers (1996) showed epiphytic DW per plant DW ranged from 0.06 to 7.03 g g^{-1} without deleterious effects to SAV even at the highest densities. The researchers suggest that decreased light attenuation at sites with low turbidity ameliorated the effect of light attenuation due to epiphytes. While in the Sagan study, epiphyte densities in the

LSJR did not appear to negatively affect SAV, timing of epiphyte load within the SAV growing season as well as the additive effect of multiple stressors could cause declines in SAV.

Additive Effect of Multiple Stressors on SAV

While many of the stressors to SAV discussed thus far appear to be of natural origin (droughts or hurricanes), SAV response during natural perturbations is also affected by other stressors present in the system, many of which are anthropogenic. For instance, while salinity appears to be the primary factor limiting SAV growth during drought conditions in Ecozone 1, SAV in the LSJR, as noted above, are routinely exposed to water quality conditions that exceed the minimum standards of other similar systems. This chronic stress, due primarily to light attenuation, may have caused SAV to be more vulnerable to increases in salinity.

French and Moore (2001) demonstrated that at high light levels, SAV were able to partially compensate for salinity stress; this was not the case at low light levels. Thus, when conditions change that require additional energy resources for physiological adaptation, such as adaptation to salinity stress, SAV in low light conditions may not have the additional energy resources to respond. Thus, acute exposure to salinity, duration, or frequency of salinity exposure aside, salinity stress may be exacerbated by the low light conditions that are prevalent in the LSJR. Similarly, while color, in most cases in the LSJR, is of natural origin, the additive stressor of color and chlorophyll-a and TSS can increase light attenuation to deleterious levels above just that of the influence of color (Gallegos 2005).

In general, poor water quality conditions make SAV more vulnerable to deleterious effects of other anthropogenic stressors or to natural perturbations in the riverine system. In Ecozone 2, tidal fluctuations are exaggerated from approximately river mile 60 to Palatka as compared to Ecozone 1 south of the Acosta Bridge (Environmental Consulting & Technology 2002), leaving Ecozone 2 more susceptible to exposure, scouring, and sediment deposition. On the other hand, much of the shoreline in Ecozone 1 is bulkheaded which exacerbates wave action through deflection, which may exaggerate incoming wave amplitude. This section is also more impacted by dock construction than is Ecozone 2. While these variables and other variables are not routinely measured at the PMN sites, they presumably account for site-by-site variation not explainable by differences in water quality.

For instance, SAV at BUC and BOL did not resurge at the same pace as MOC after the 1999 – 2001 drought. Physical roadblocks to the recovery of SAV at these sites were observed at the BUC site. Observations at the site during that time were mirrored by those described by Koch (2001) regarding the benefits of wave energy attenuation and current velocity attenuation by SAV and are summarized below.

Wave energy and current velocity attenuation by SAV provides many benefits for the SAV meadow. There are two of particular importance in this case: 1) sediments fall out faster along the outer edge of the SAV bed and 2) the scouring effects and drag by unattenuated wave energy is reduced. In addition, a reduction in wave energy further reduces the resuspension of particles within the water column thereby decreasing turbidity. In spring 1998, BUC had continuous SAV coverage from within 4 to 12 meters from the shoreline to approximately 85 m from shore. Inshore SAV included dense, continuous patches of mostly *Najas* and less frequent occurrences of charophytes, *Eleocharis, Micranthemum, Potamogeton pusillus, Ruppia, Sagittaria,* and *Zannichellia*. At greater depths the occurrence of these species decreased while *Vallisneria* appeared and persisted throughout the remainder of the SAV bed. In 1998 the SAV bed at BUC was a lush, dense meadow with mean SAV canopy height of 0.33 cm with a great potential for wave energy attenuation.

However, during the 1999 – 2001 drought, the sparse, small SAV at BUC did not provide a baffle to wave and current energy. The effects of unattenuated wave energy were apparent. Across a period of many months (February 2001 through May 2001), during which a resurgence of SAV began at MOC, BUC showed no improvement. During this time sediment deposition over emerging shoots of *Vallisneria* at BUC was evident throughout near- and mid-shore areas. Four- to five-centimeter tall plants were buried up to 3 cm from the root top. The buried portions were achlorotic. At other times, emerging patches of *Vallisneria* and *Ruppia* in nearshore areas were completely gone the next month. Anecdotal observations of wave energy were that it appeared to be greater than seen before as it pounded the nearshore littoral zone, especially at low tides. In early 2001, the wave energy was greater than in previous decades as the owners at the site, who had lived there since the 1960s, had to put up a bulkhead to stop the rapid progression of shoreline erosion which had occurred since the SAV had declined in 1999.

This phenomenon was not seen at MOC where SAV foliar cover and canopy height, mostly *Vallisneria*, had steadily increased since spring 2001. The discrepancy in recovery status of MOC versus BUC may have to do with the deeper slough area within the first 100 m of the MOC site. Substrate scouring due to wave energy is reduced at increasing water depths (Koch 2001). So while wave energy was no longer attenuated by SAV at either site, a greater water depth at MOC may have dampened wave energy and reduced the scouring effects on the substrate and rooted SAV. In addition, a sandbar which may have also attenuated wave action borders the inner 75% of the SAV bed. Finally, MOC is located at the upstream-most reach of Ecozone 1 and salinity may have dropped to levels less stressful to SAV than in the more downstream sections of Ecozone 1.

Similarly, other potential stresses on the system as noted by Sagan (1999) are seen basin-wide. Many species of SAV within the shallow zones of some sites show signs of stress (browning, broken off leaf tips, brittle stems) during winter and spring surveys. Water levels tend to be very low during these seasons because of the predominance of south-, south-west winds which push the water out towards the mouth of the river. During these periods the first fourth to third of the SAV bed can be exposed during low tides. For example, exposure during low tide occurred at the BUC site during spring 2004. The first 31 m and 52 m of the near-shore bed was completely exposed (water depth = 0 cm) during low tide during sampling in April and May, respectively. During May, complete exposure occurred throughout the first 12 m of the near-shore bed at MOC and throughout the first 100 m at SCA. However, complete exposure is not necessary in order for damage to plant tissue to occur. Whatever portion of aboveground foliage is exposed during low tides is susceptible to desiccation, UV damage, or freezing and ultimately dies and shears off. Under these exposed conditions, the upper 2/3 of long *Vallisneria* leaves desiccate when water depths are < 10 cm (personal observation). Many species of SAV within the shallow zones of some sites show signs of exposure (browning, broken off leaf tips, brittle stems) during these periods. Heat stress and desiccation during these exposed periods may account for the reductions in maximum canopy height as seen in the winter months (Figures 23 – 32) as well as outright diebacks in these areas of the SAV bed.

In summary, high salinity levels appear to be predominantly responsible for the dramatic decline in SAV in Ecozone 1 during the 1999 – 2001 and 2006 - 2007. However, SAV within the LSJRB may be 1) chronically stressed by WQ conditions that greatly attenuate light and 2) periodically stressed by seasonal exposure to harmful ambient temperature conditions (sun or freezing conditions). Both conditions may make SAV more susceptible to acute stressors such as spikes in salinity levels. Thus, high salinity levels may have weakened an already taxed system.

Setting Light Thresholds in the LSJR

Light Thresholds and Growth Stage of SAV

Light attenuation levels or water quality conditions that support mature plants may not be conducive to seed germination or seedling growth. One area of the river in which this hypothesis may explain why a section remains denuded, was the downstream reach near river mile 26. In 1998, 33 m of *Vallisneria* grew at the groundtruthing site GT002 (Figure 3a). After the drought of 1999 – 2001 *Vallisneria* never reappeared at that site although a small patch (< 1m) of *Ruppia* appeared in a subsequent year and *Zannichellia* appeared in three later surveys (< 8 m). If this area is to recover, it must do so from vegetative propagules or seed stores, the viability of which after three or more years is unknown. High salinity may also inhibit germination as it does in *Ruppia* (Kantrud 1991). Salinities of 30 ppt were found to inhibit the germination of a Florida population of *Ruppia* (Koch and Dawes 1991). Even if a seed bank is present or if recruitment to this area of viable propagules occurs, the turbid conditions may reduce the survivability and growth of seedlings or plantlets (Kimber et al. 1995a, Kimber et al. 1995b, Doyle and Smart 2001).

It may be crucial, therefore, to distinguish between water quality standards that result in light levels sufficient for sustaining growth of SAV beds in established meadows versus light levels necessary for seed germination or propagule budding during recolonizing attempts. A standard mean water column photosynthetically active radiation (PAR) may be less important than the percentage of leaf biomass located above the light compensation point. Blanch et al. (1998) found that plant growth ceased if the percentage of plant biomass within the light compensation zone was less than 22%. Established meadows often have plant foliage near or at the surface of the water providing increased surface area for photosynthesis. In fact, SAV, including *Vallisneria*, will counteract light attenuation due to increased turbidity by preferentially shunting resources towards leaf elongation (Doyle and Smart 2001, Blanch et al. 1998) and thereby concentrating plant foliage near the water surface where light irradiance levels are higher. Further, at low tide intervals in the LSJR, the upper portion of *Vallisneria* leaves are routinely exposed and are horizontally oriented on top of the water surface. These leaf lengths receive unattenuated ambient light for a few hours each day during low low tide events. Newly emerging plantlets such as those in section 1 are at a disadvantage in the highly turbid section as they may not obtain leaf lengths that place the foliage above the crucial light compensation point.

Light Thresholds and Biologically Significant SAV

Not only should light thresholds support seed germination and seedling growth for reestablishment of perturbed SAV beds, but it should also support a biologically significant abundance of SAV. Many studies have shown SAV complexity is a predictor of fish and invertebrate diversity and abundance. Nekton abundance was positively correlated with SAV biomass (Raposa and Oviatt 2000, Rozas and Minello 2006). Wyda and coworkers (2002) found that fish communities found in *Zostera marina* beds with biomass and density of > 100 wet g m^{-2} and 100 shoots m^{-2}, respectively, had significantly higher species diversity, abundance, and biomass as compared to beds of low complexity. As shown in figures 16 – 22, SAV cover at the maximum water depth is usually less than 50% and is often less than 10%. Setting light attenuation values that correspond to a maximum depth, therefore, will not likely result in SAV habitat that supports other biota.

Future Stressors

Conversion of Natural Areas to Residential and Commercial Development

Many shoreline areas within Clay, Putnam, and St. Johns Counties that abut the LSRJ are still naturalized. Further, the subbasins within in them are not yet as developed as in Duval County. A loss of riparian buffers and increased nutrients and suspended solids that result from development in this area would occur concomitant to increased development. This would have a multiple negative impact. Increases in nutrients from point (water treatment plants) and non-point sewage treatment facilities (septic tanks) would ensue, as would nutrients in the form of fertilizer runoff from housing development lawns. Naturalized upland areas and wetland recharge areas would be decreased, removing a natural uptake system that filters runoff components before discharge into the LSJR. These increases in nutrients and sediment have been shown to spawn algal blooms and increase light attenuation in the water column, respectively.

Surface Water Withdrawal

It is projected that in the next 20 years, Central Florida will no longer be able to rely solely on water from the aquifer to sustain its water consumption. Thus, as early as 2013, it has been proposed that 155 million gallons of water per day will be withdrawn from the St. Johns River near Deland (St. Johns River Water Management District 2006). In addition, surface water withdrawal projects are projected for four other locations within the SJR and from the lower Ocklawaha River. There are many potential effects of water withdrawal that could negatively impact SAV. These include increases in water retention time, increases in duration and amplitude of high salinity events, and exposure of littoral zone due to decreased water levels.

If water withdrawal reduces the rate at which the water discharges from the mouth, or in other words, increases water retention time, flushing of pollutants will take longer. In terms of nutrient pollution, specifically phosphorus and nitrogen, it has been shown that increased residence time of nutrients is one of the factors that spawn algal blooms. As nutrients “sit” in one location, algae have extended exposure time to these nutrients and assimilate the nutrients for use in cell production. Thus, both the frequency of occurrence of phytoplankton and SAV littoral zone algae (epiphytes and macroalgae) as well as the algal load within the LSJR may increase. As described, phytoplankton, as measured as chlorophyll-a and TSS, is one of the three water quality variables within the LSJR that increases light attenuation (Gallegos 2005). In addition, epiphytic algae decrease light transmittance to the SAV host leaves and interfere with gas exchange.

Further, although a modeling study investigating salinity changes due to recommended surface water withdrawal levels (Environmental Consulting & Technology 2002, 2006) reported only slight increases in salinity relative to a three-year salinity mean, SAV response to salinity levels is not described well by exposure to mean or median values. For example, mean salinity values associated with the Buckman SAV permanent monitoring station, during the 1999 – 2001 drought, showed mean salinity at 4.82 ppt. This value was well within reported tolerance of *Vallisneria*, and yet, a huge die back occurred at this site, and at other upstream sites. What was most significant about the salinity during the 1999 – 2001 period at Buckman, was that salinity levels (as recorded by SJRWMD during biweekly sampling) exceeded 10 ppt and remained at greater than 5 ppt for approximately 5 months during 1999 alone. Elevated salinities continued through July 2001. USGS hourly data for 1999 (Environmental Consulting & Technology 2002) showed a peak of approximately 27 ppt at the Buckman bridge and salinity levels of greater than 9 ppt for approximately a month and a half. In situ and mesocosm studies (Boustany et al. 2001, Doering 2001) have shown that exposure to peaks in salinity levels and/or extended exposure to only slightly elevated levels is what causes declines in growth parameters. Further, increased duration at even low salinity concentrations has been shown to deleteriously impact SAV, and particularly *Vallisneria*. It is critical that any increases in frequency and duration of high salinity events are clearly shown in models if the extent to which SAV habitat in the LSJR will be affected can be determined. Specifically, for the model to be truly predictive of possible deleterious affects on SAV, it must 1) show the number of incidence of exposure over a critical salinity level and 2) how the duration of moderate salinity levels may increase.

Another potential factor that could impact SAV beds is exposure resulting from decreased flow volumes. If water withdrawal decreases river levels, greater extents of the current SAV bed could be exposed and with greater frequency. As described earlier, during the winter and early spring, SAV beds are routinely exposed when southerly winds predominant. An assessment should be whether lower river levels will prolong this exposure, or cause it to occur more frequently. Directly related to the extent and duration of exposure due to surface water withdrawals, as well as for increases in salinity and retention times, is what the additive effect of withdrawal from four locations within the SJR and from the Ocklawaha River, will have on the minimum flow and river levels. Currently, the simulation model of withdrawal at S.R. 44 near Deland (Environmental Consulting & Technology 2006) only takes into account withdrawal at that location. No report has yet been published that predicts minimum flows and levels of the river when withdrawal occurs at multiple locations.

Further, all of these impacts have greater or lesser effects depending on the natural seasonal changes in water flow due to precipitation events as well as wind-driven changes in flow rate and direction. For instance, as described in the Environmental Consulting & Technology (2002) report, the model used to determine salinity changes in the LSJR was based on data from 1997 – 1999. Two of those years represent normal or above normal annual precipitation levels. Data from the third year came from a below-normal precipitation year which resulted in elevated salinities beginning in June 1999. If the model were run during drought conditions, as occurred from 1999 – 2001 and again in 2006 – 2007, the additive effect of surface water withdrawal on low freshwater input conditions may reveal more extreme changes in salinity. In addition, impacts will be more deleterious depending both on the growth stage of the SAV as well as the period within the growing season and could cause outright diebacks, affect resource allocation to below-ground storage structures, or interfere with production of reproductive structures.

Finally, little has been described regarding the effluent discharge from the water treatment facilities which will result. Tannins, electrolytes, and other constituents of SJR water will have to be removed before it is potable. Presumably, the remaining waste will be discharged back into the SJR as it is now done after treatment by water treatment facilities. If not properly treated, that effluent will contain concentrated levels of those constituents that attenuate light and increase salinity.

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Figure 1: The Lower St. Johns River Basin (LSJRB), Florida

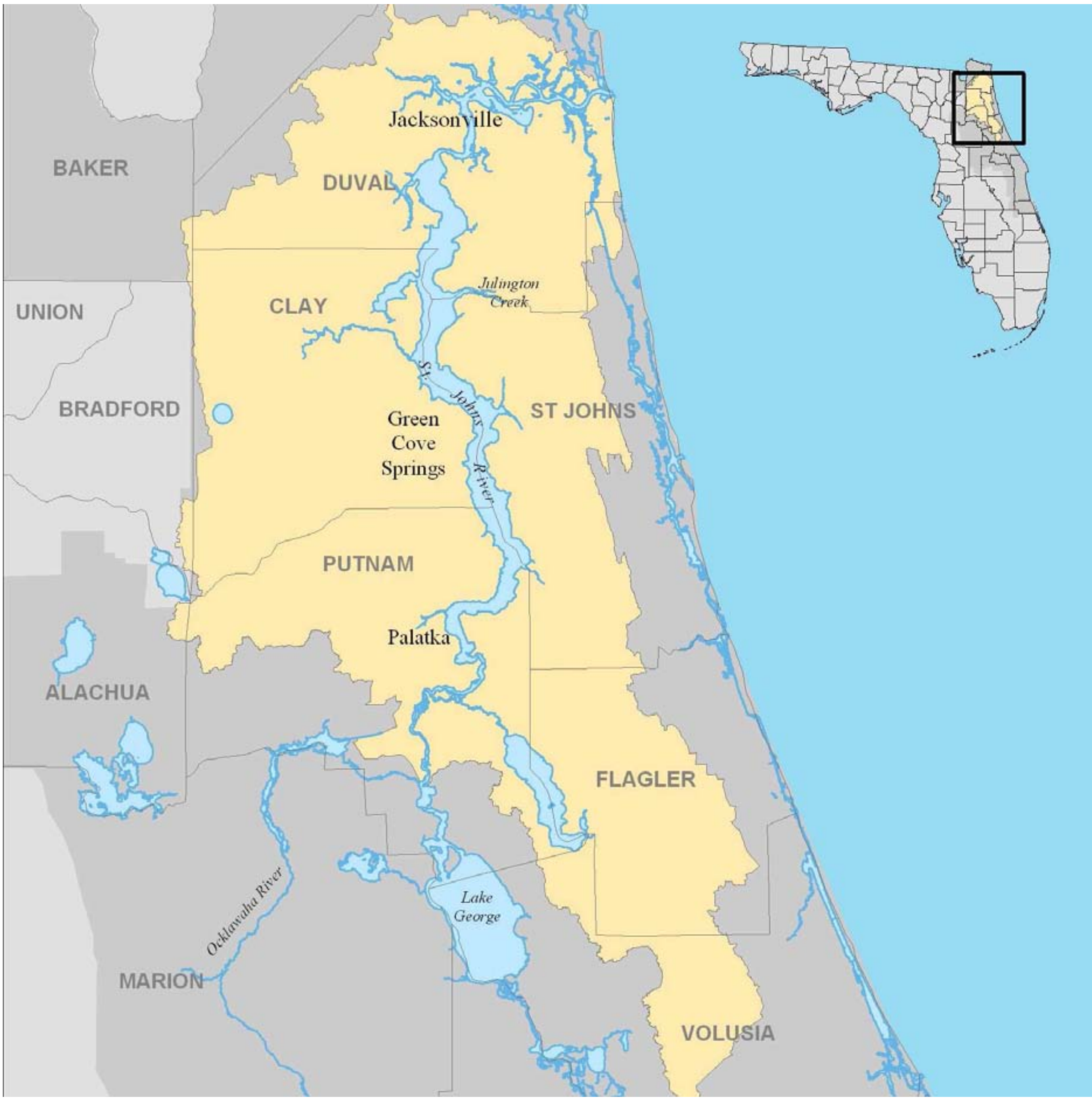


Figure 2: Approximate Locations of PMN Sites Within the LSJRB

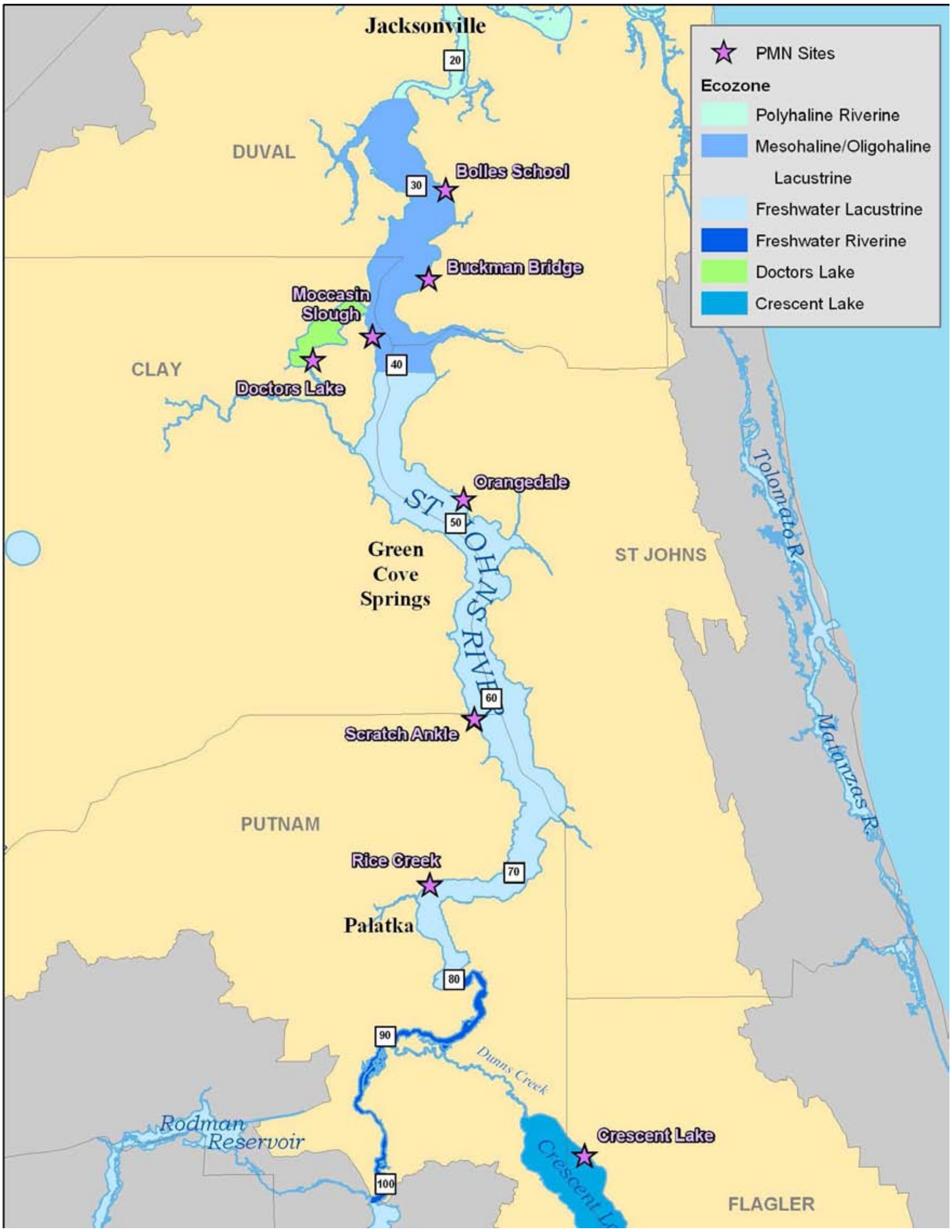


Figure 3a: Groundtruthing Sites Oligohaline, Lacustrine Ecozone (Ecozone 1)

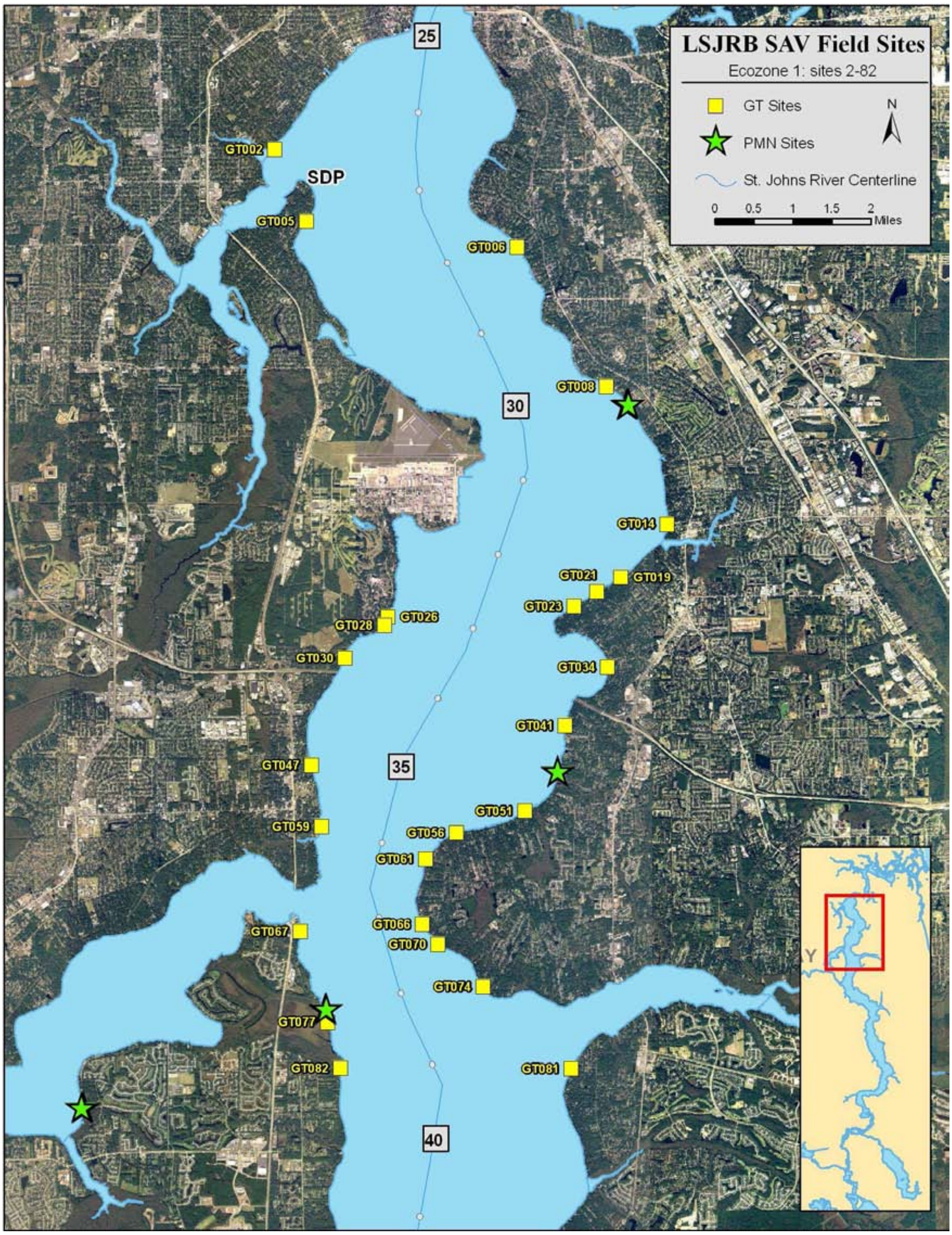


Figure 3b: Groundtruthing Sites Freshwater, Lacustrine Ecozone (Ecozone 2)

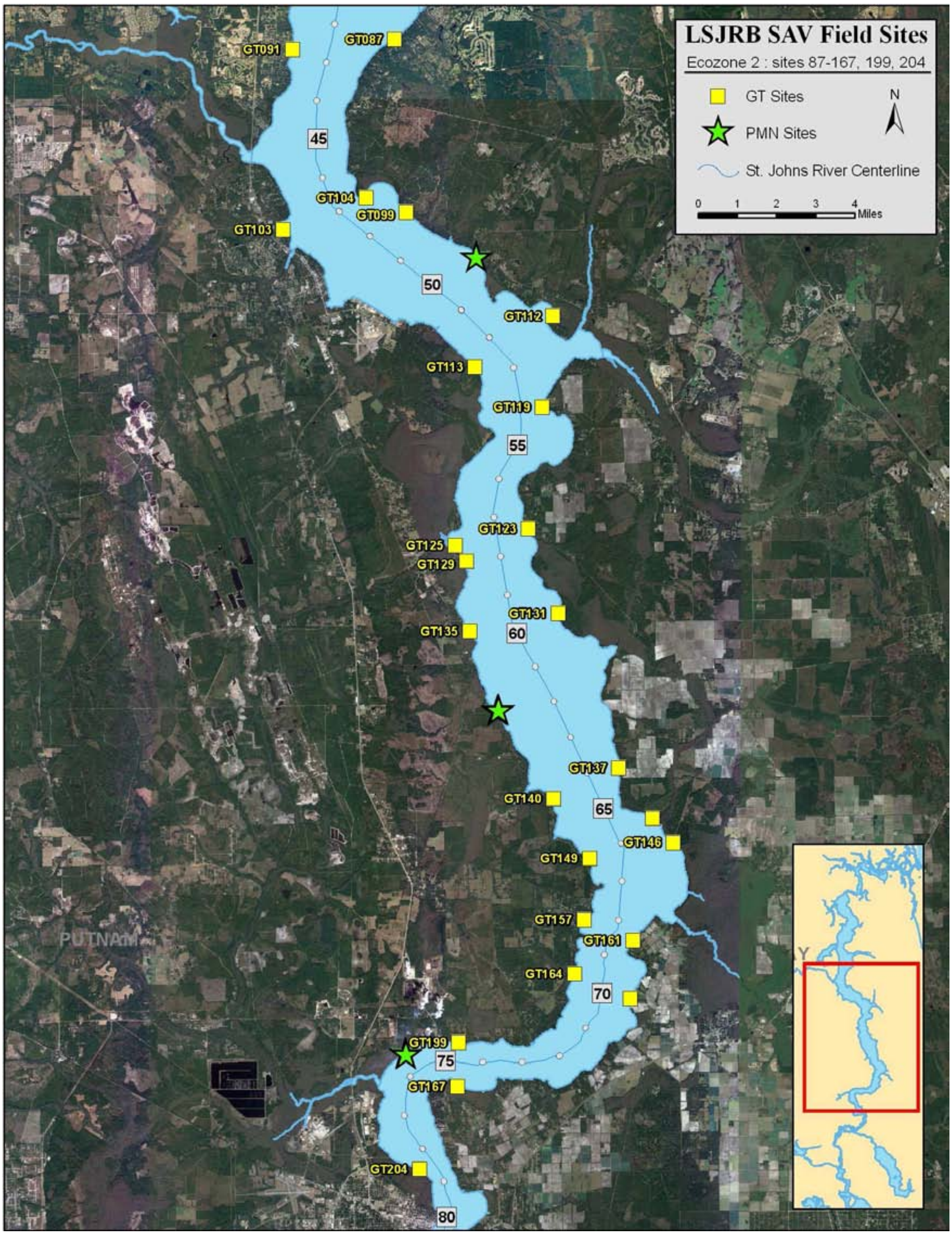


Figure 3c: Groundtruthing Sites Freshwater, Riverine Ecozone (Ecozone 3)

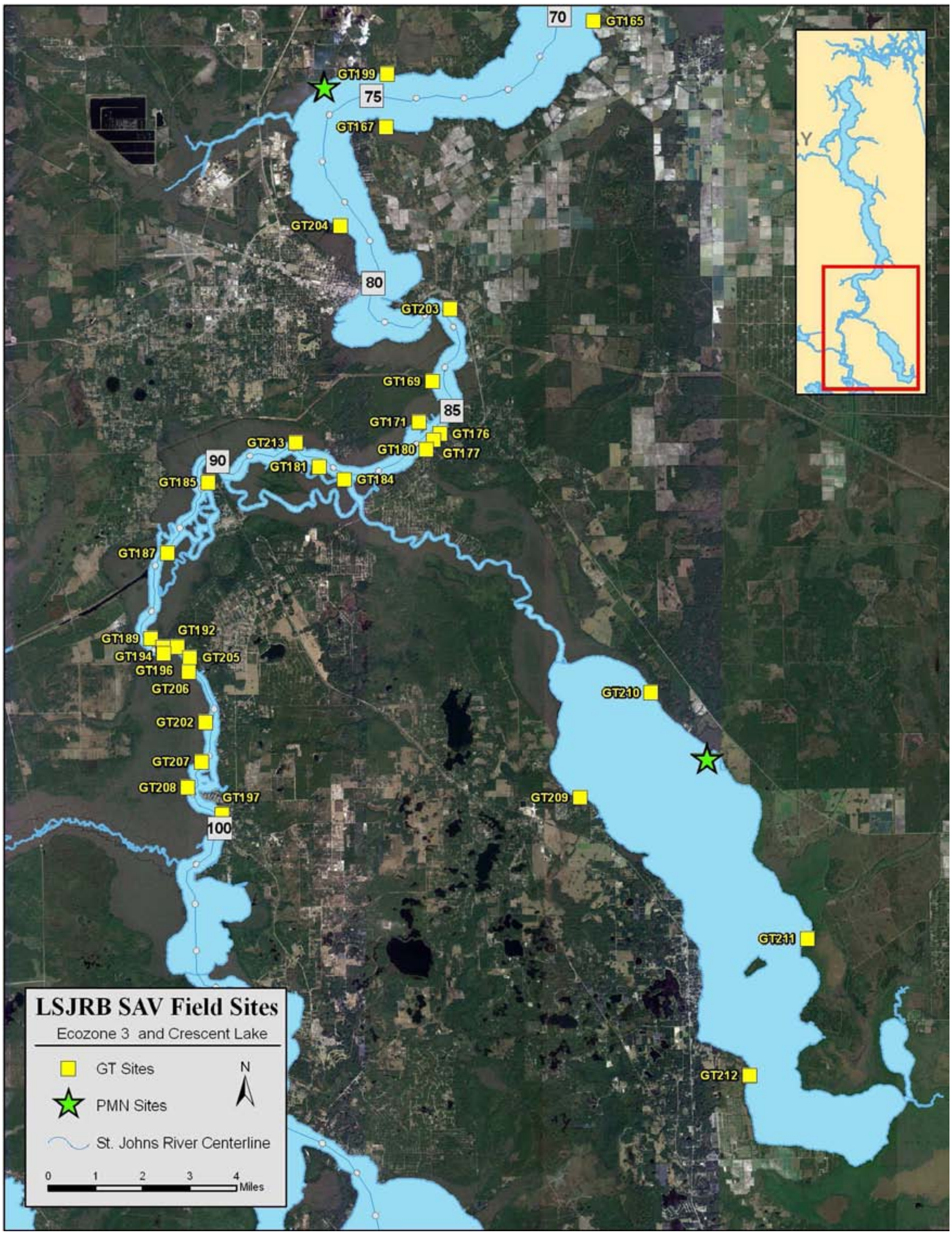
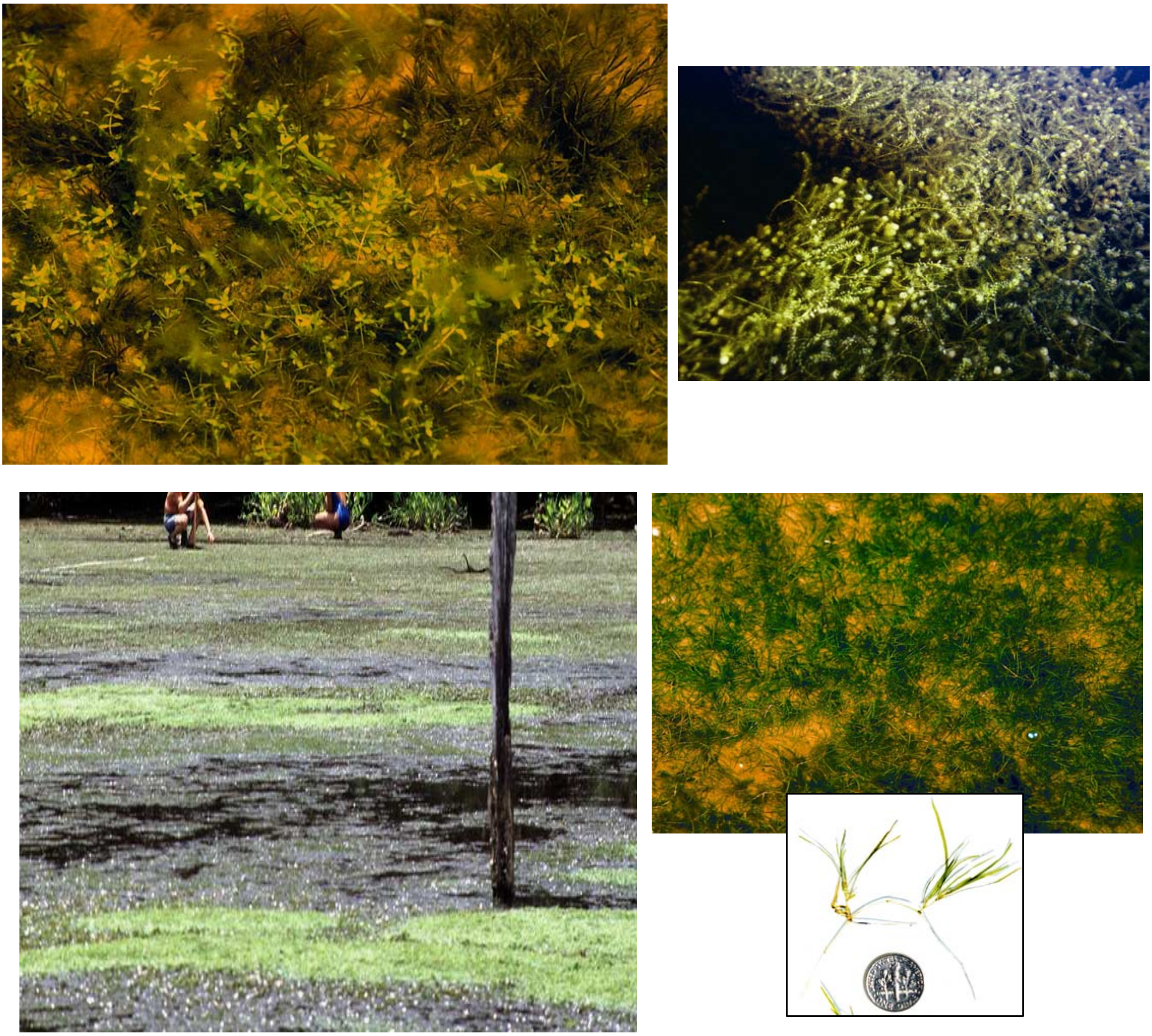


Figure 4a: Examples of SAV Morphology and Density as Seen in the LSJRB



Clockwise from top-left: 1) Approx. 30 cm x 30 cm view of *Eleocharis* sp., charophytes, *Micranthemum* sp., *N. guadalupensis*, *S. subulata*, & *Z. palustris*; 2) *H. verticillata*; 3) 25 cm x 25 cm view of *Z. palustris* with inset of typical plant size; 4) At Scratch Ankle, light green *Micranthemum* sp. mats overlying and around beds of charophytes, *Eleocharis* sp., *N. guadalupensis*, *P. pusillus*, *S. subulata*, *V. americana*, *Z. palustris*. Note that water clarity in many of these photos is atypical; they were taken during the height of the drought in 2001

Figure 4b: Examples of SAV Morphology and Density as Seen in the LSJRB continued

Approx. 1.0 m x 1.5 m view of predominantly *V. americana* with *R. maritima* interspersed. Note *Rhizoclonium* sp. entangled around *R. maritima* (Buckman, June 2003).

Figure 5: Schematic of SAV Transect Grid

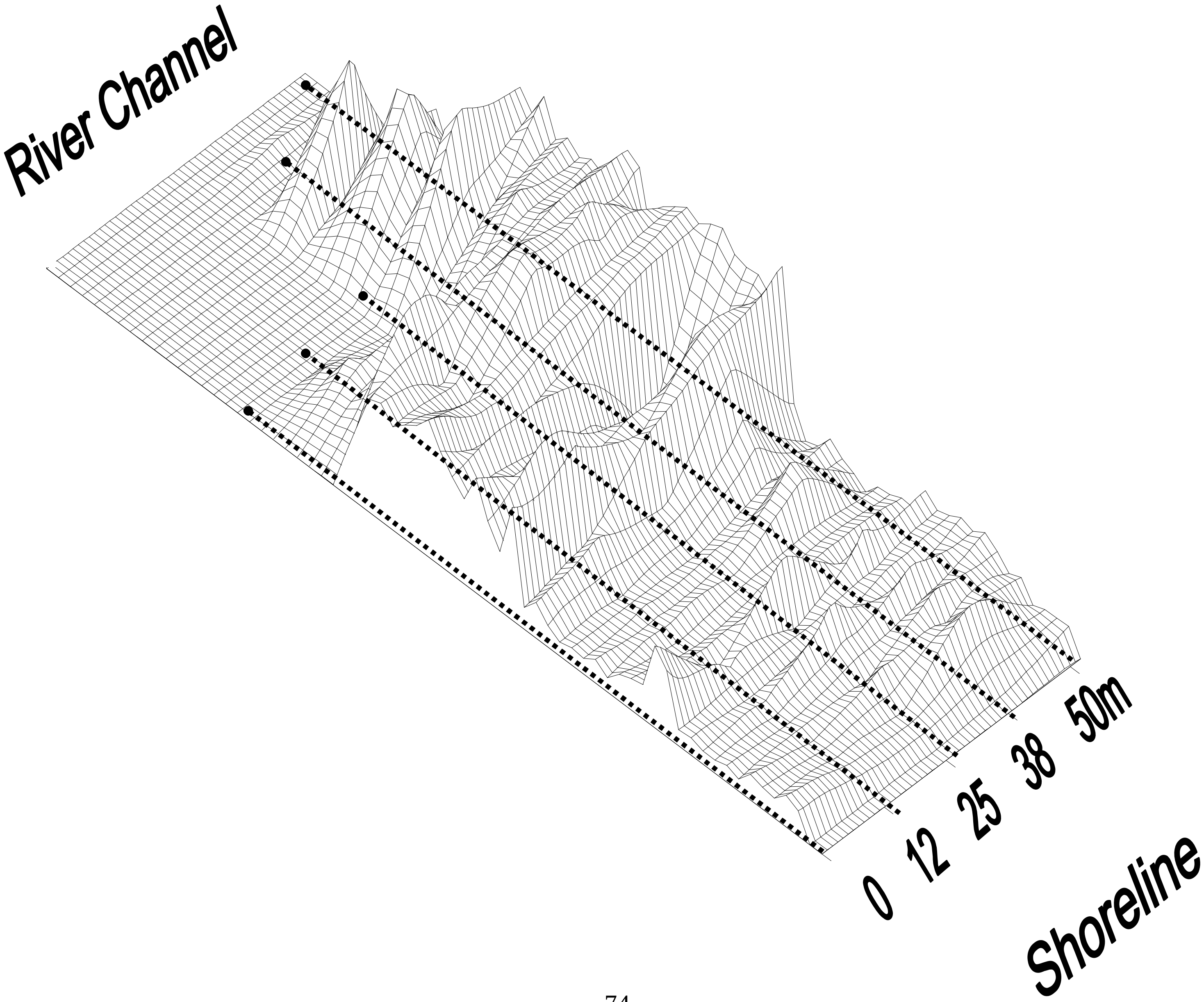


Figure 6: Line Intercept Data Collection Methods

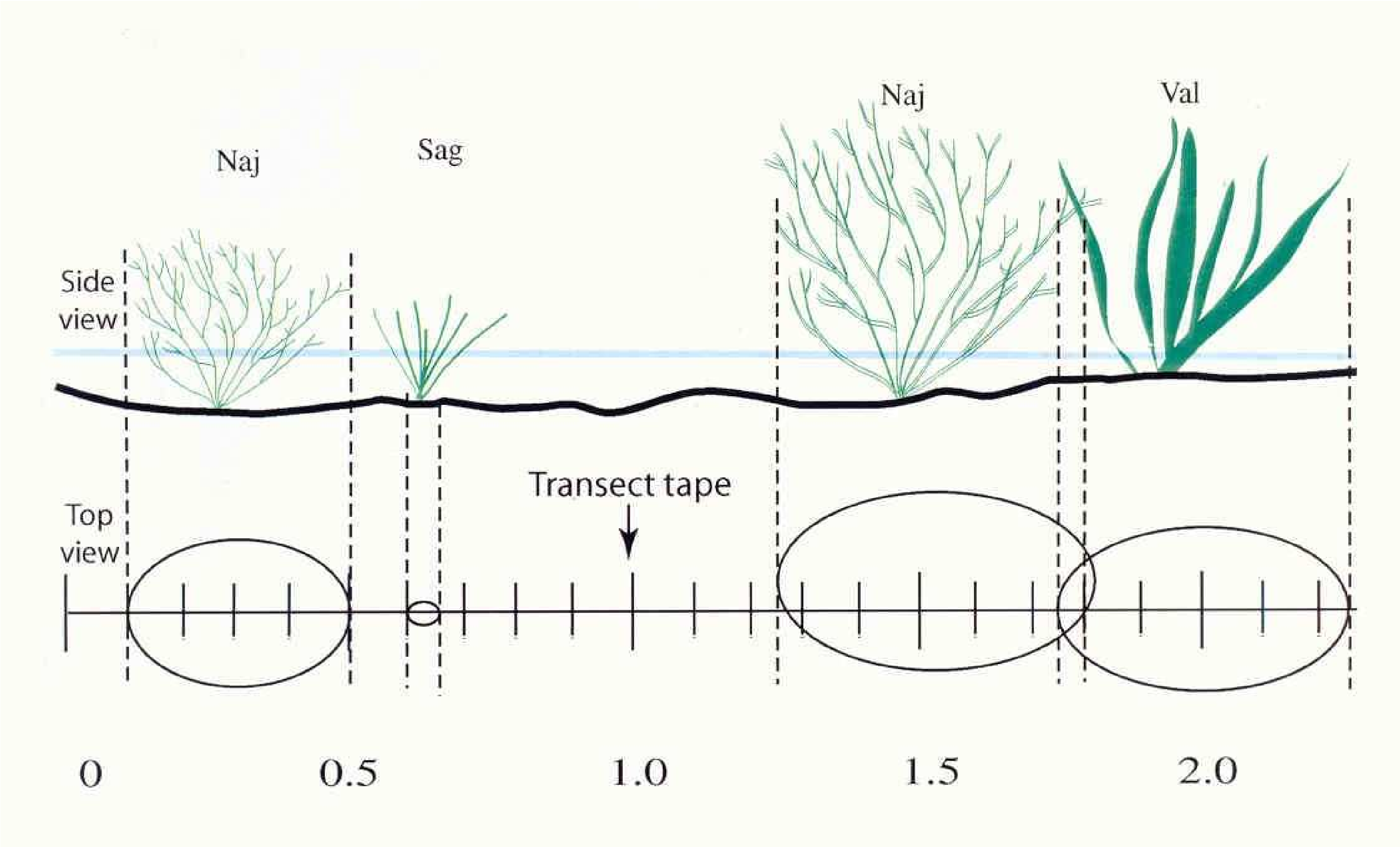
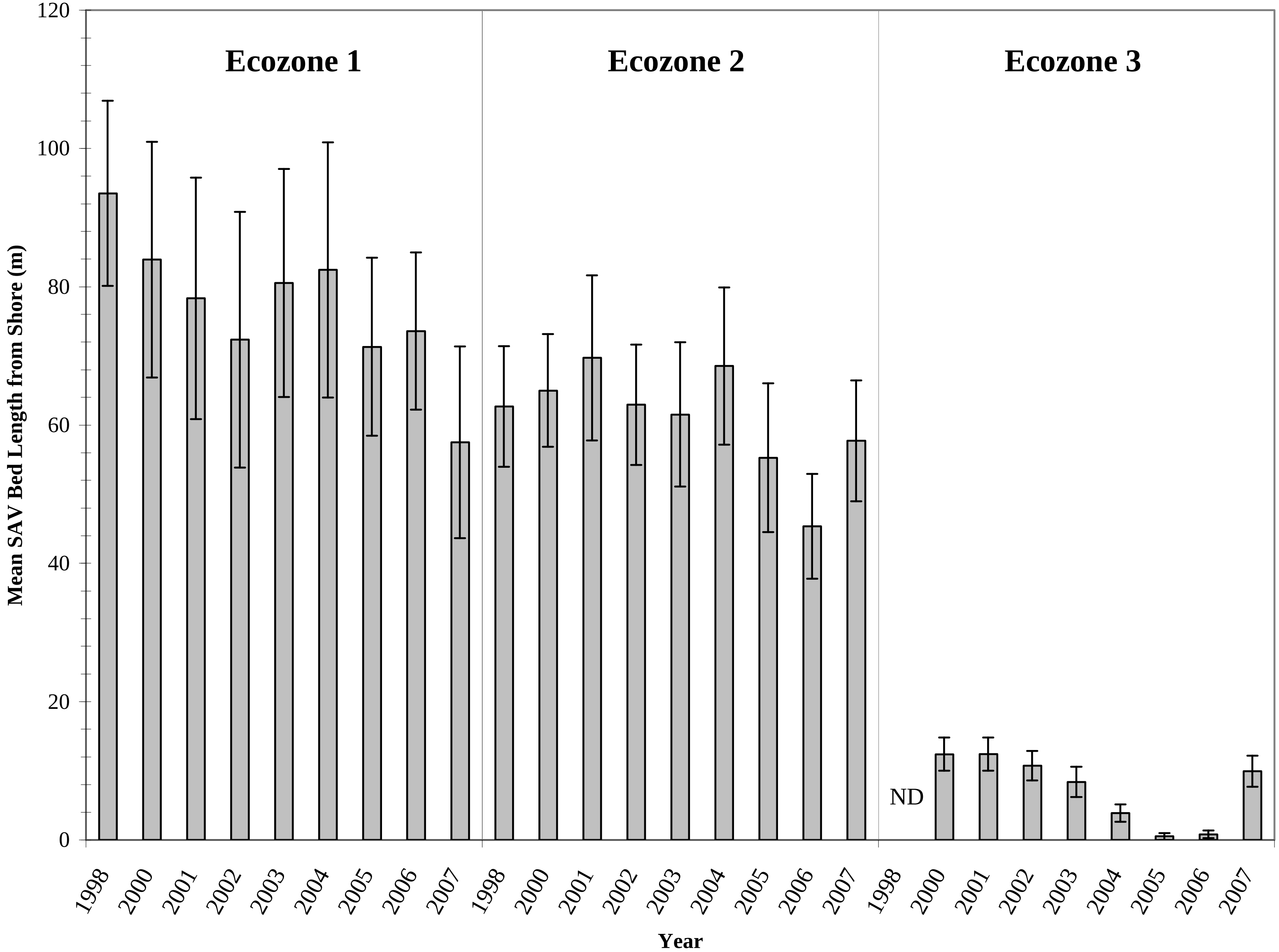


Figure 7:
SAV Bed Length from Shore
Ecozones 1 - 3



ND = No data . Adapted from Sagan 2007b.

Figure 8a: Bolles
SAV Percent Occurence
1996 - 2007

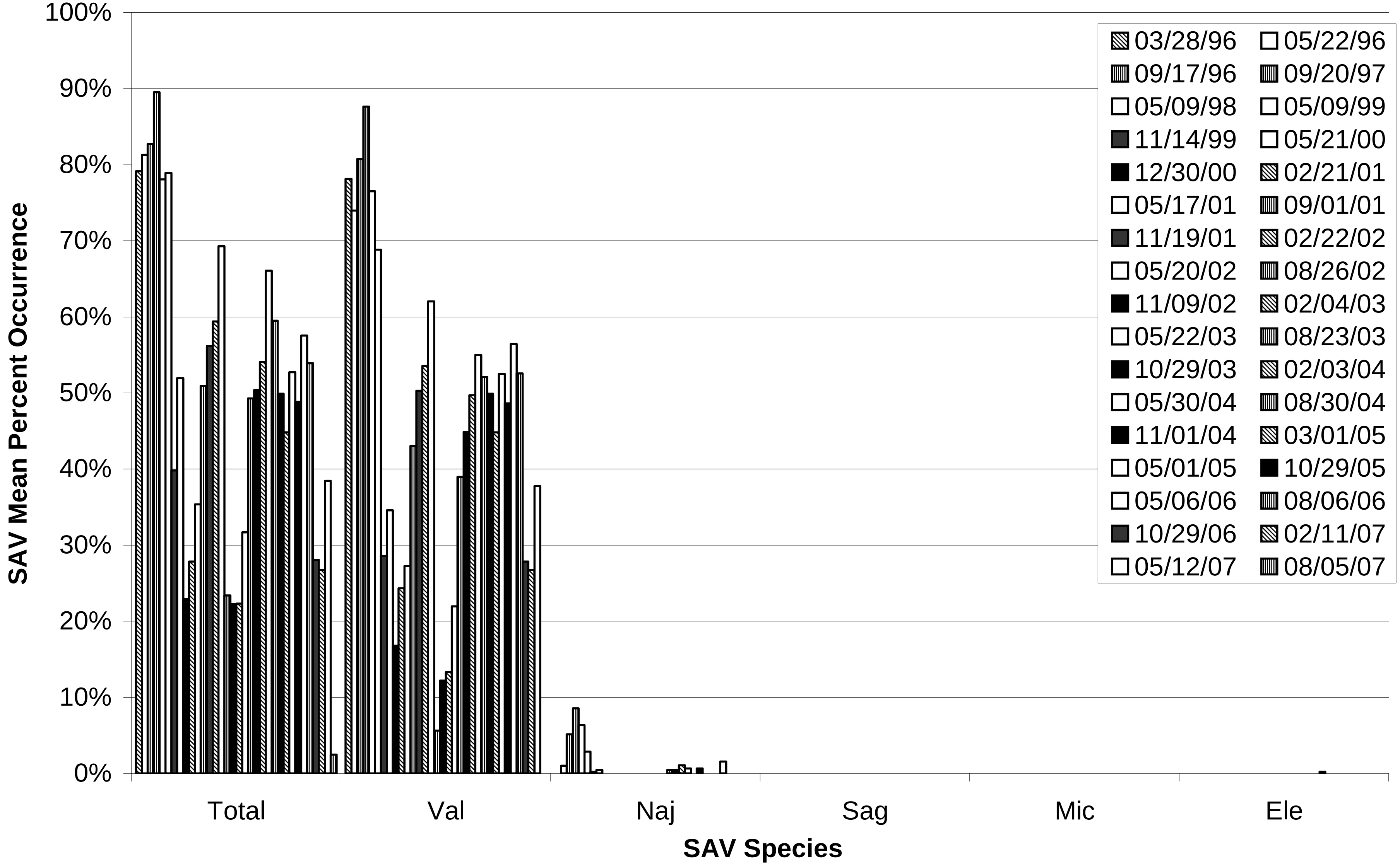
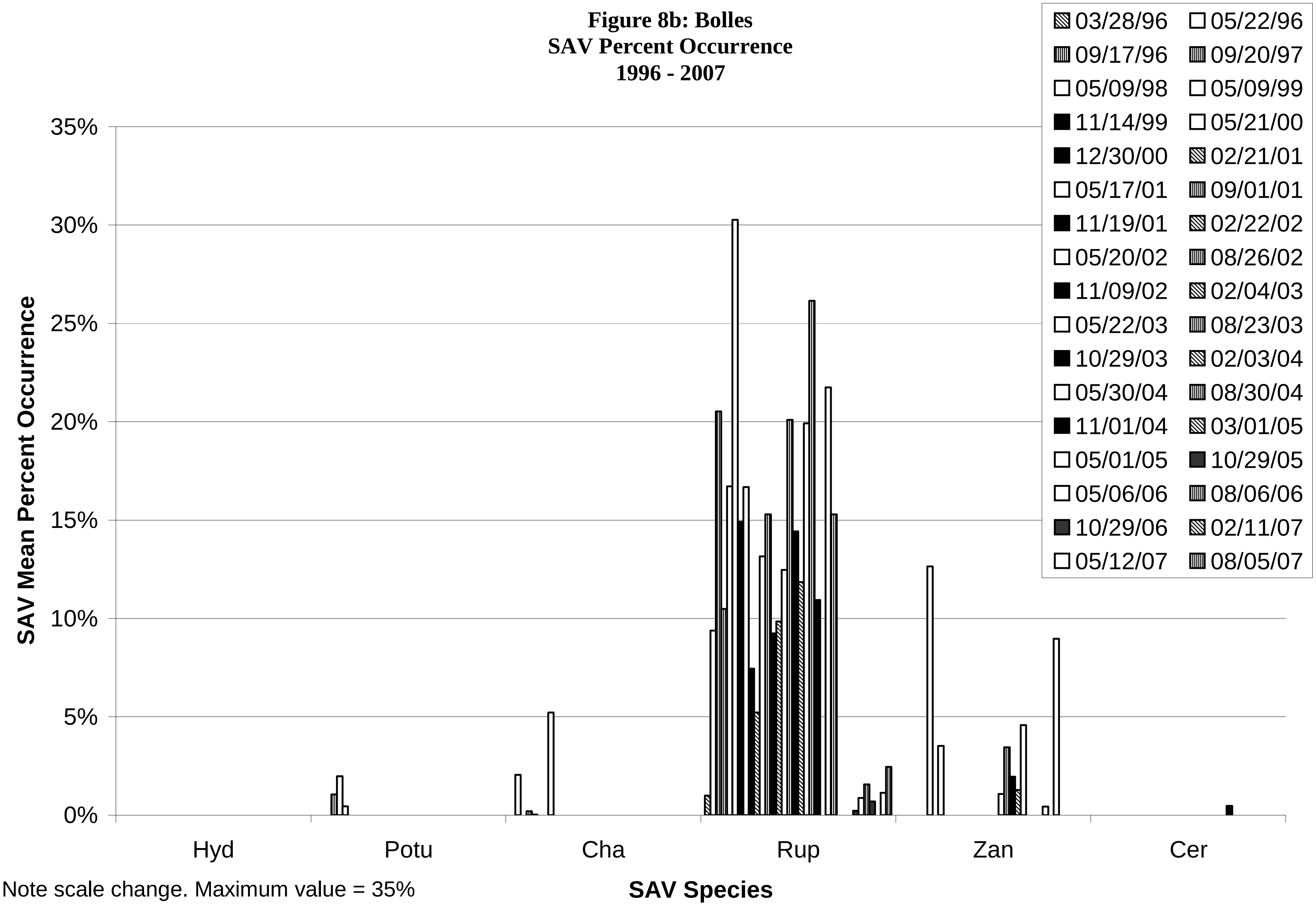


Figure 8b: Bolles
SAV Percent Occurrence
1996 - 2007



Note scale change. Maximum value = 35%

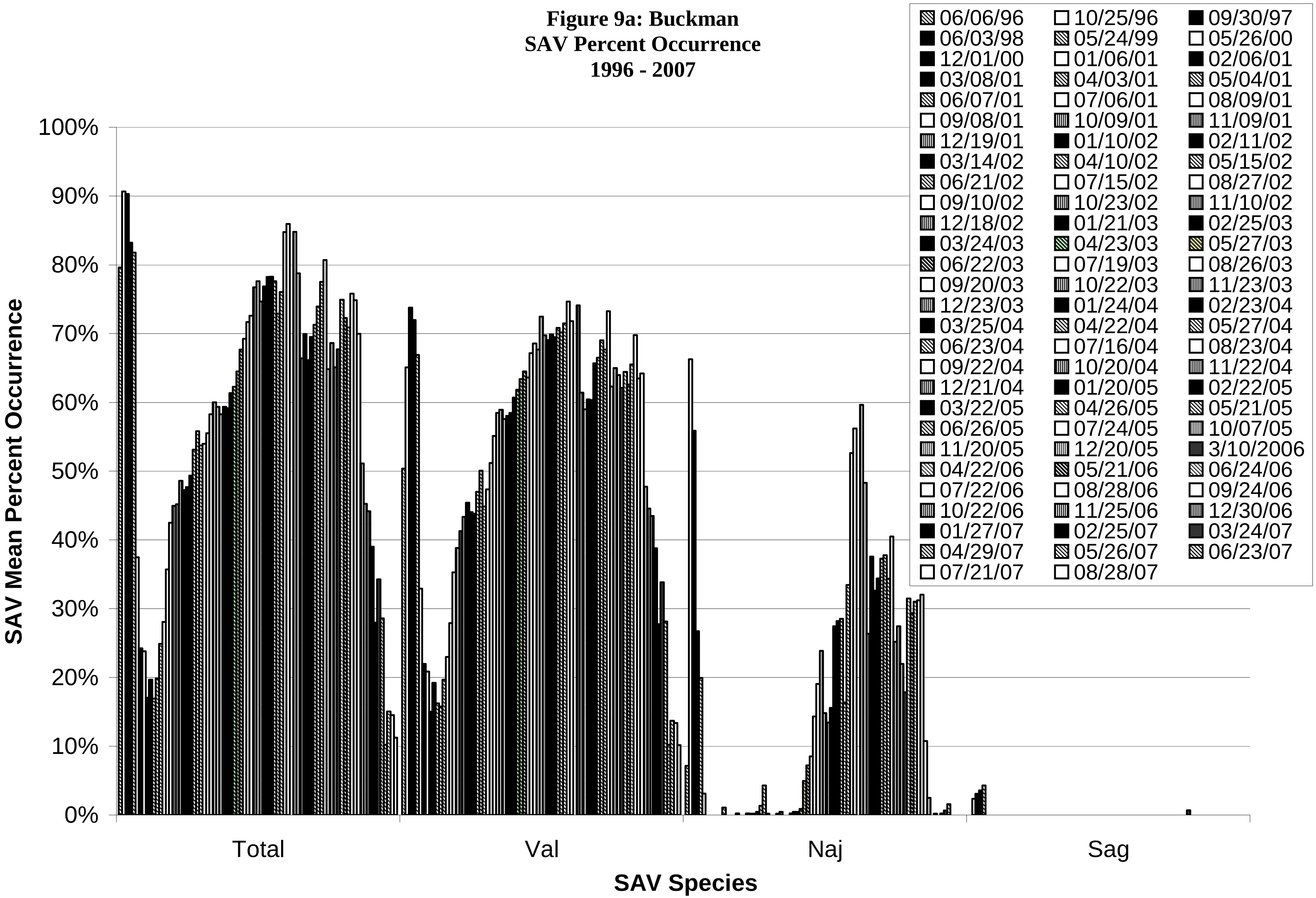


Figure 9a: Buckman
SAV Percent Occurrence
1996 - 2007
06/06/96
10/25/96
09/30/97
06/03/98
05/24/99
05/26/00
12/01/00
01/06/01
02/06/01
03/08/01
04/03/01
05/04/01
06/07/01
07/06/01
08/09/01
09/08/01
10/09/01
11/09/01
12/19/01
01/10/02
02/11/02
03/14/02
04/10/02
05/15/02
06/21/02
07/15/02
08/27/02
09/10/02
10/23/02
11/10/02
12/18/02
01/21/03
02/25/03
03/24/03
04/23/03
05/27/03
06/22/03
07/19/03
08/26/03
09/20/03
10/22/03
11/23/03
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02/23/04
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02/22/05
03/22/05
04/26/05
05/21/05
06/26/05
07/24/05
10/07/05
11/20/05
12/20/05
3/10/2006
04/22/06
05/21/06
06/24/06
07/22/06
08/28/06
09/24/06
10/22/06
11/25/06
12/30/06
01/27/07
02/25/07
03/24/07
04/29/07
05/26/07
06/23/07
07/21/07
08/28/07
SAV Mean Percent Occurrence
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Total
Val
Naj
Sag
SAV Species

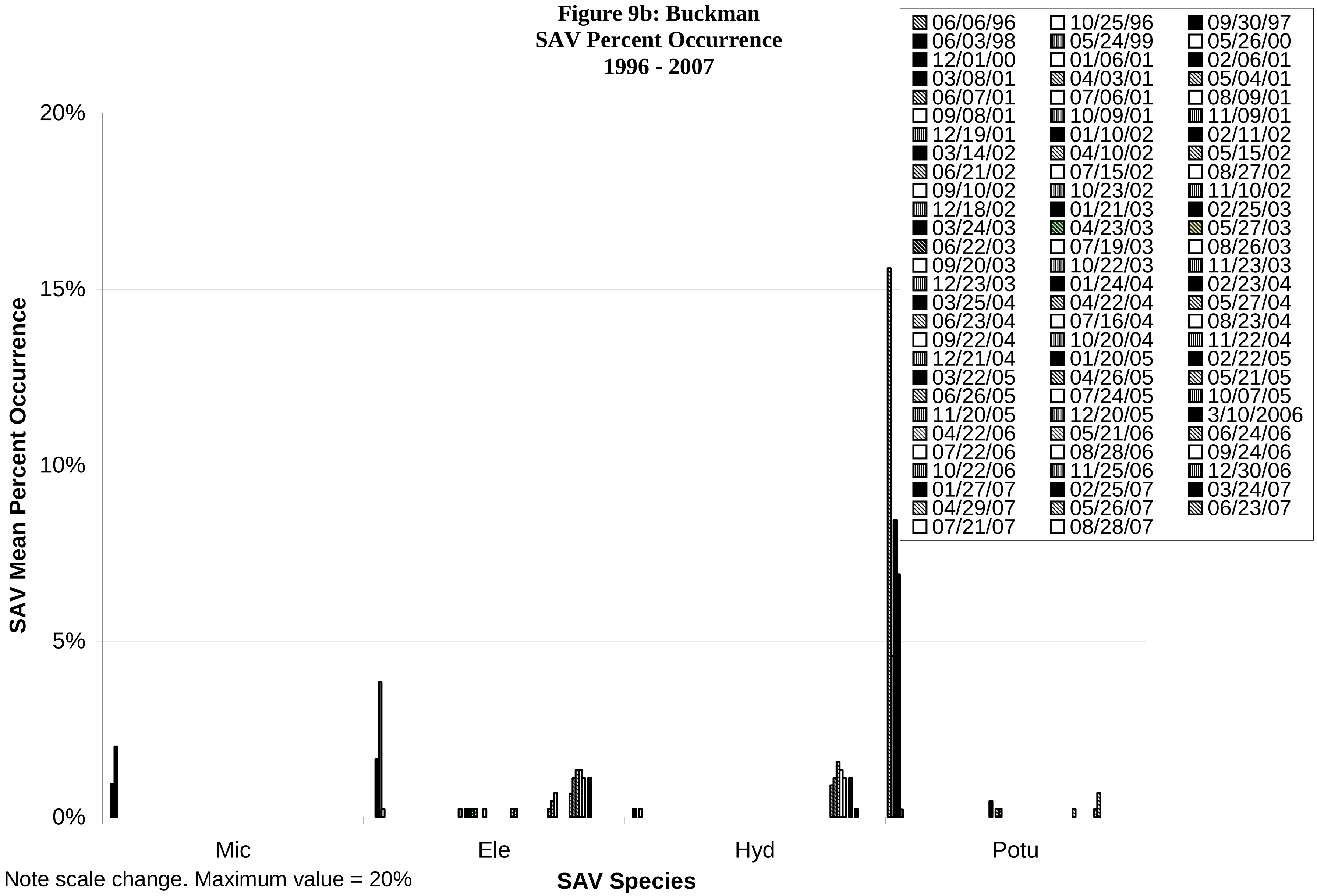
Figure 9b: Buckman
SAV Percent Occurrence
1996 - 2007
SAV Mean Percent Occurrence
20%
15%
10%
5%
0%
Mic
Ele
Hyd
Potu
SAV Species
Note scale change. Maximum value = 20%
06/06/96
10/25/96
09/30/97
06/03/98
05/24/99
05/26/00
12/01/00
01/06/01
02/06/01
03/08/01
04/03/01
05/04/01
06/07/01
07/06/01
08/09/01
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08/28/06
09/24/06
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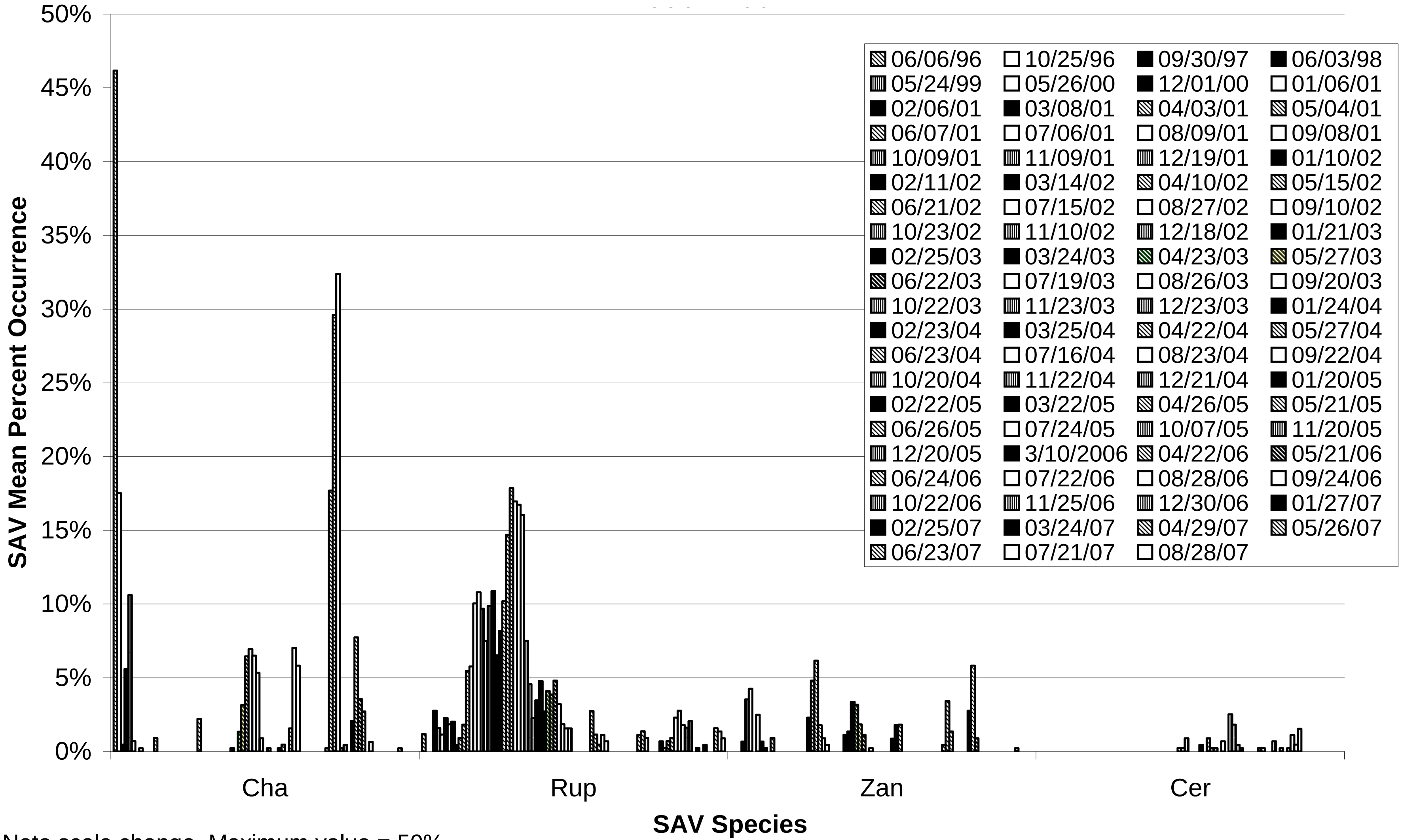
11/25/06
12/30/06
01/27/07
02/25/07
03/24/07
04/29/07
05/26/07
06/23/07
07/21/07
08/28/07

Figure 9c: Buckman
SAV Percent Occurrence
1996 - 2007



Note scale change. Maximum value = 50%

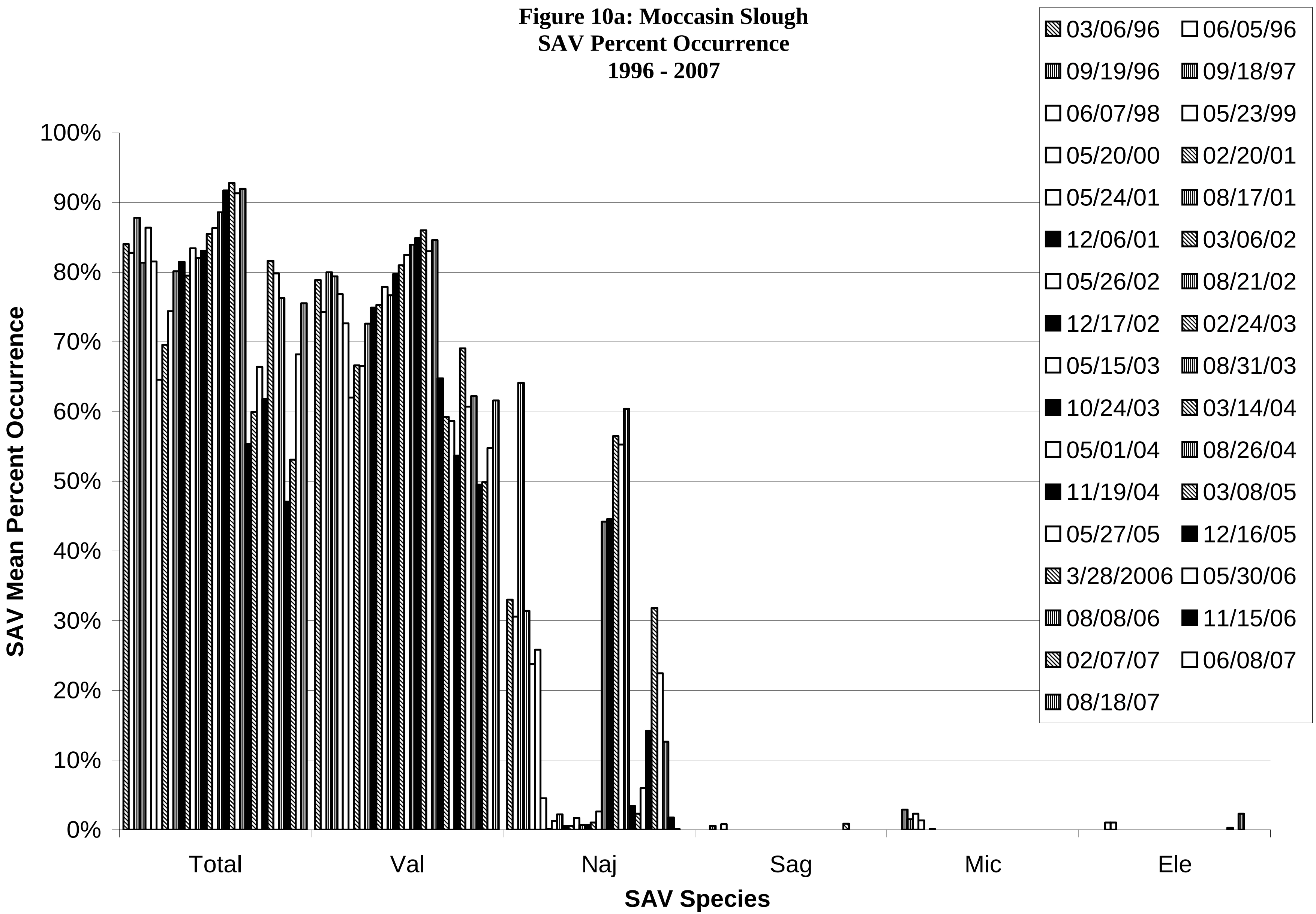
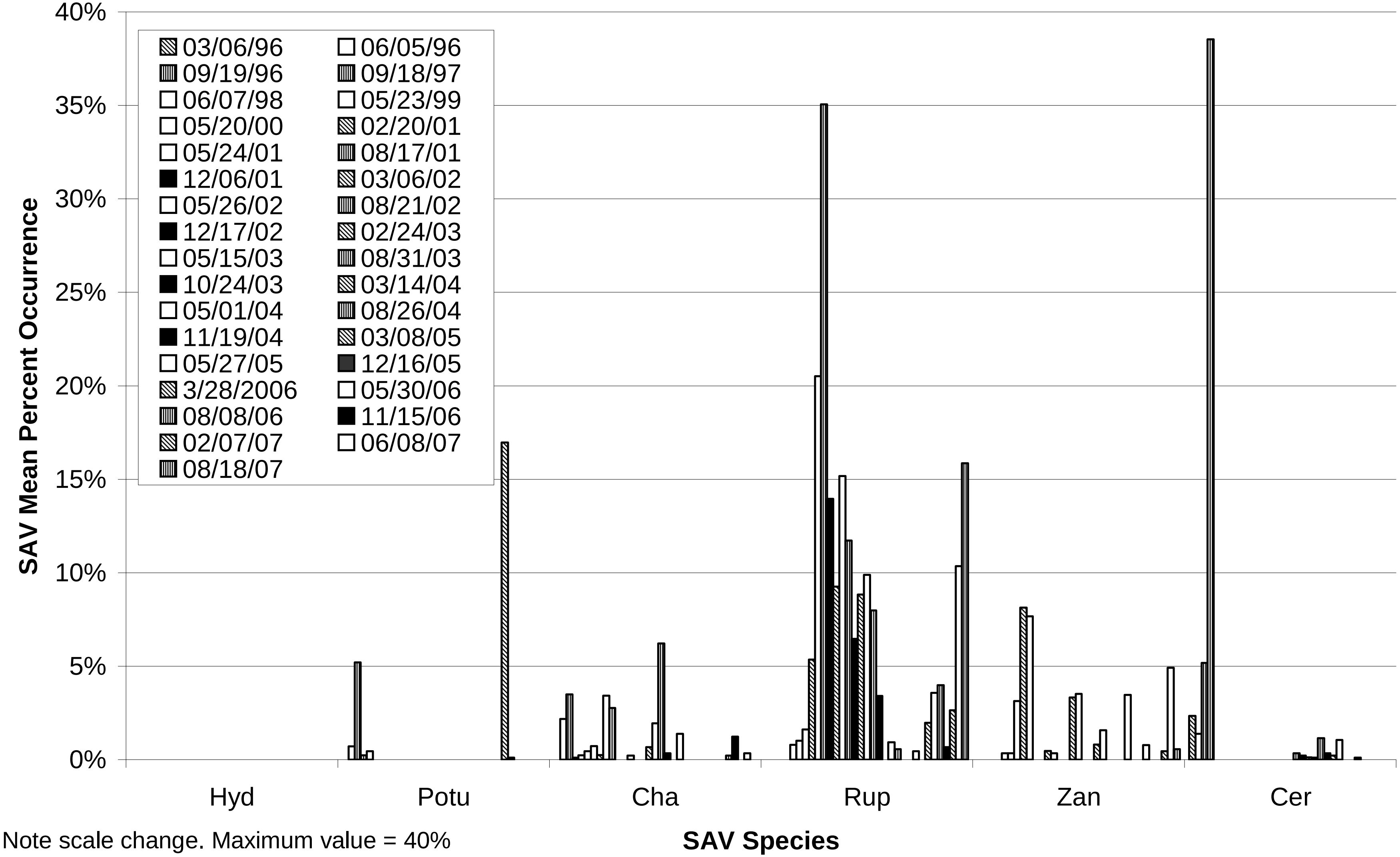


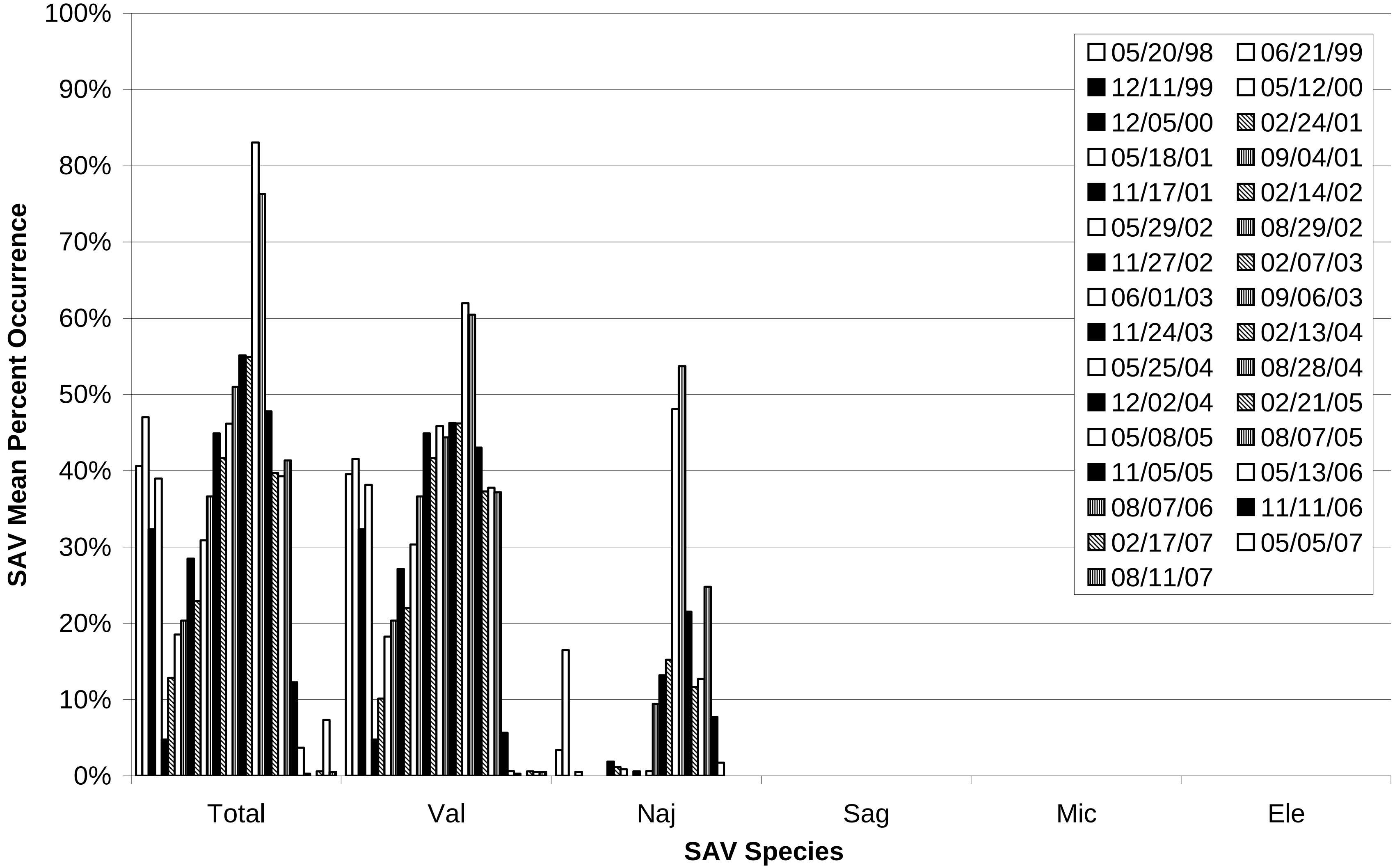
Figure 10a: Moccasin Slough
SAV Percent Occurrence
1996 - 2007
SAV Mean Percent Occurrence
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Total
Val
Naj
Sag
Mic
Ele
SAV Species
03/06/96
06/05/96
09/19/96
09/18/97
06/07/98
05/23/99
05/20/00
02/20/01
05/24/01
08/17/01
12/06/01
03/06/02
05/26/02
08/21/02
12/17/02
02/24/03
05/15/03
08/31/03
10/24/03
03/14/04
05/01/04
08/26/04
11/19/04
03/08/05
05/27/05
12/16/05
3/28/2006
05/30/06
08/08/06
11/15/06
02/07/07
06/08/07
08/18/07

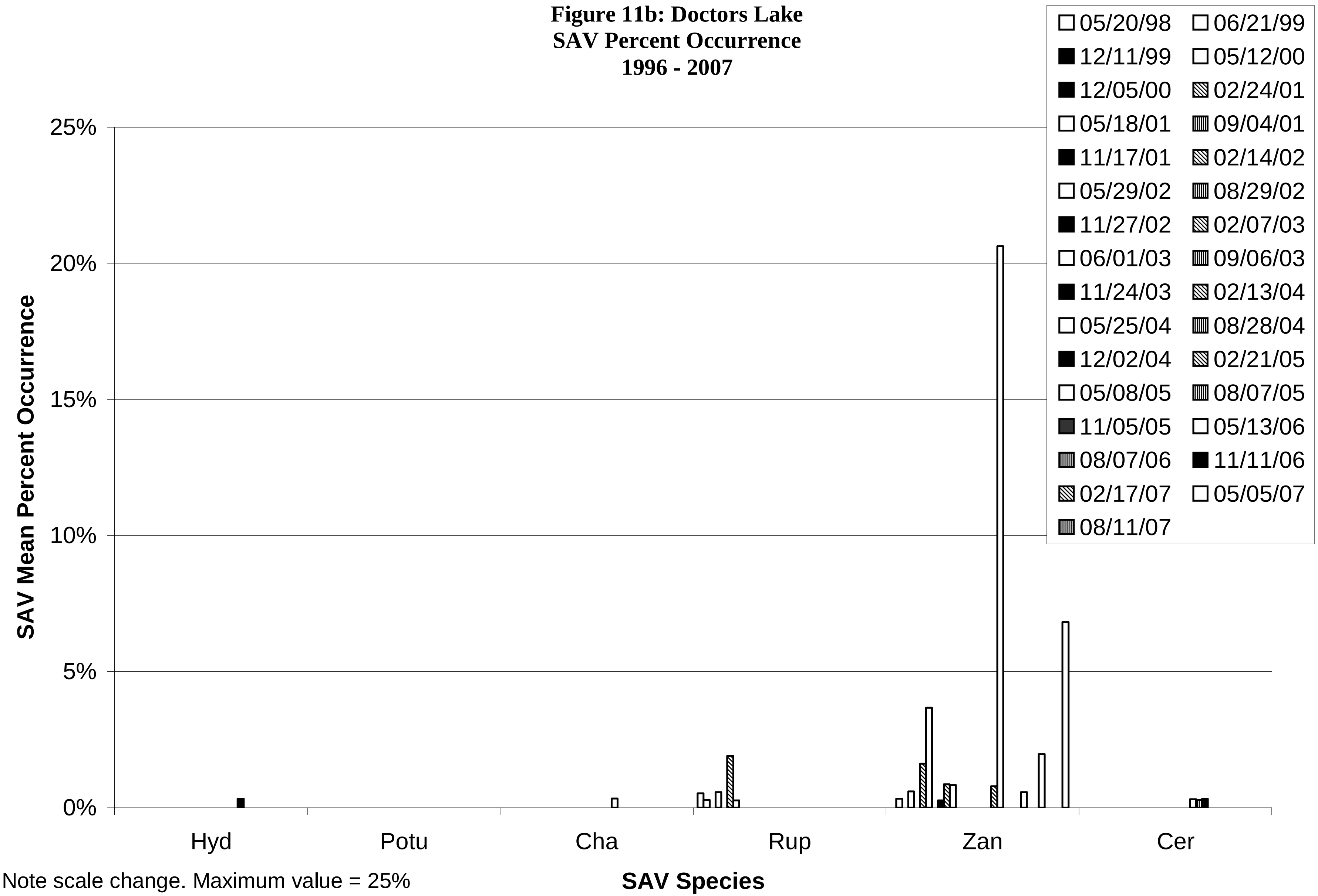
Figure 10b: Moccasin Slough
SAV Percent Occurrence
1996 - 2007



Note scale change. Maximum value = 40%

Figure 11a: Doctors Lake
SAV Percent Occurrence
1998 - 2007





Note scale change. Maximum value = 25%

Figure 12: Orangedale
SAV Percent Occurrence
1996 - 2000 & 2006 - 2007

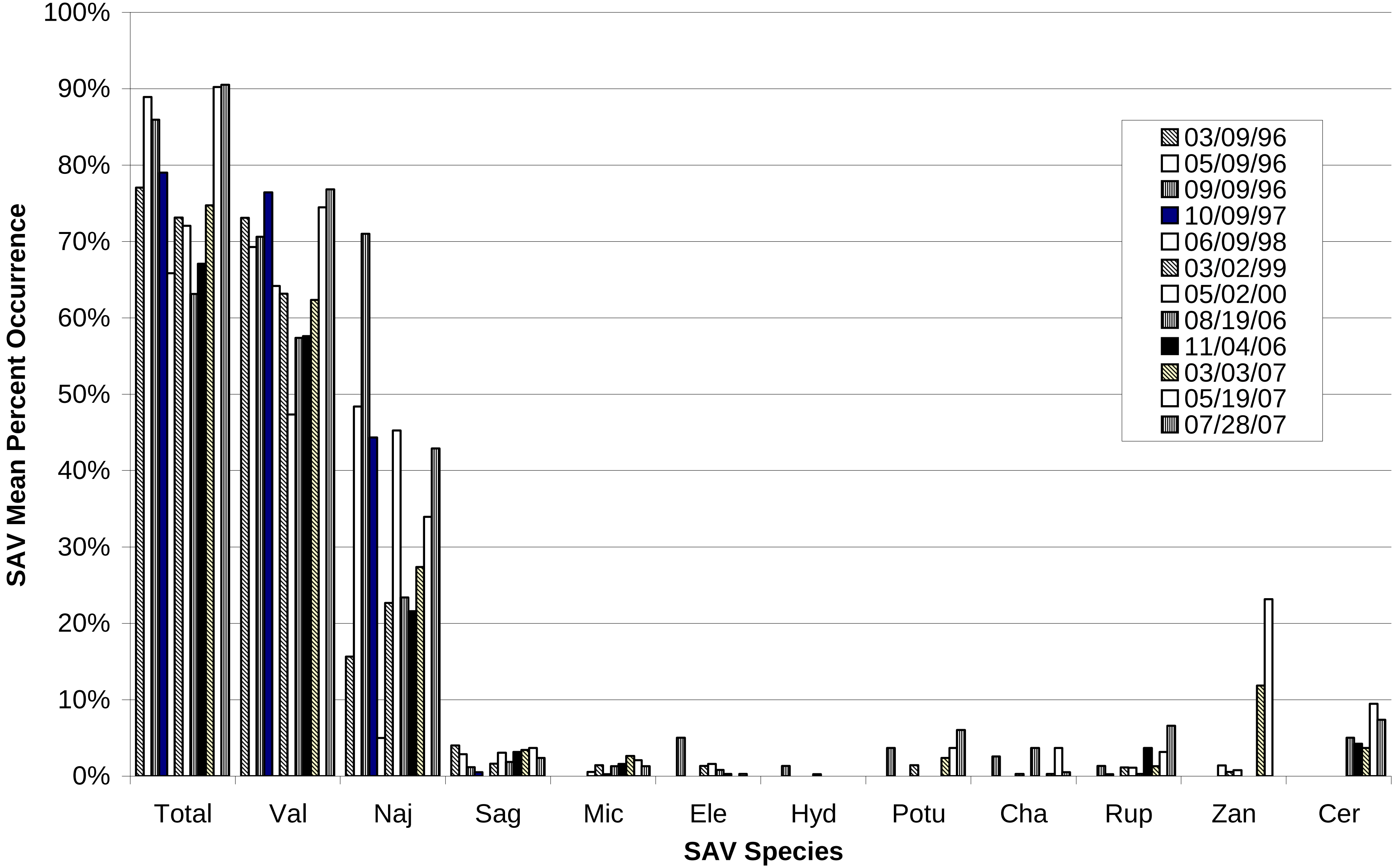
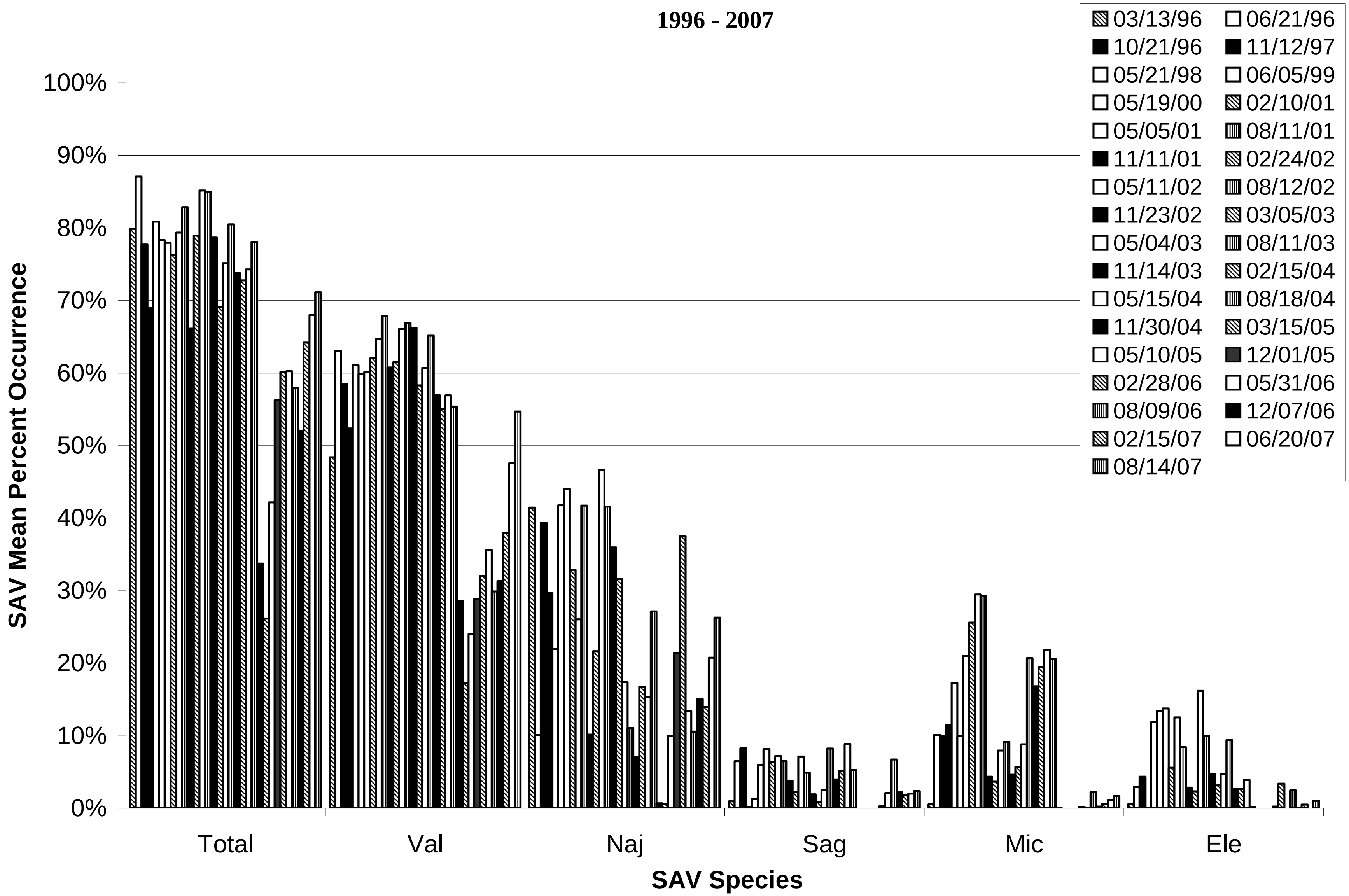
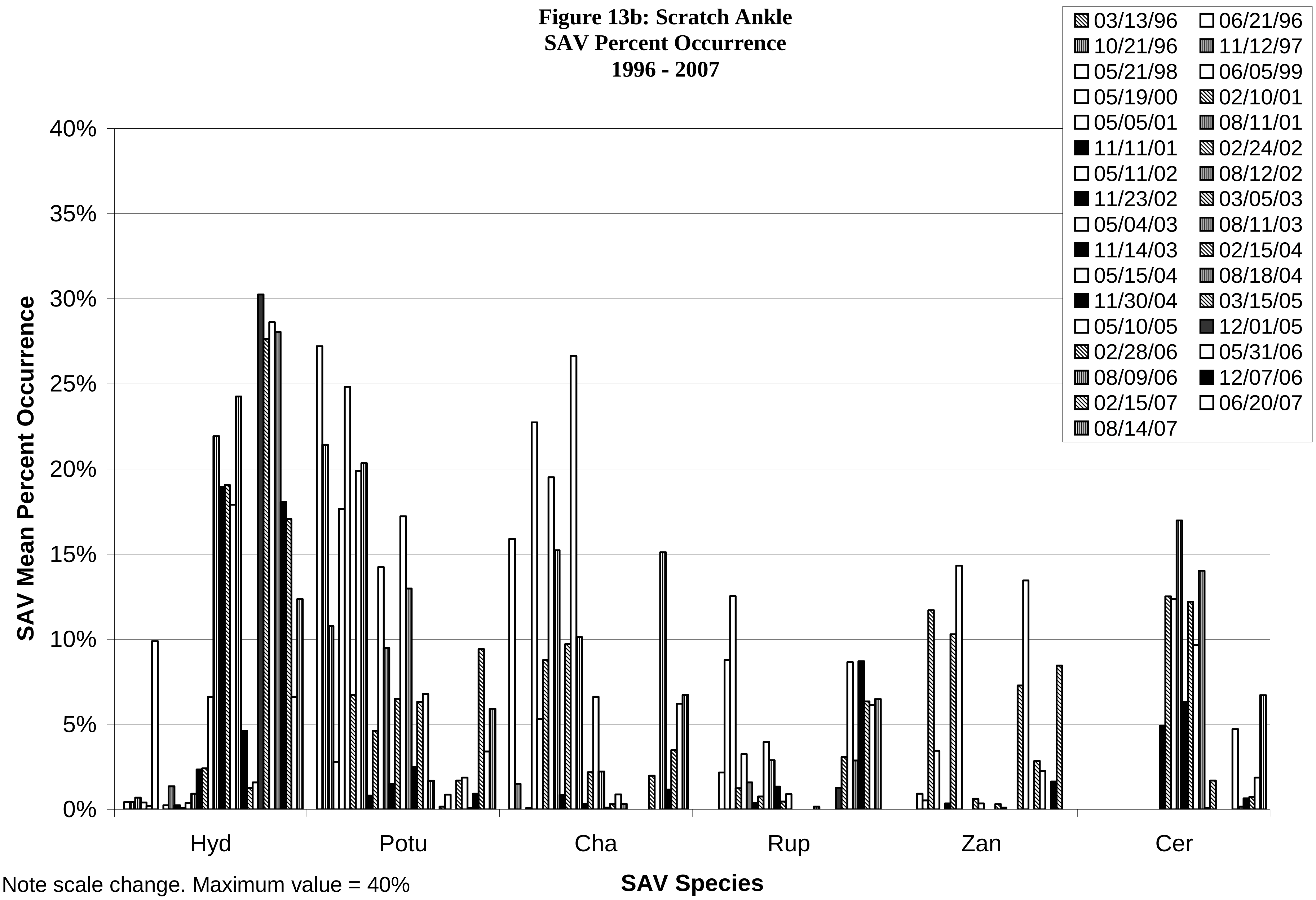


Figure 13a: Scratch Ankle
SAV Percent Occurrence
1996 - 2007





Note scale change. Maximum value = 40%

Figure 14a: Rice Creek
SAV Percent Occurrence
1996 - 2007

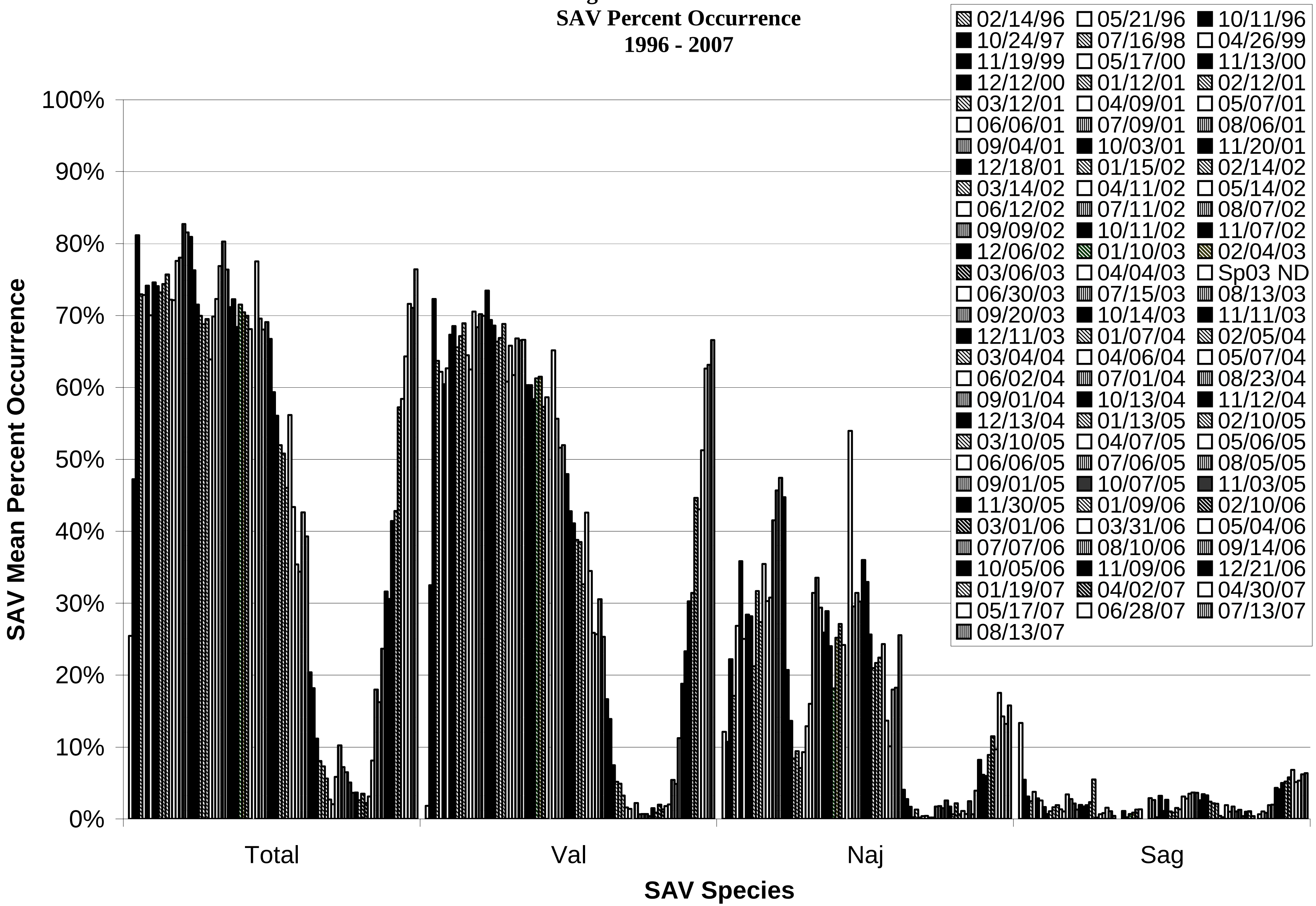
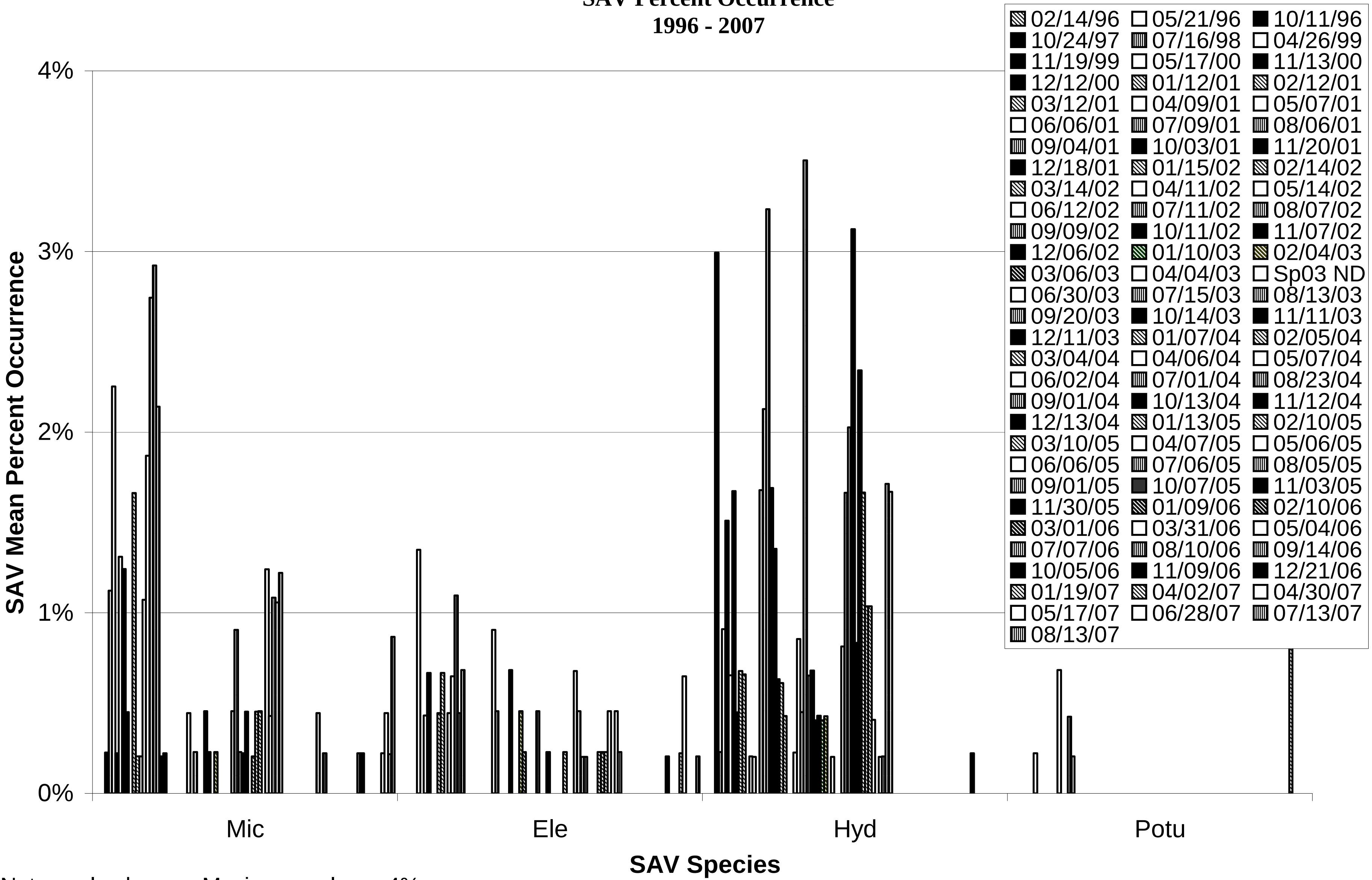
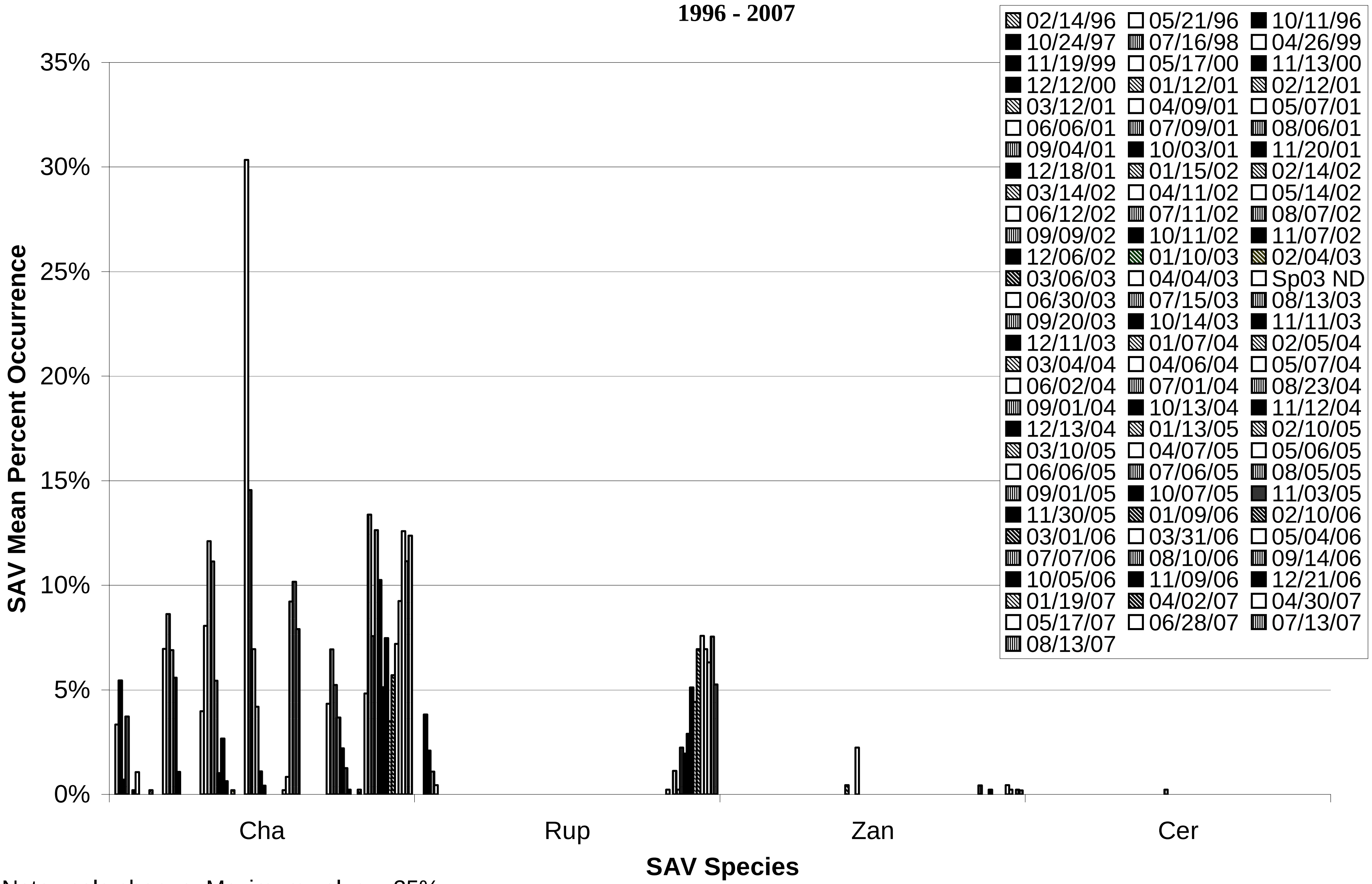


Figure 14b: Rice Creek
SAV Percent Occurrence
1996 - 2007



Note scale change. Maximum value = 4%

Figure 14c: Rice Creek
SAV Percent Occurrence
1996 - 2007



Note scale change. Maximum value = 35%

Figure 15a: Crescent Lake
SAV Percent Occurrence
1998 - 2007

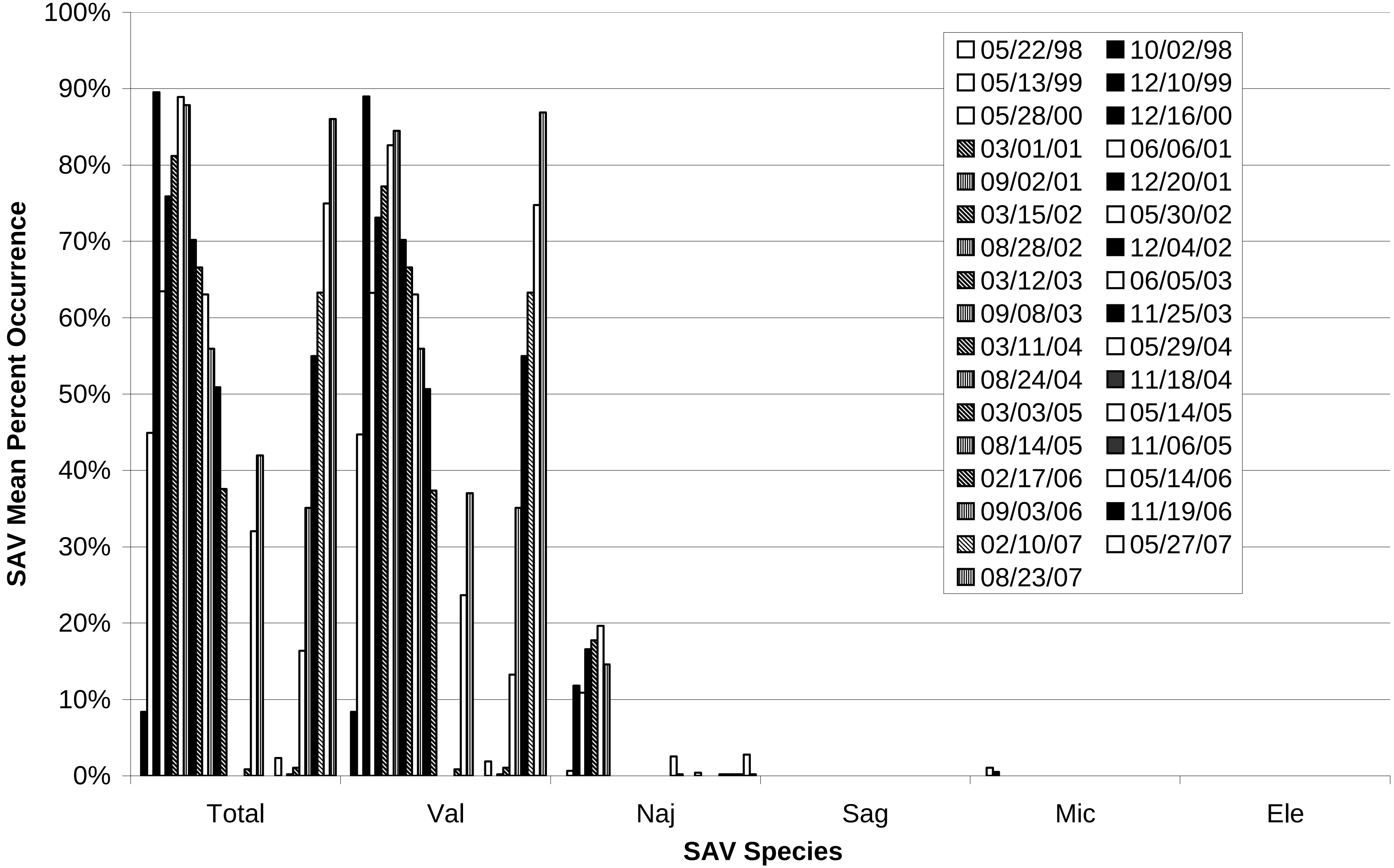


Figure 15b: Crescent Lake
SAV Percent Occurrence
1998 - 2007

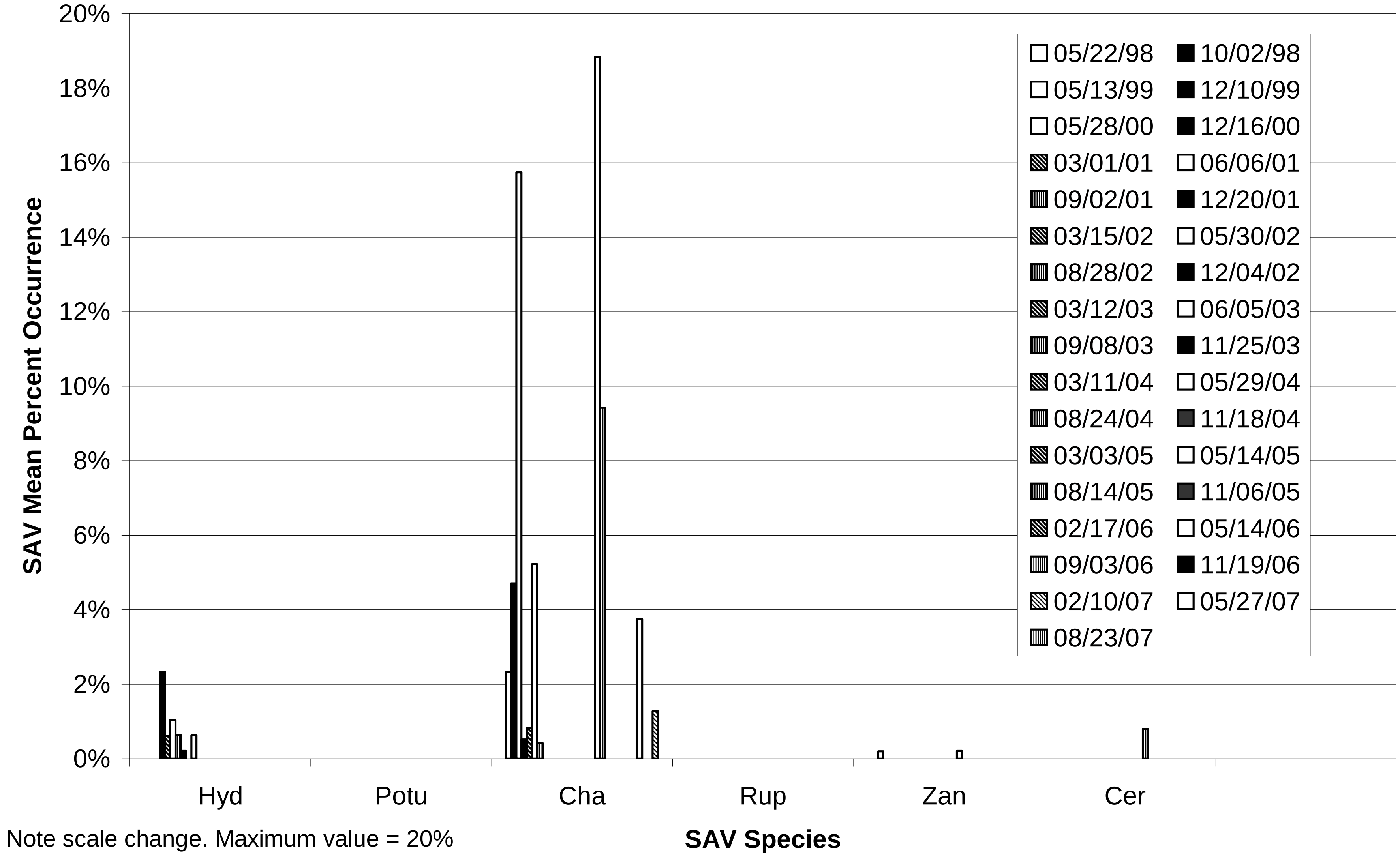


Figure 16: Water Depth Distribution of *Najas guadalupensis, Ruppia maritima, and Vallisneria americana*: Bolles School (taken from Sagan 2004a)

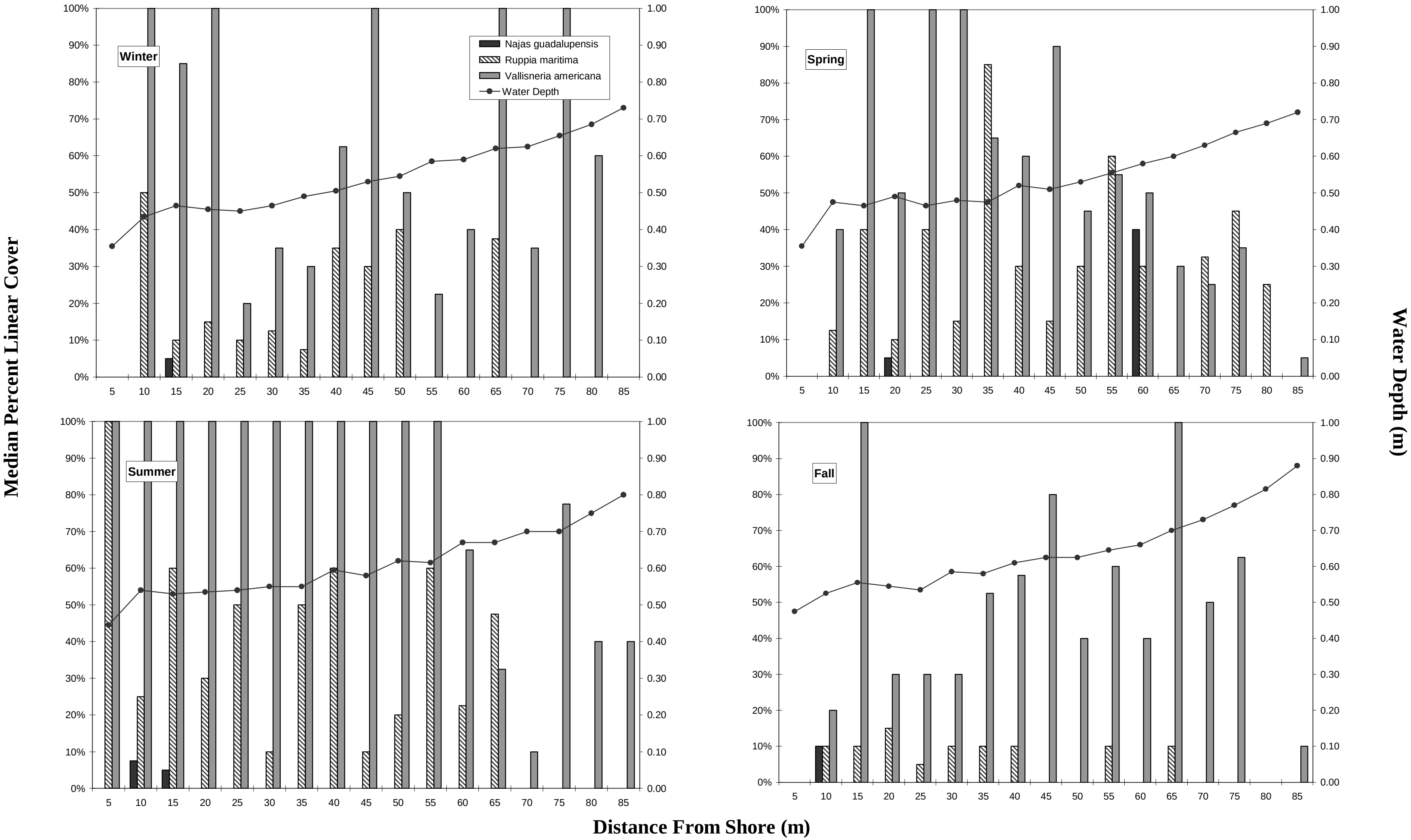


Figure 17: Water Depth Distribution of *Najas guadalupensis, Ruppia maritima, and Vallisneria americana*: Buckman (taken from Sagan 2004a)

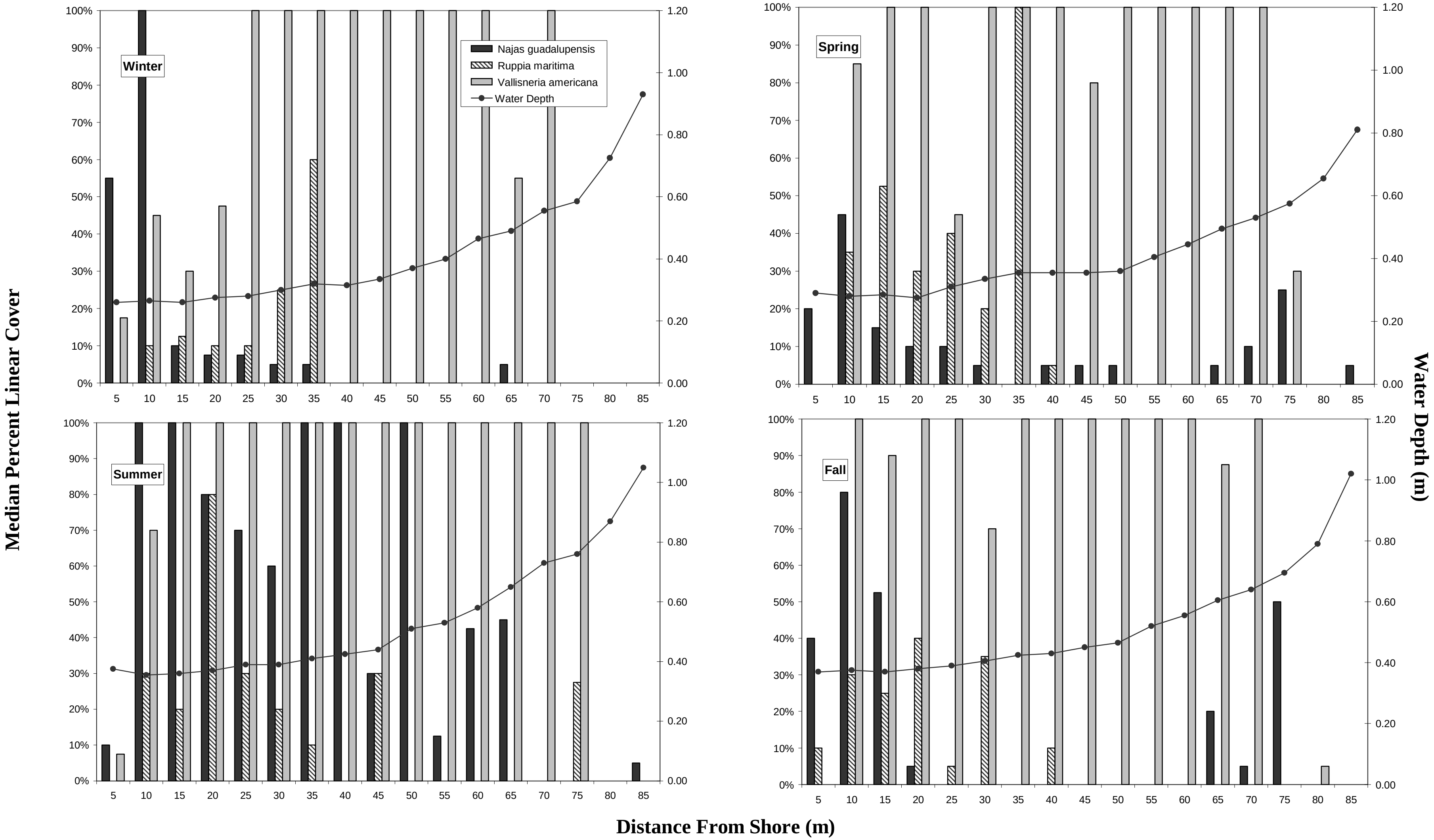


Figure 18: Water Depth Distribution of *Najas guadalupensis, Ruppia maritima, and Vallisneria americana*: Moccasin Slough
(taken from Sagan 2004a)

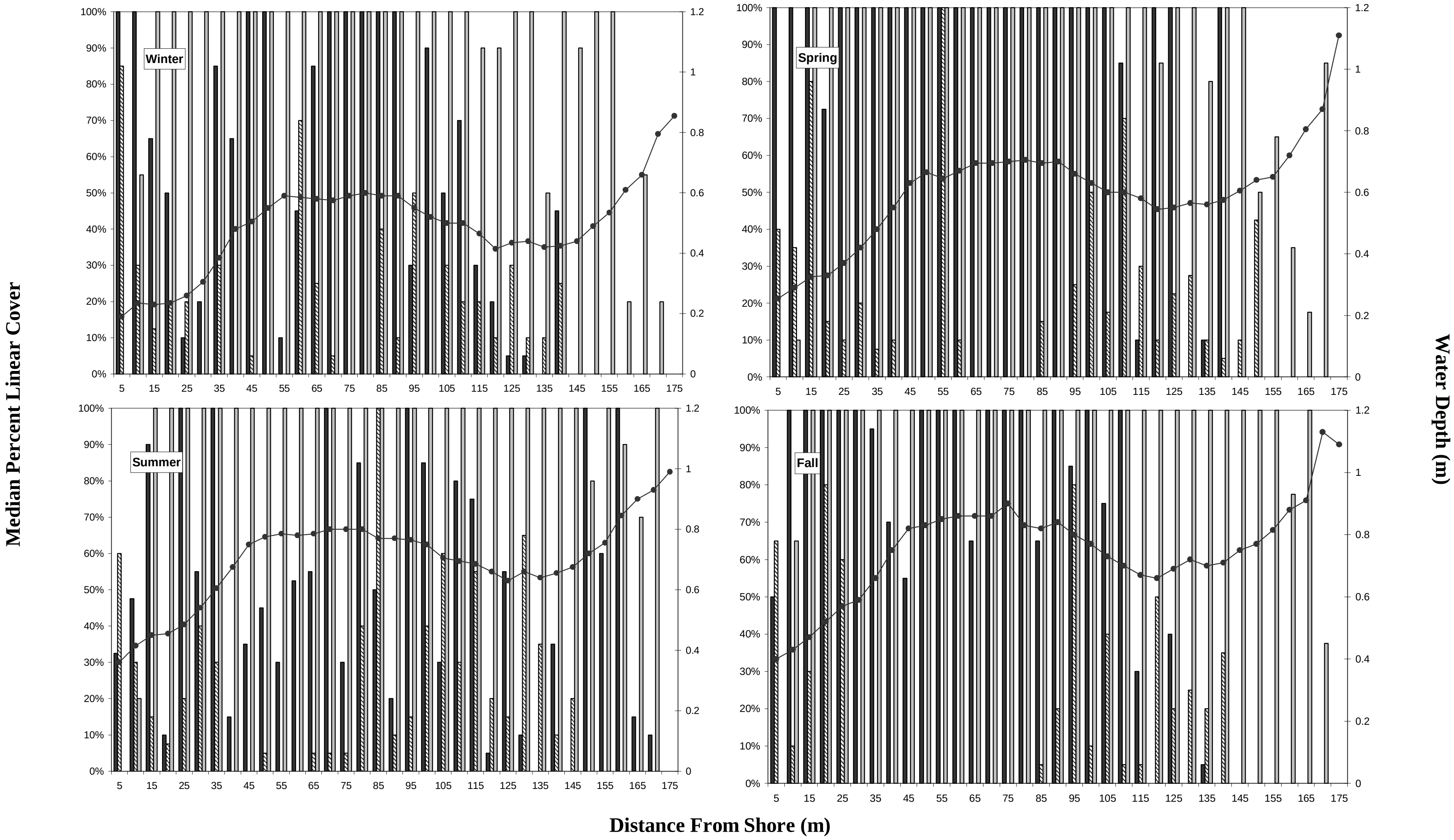


Figure 19: Water Depth Distribution of *Najas guadalupensis, Ruppia maritima, and Vallisneria americana*: Doctors Lake (taken from Sagan 2004a)

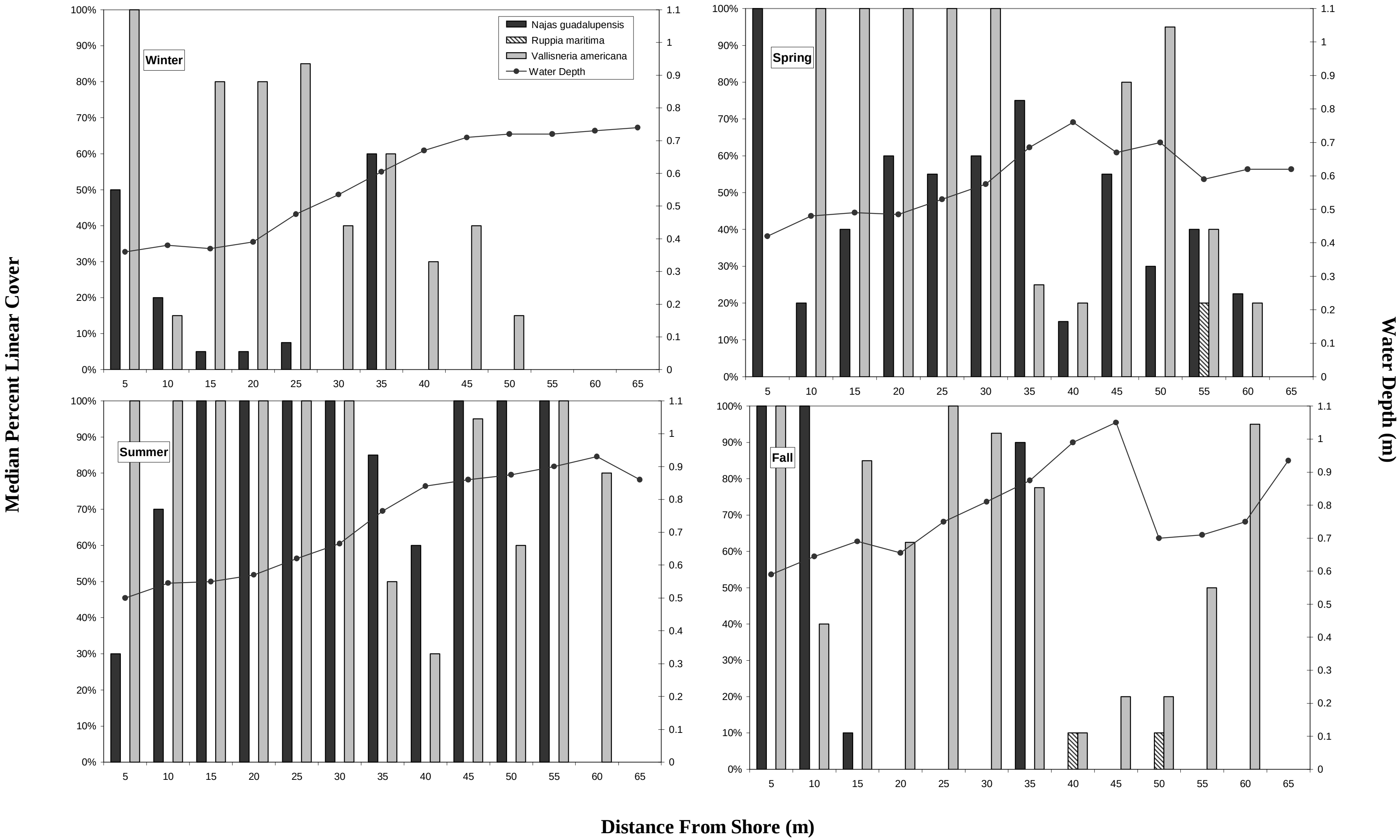


Figure 20: Water Depth Distribution of *Najas guadalupensis*, *Ruppia maritima, and Vallisneria americana*: Scratch Ankle
(taken from Sagan 2004a)

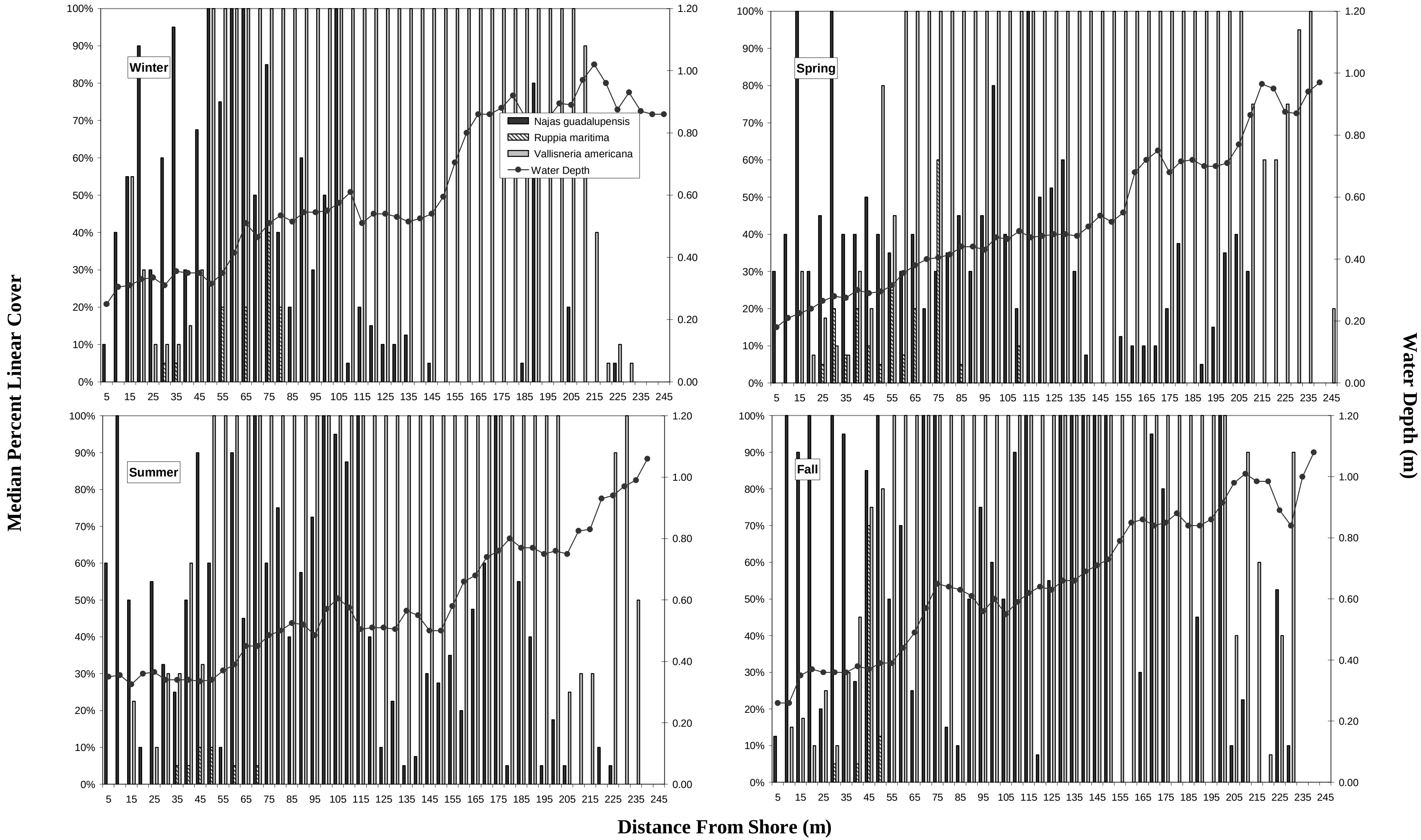


Figure 21: Water Depth Distribution of *Najas guadalupensis, Ruppia maritima, and Vallisneria americana*: Rice Creek (taken from Sagan 2004a)

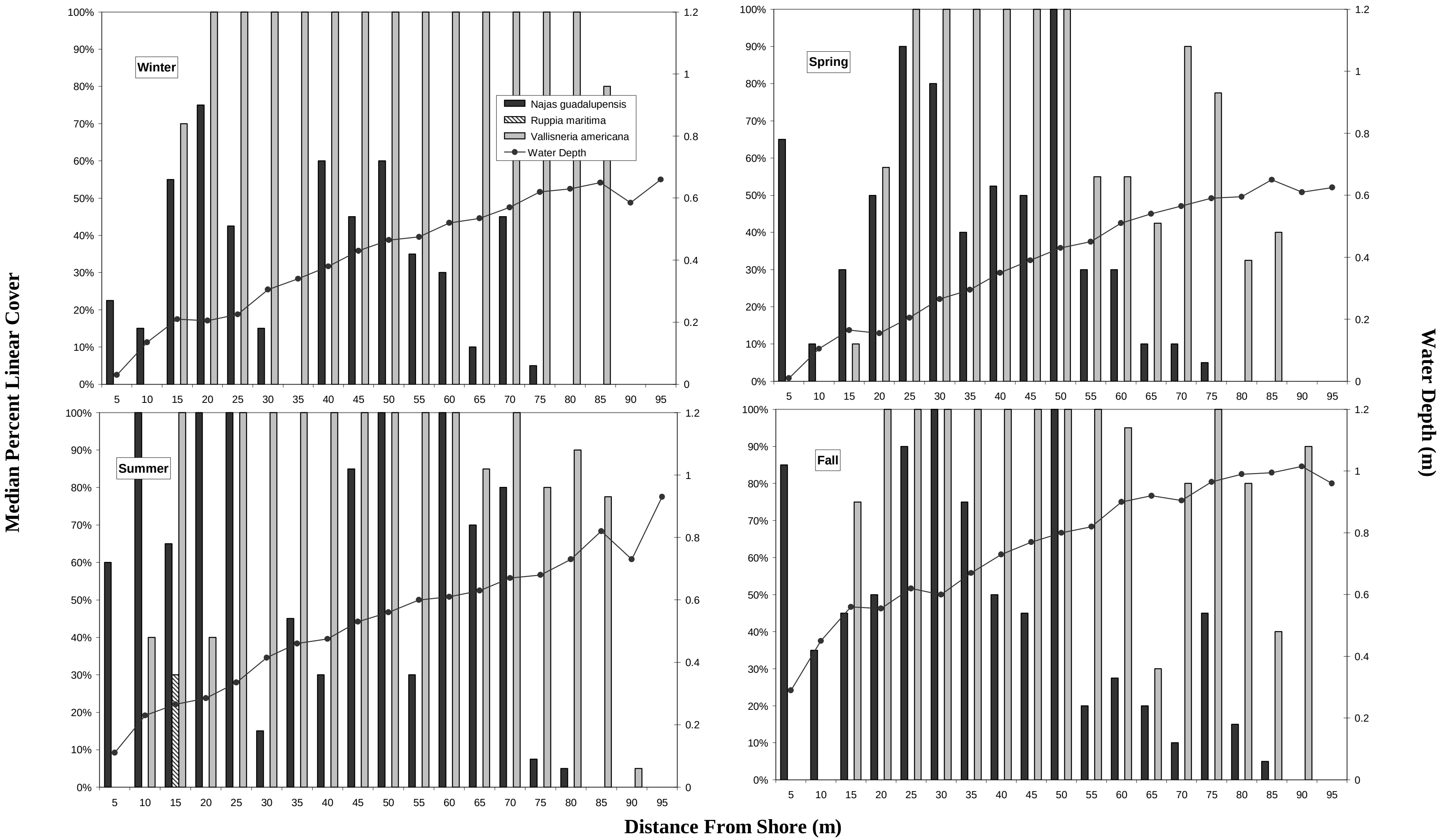


Figure 22: Water Depth Distribution of *Najas guadalupensis, Ruppia maritima, and Vallisneria americana*: Crescent Lake
(taken from Sagan 2004a)

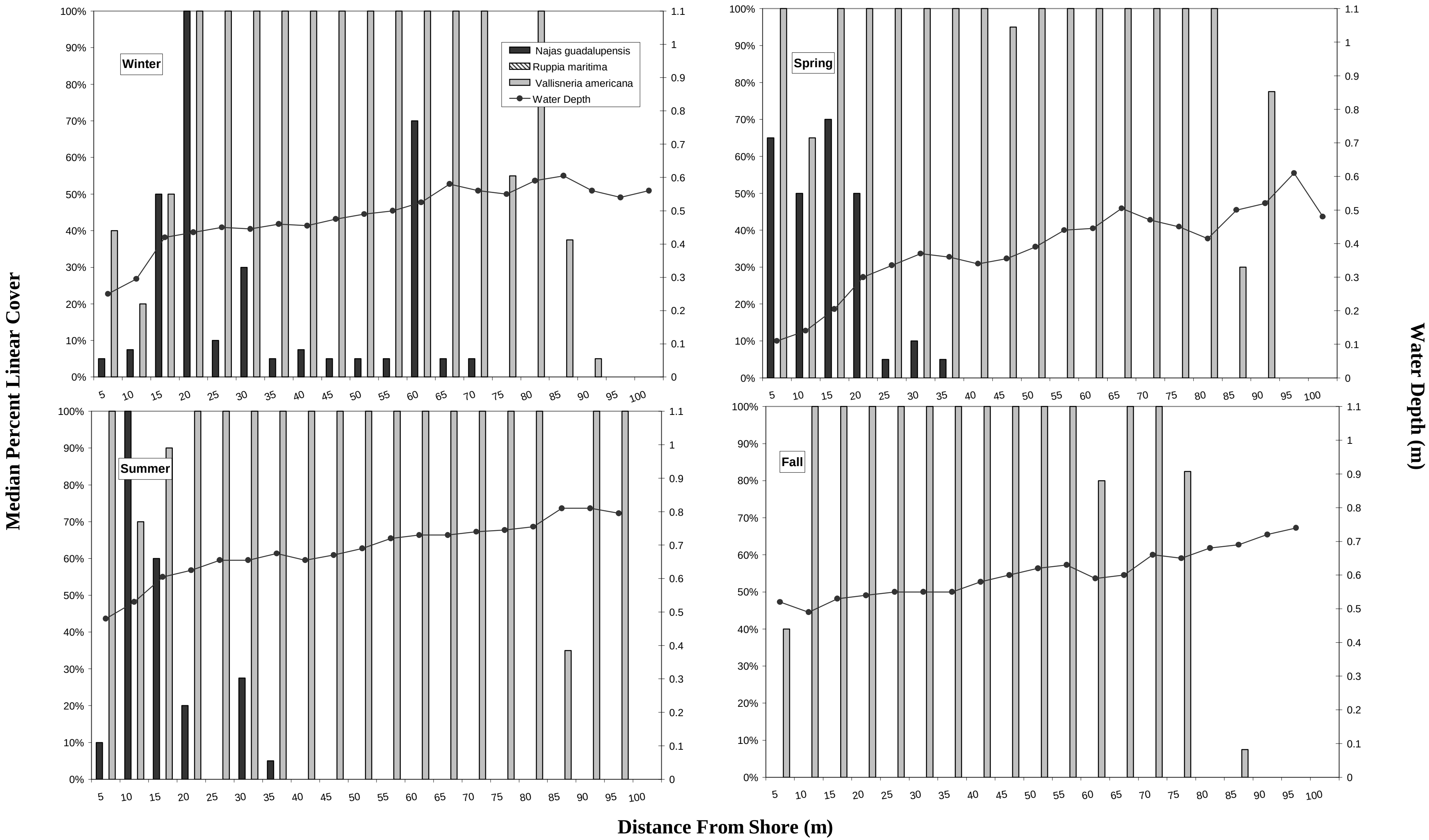
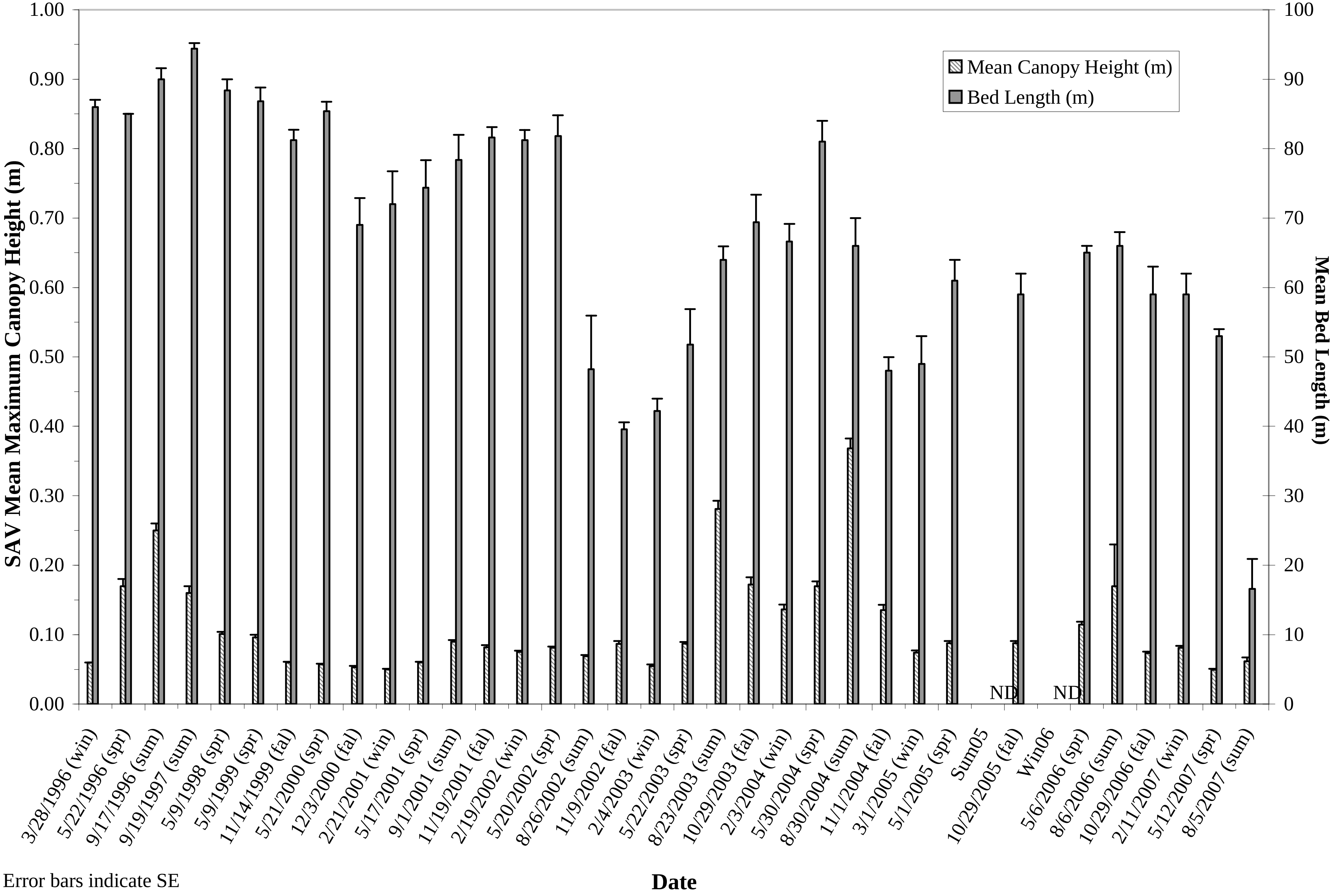


Figure 23: SAV Mean Maximum Canopy Height & Bed Length
Bolles School 1996 - 2007



Error bars indicate SE

Figure 24: SAV Mean Maximum Canopy Height & Bed Length
Buckman 1996 - 2007

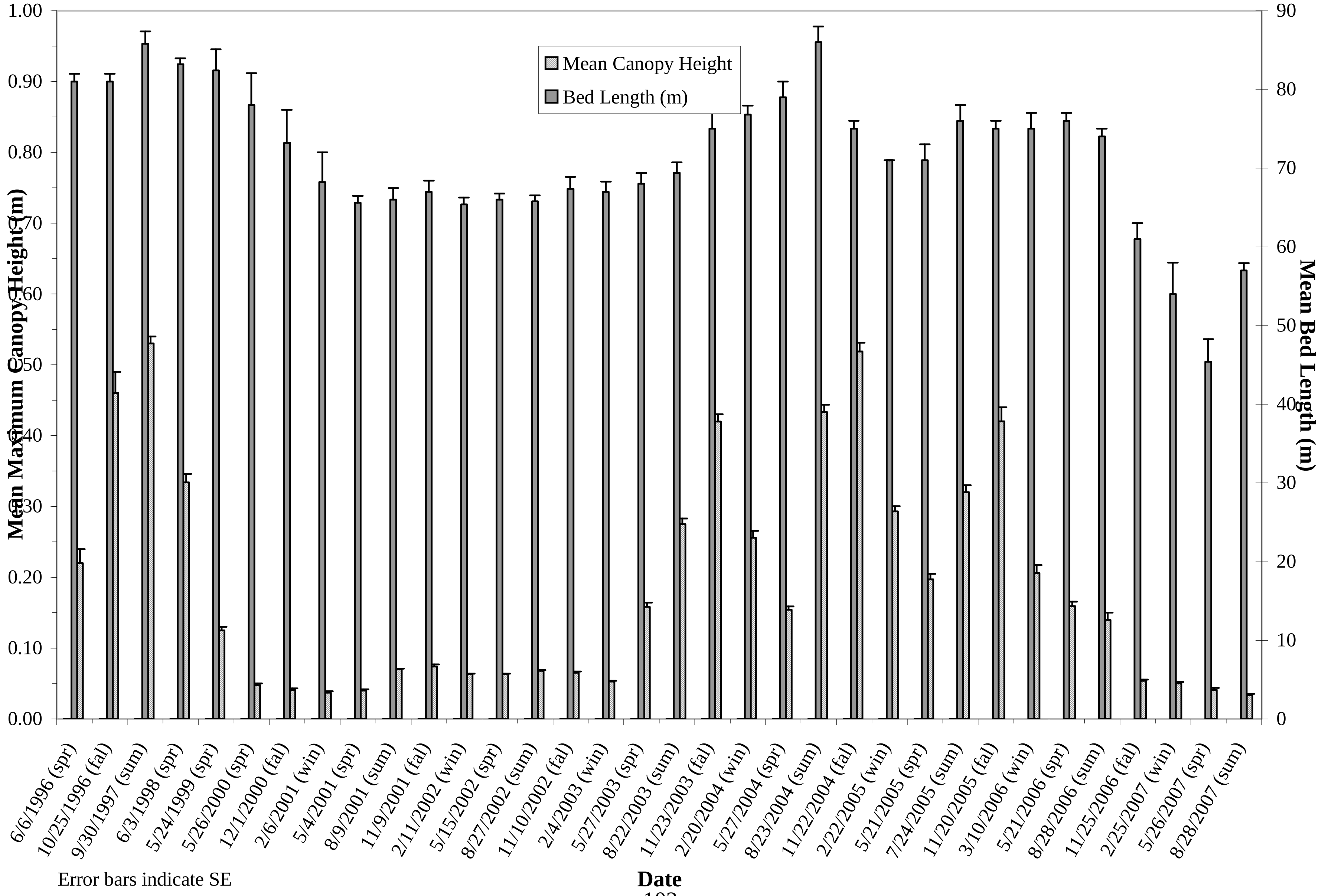


Figure 25: Monthly SAV Mean Maximum Canopy Height
Buckman 2000 - 2007

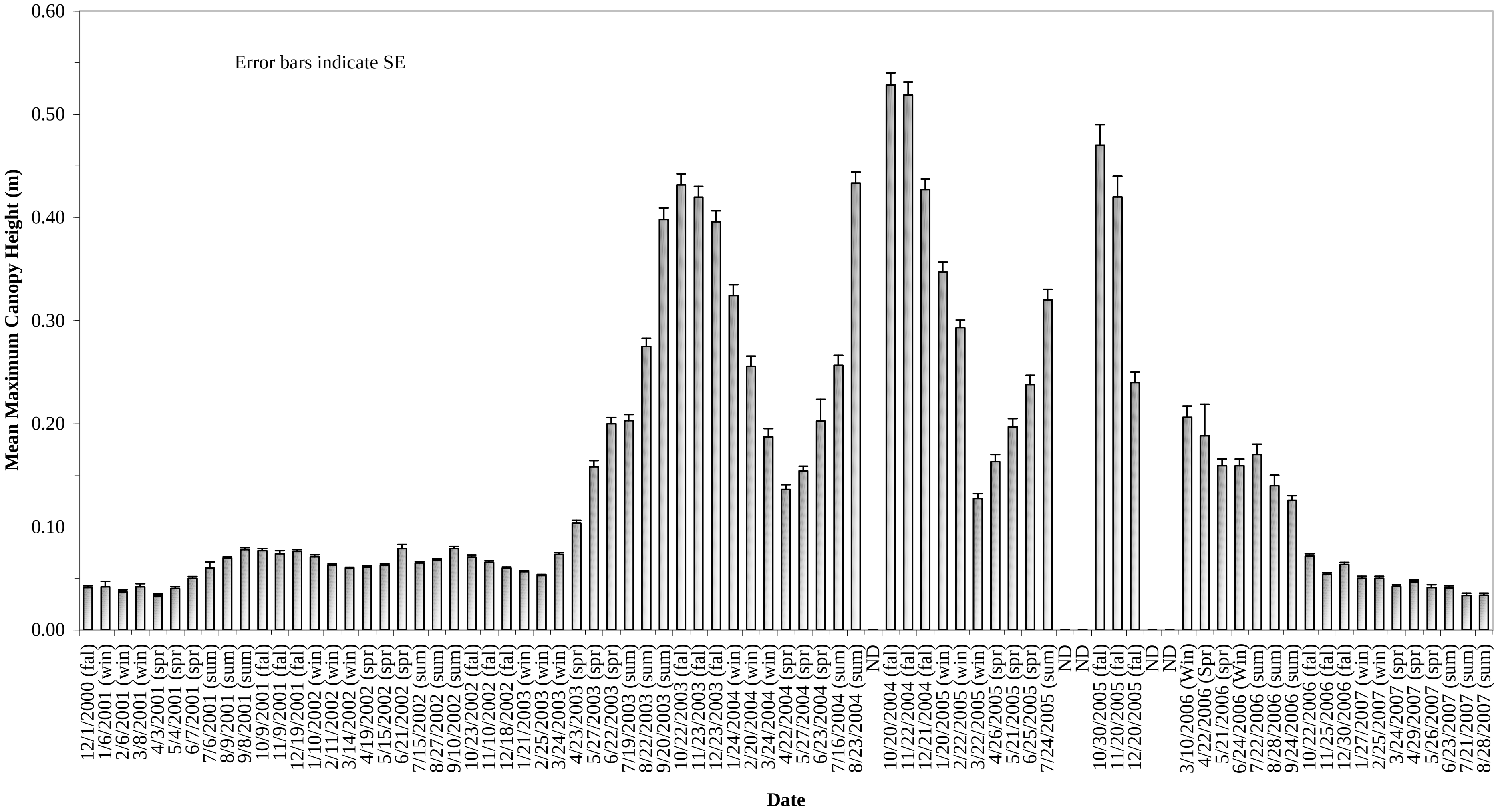
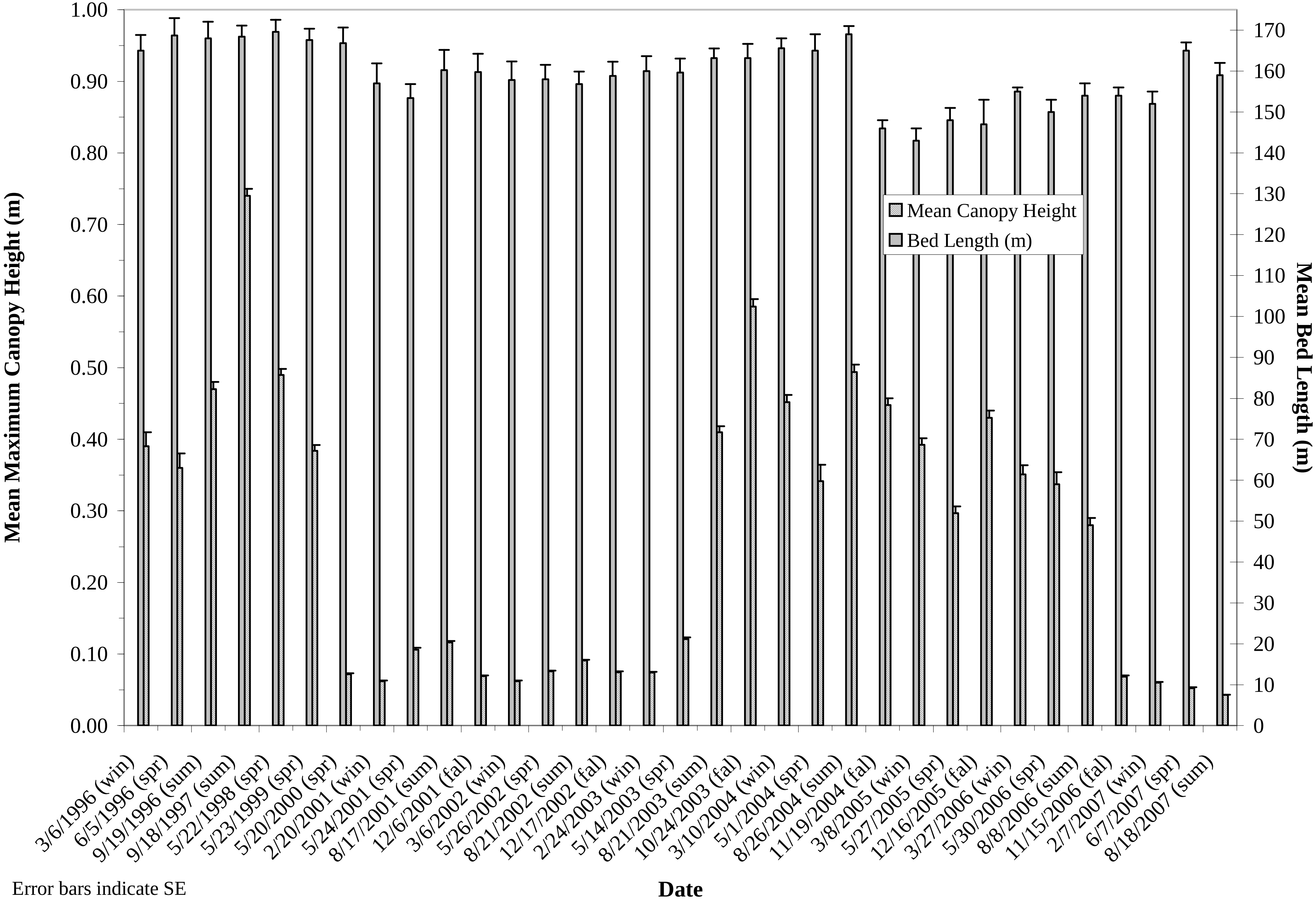
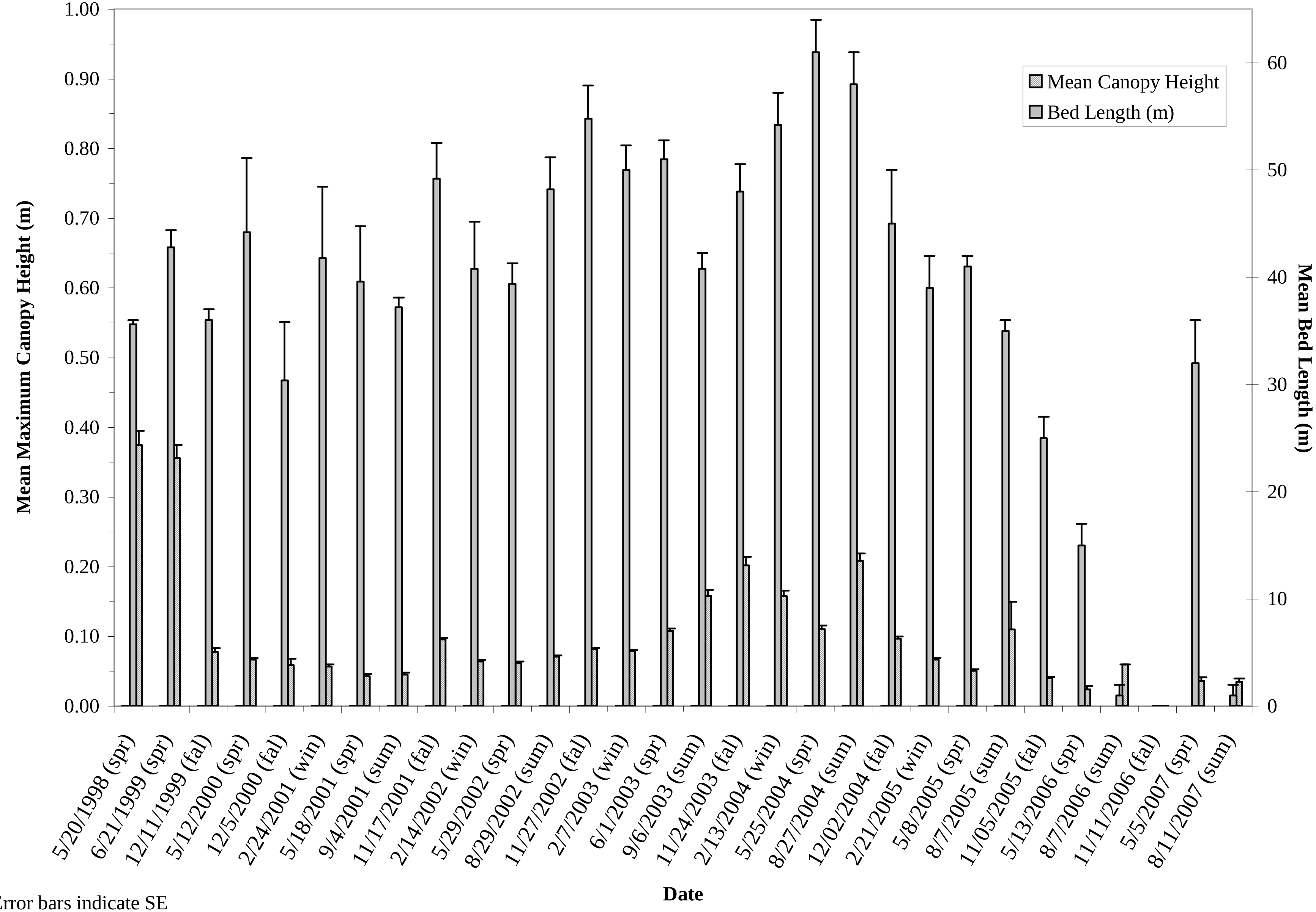


Figure 26: SAV Mean Maximum Canopy Height & Bed Length
Moccasin Slough 1996 - 2007



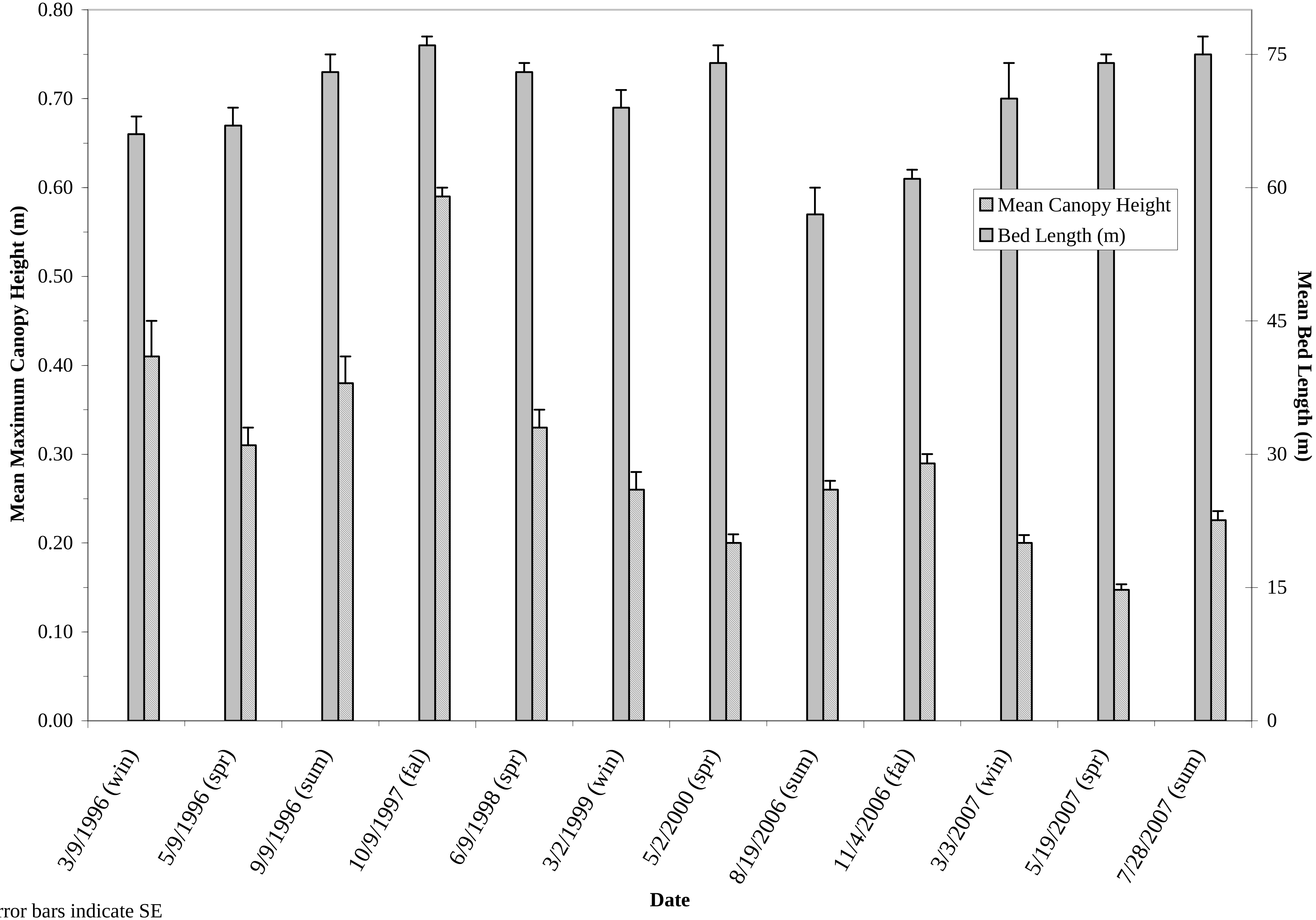
Error bars indicate SE

Figure 27: SAV Mean Maximum Canopy Height & Bed Length
Doctors Lake 1998 - 2007



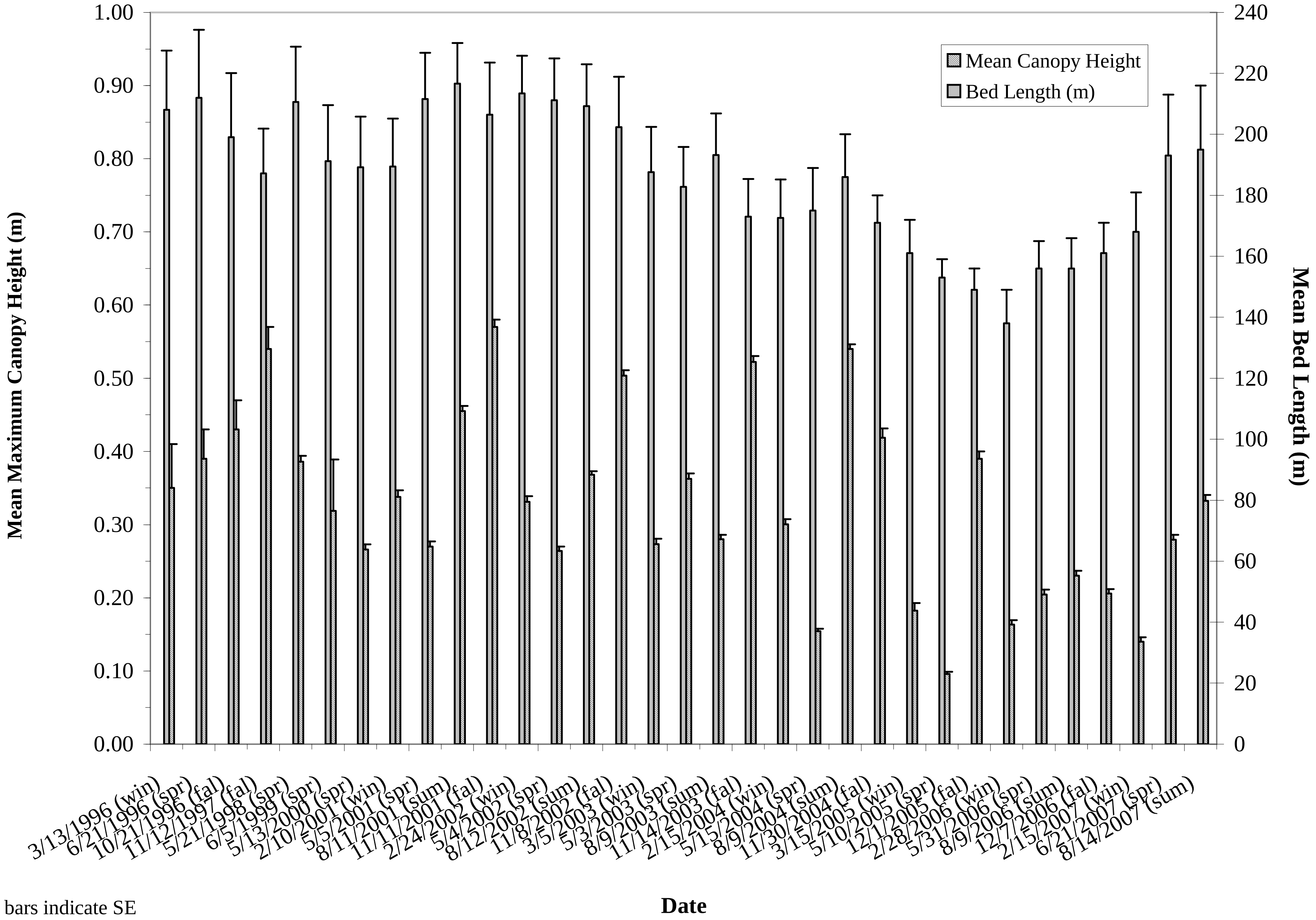
Error bars indicate SE

Figure 28: SAV Mean Maximum Canopy Height & Bed Length
Orangedale 1996 - 2007



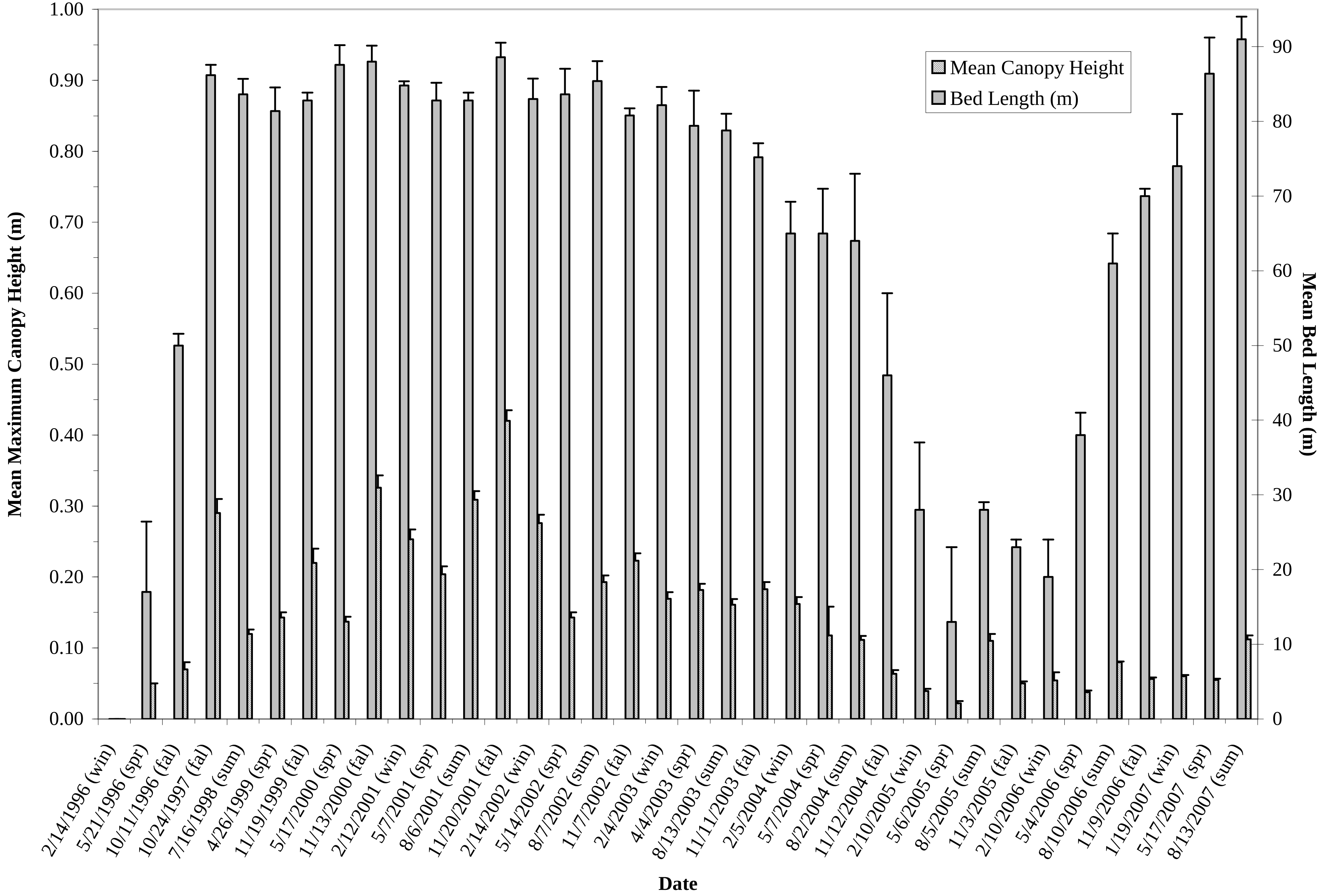
Error bars indicate SE

Figure 29: SAV Mean Maximum Canopy Height & Bed Length
Scratch Ankle 1996 - 2007



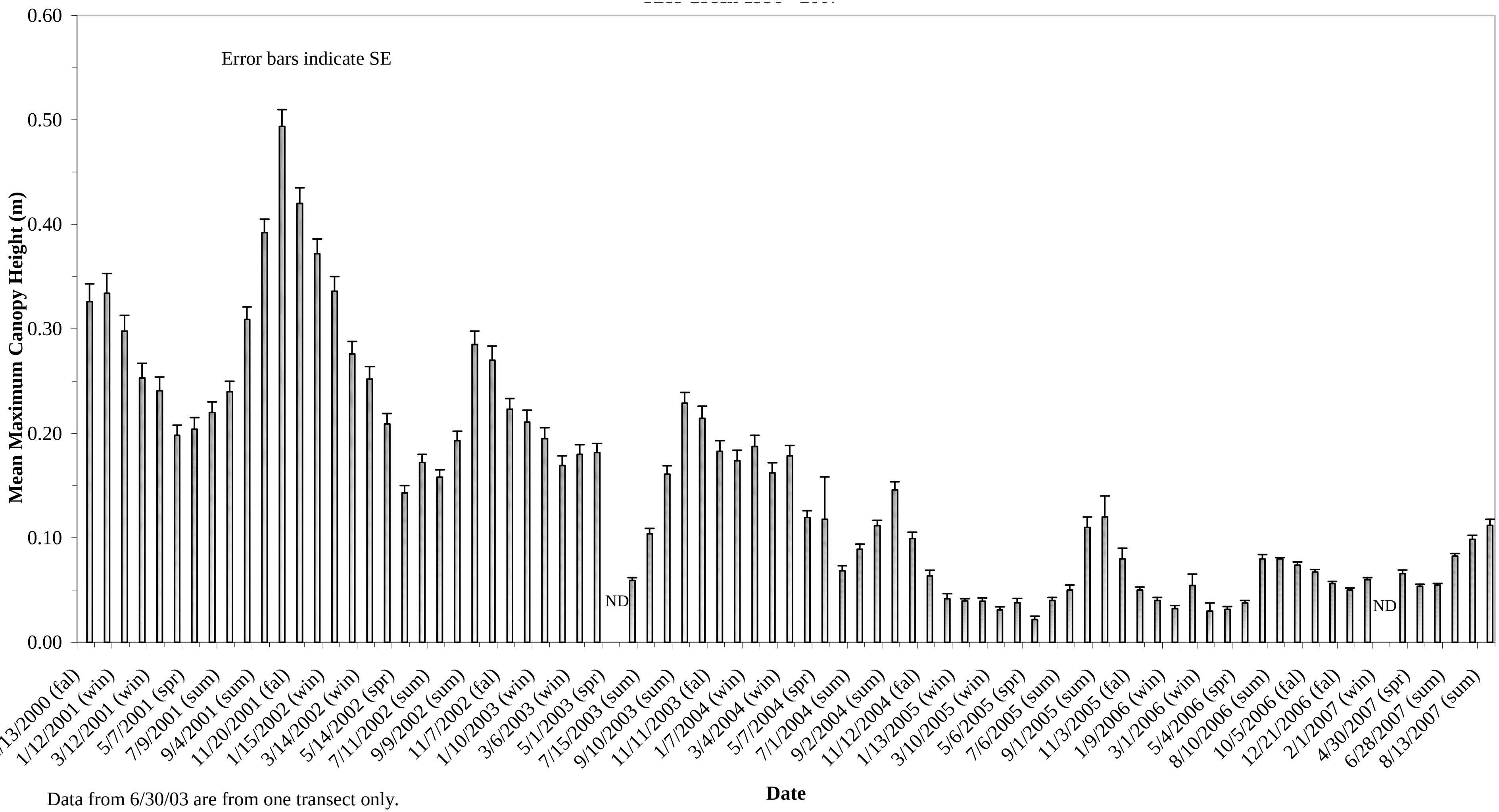
Error bars indicate SE

Figure 30: SAV Mean Maximum Canopy Height & Bed Length
Rice Creek 1996 - 2007



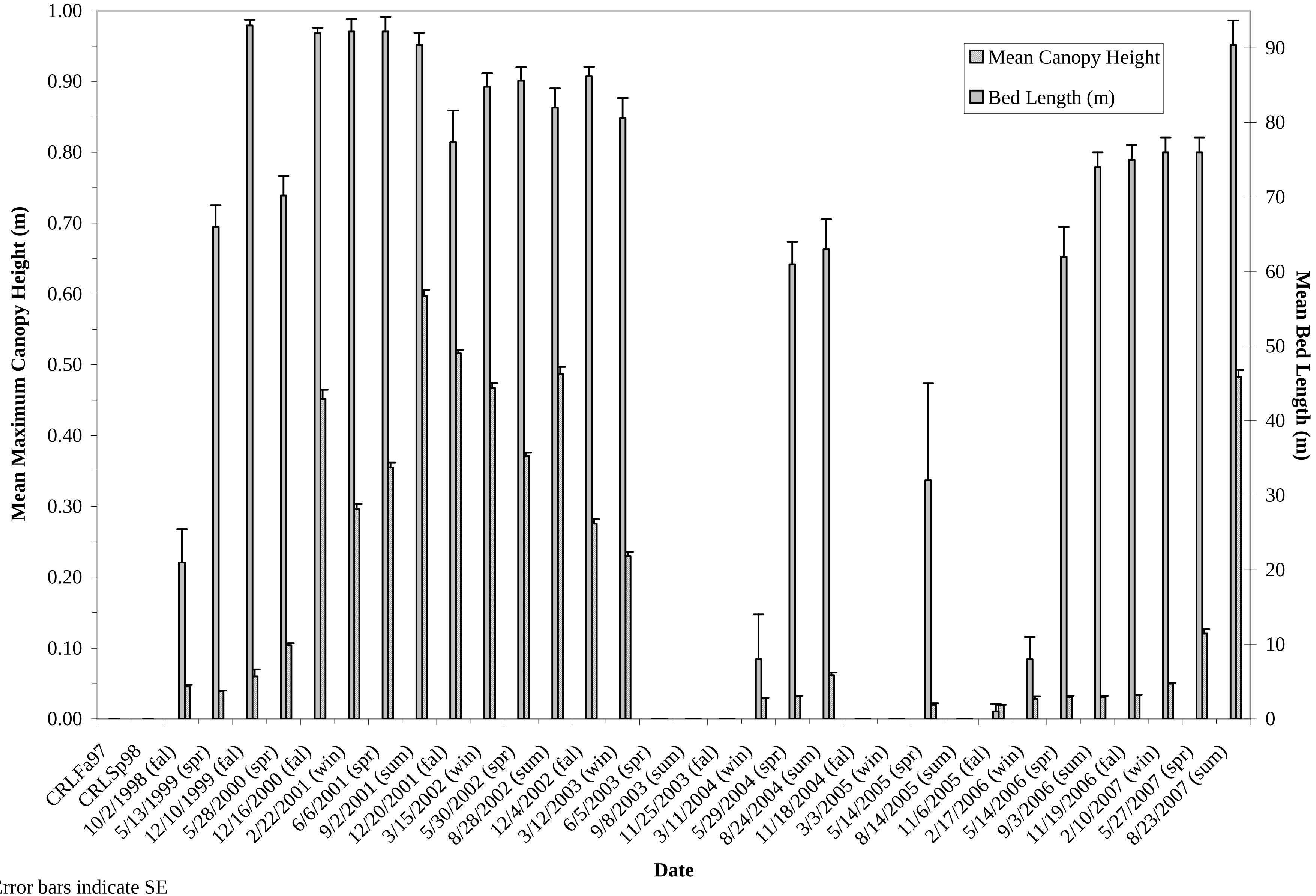
Error bars indicate SE

Figure 31: Monthly SAV Mean Maximum Canopy
Rice Creek 2000 - 2007



Data from 6/30/03 are from one transect only.

Figure 32: SAV Mean Maximum Canopy Height & Bed Length
Crescent Lake 1997 - 2007



Error bars indicate SE

Figure 33: Bi-monthly salinity values, between October 1997 – July 2007, for BOL, BUC, MOC, DRL, SCA, RIC, and CRL

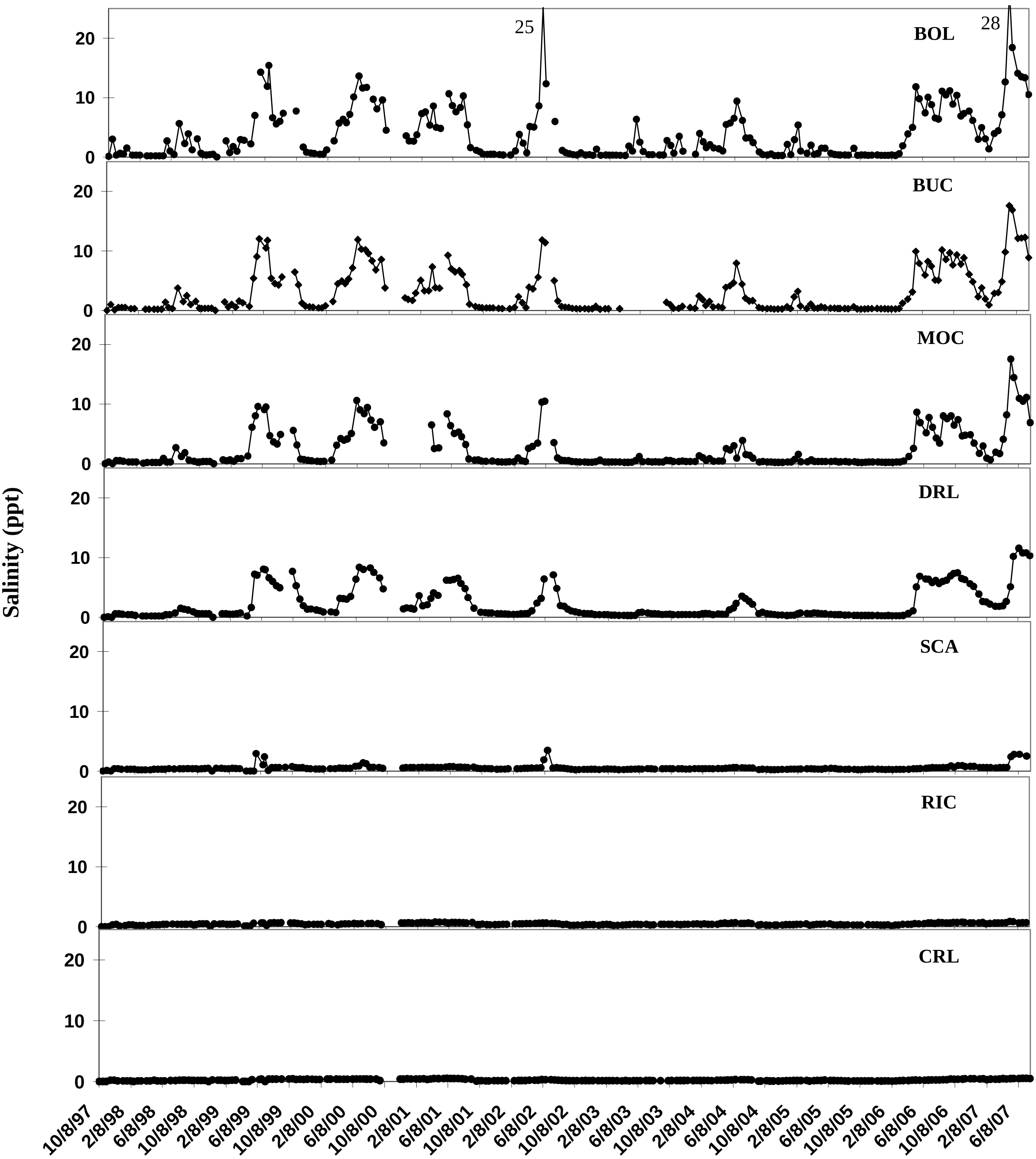


Figure 34: Bi-monthly chlorophyll-a values, between October 1997 – July 2007, for BOL, BUC, MOC, DRL, SCA, RIC, and CRL

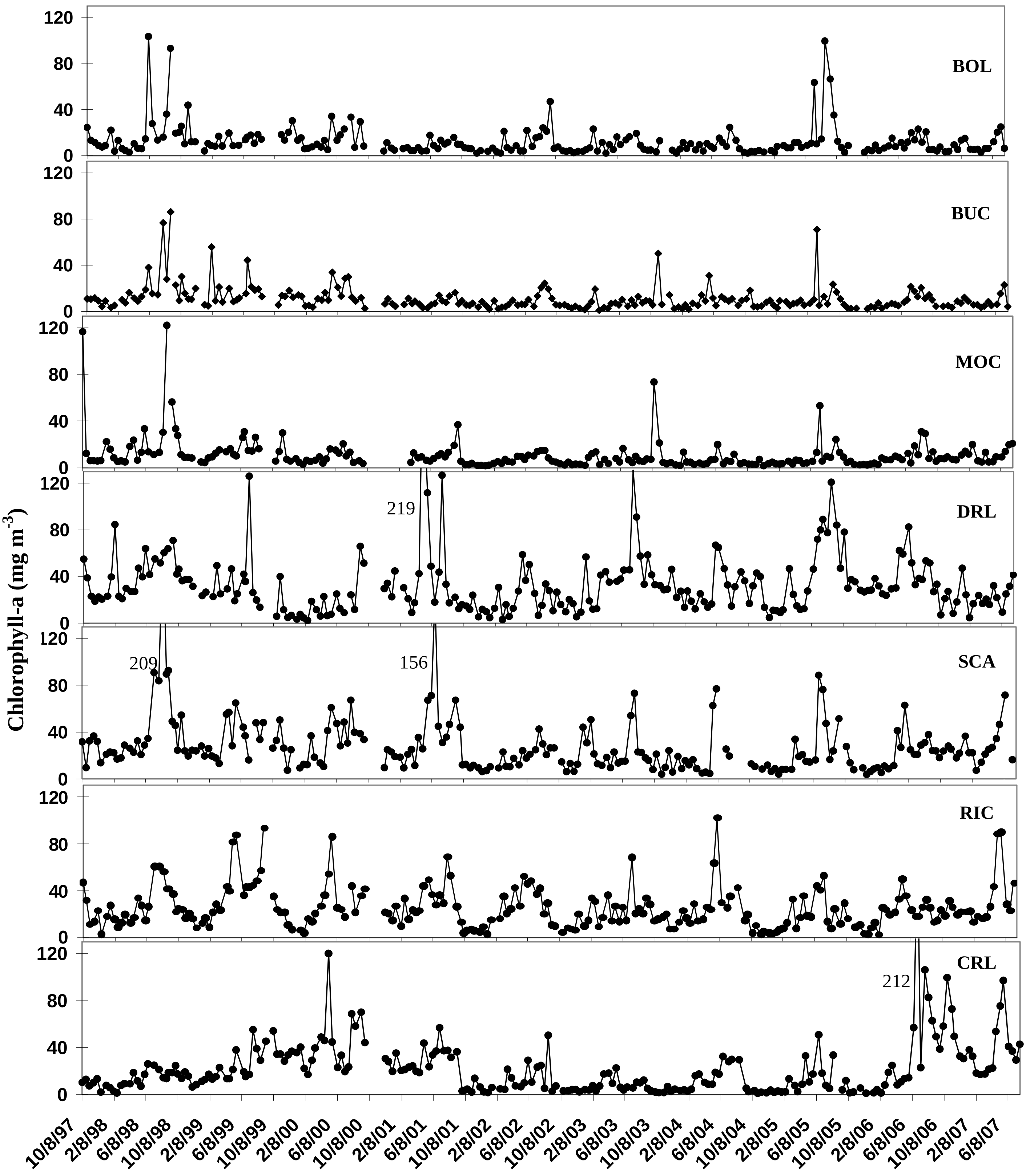


Figure 35: Bi-monthly color values, between October 1997 – July 2007, for BOL, BUC, MOC, DRL, SCA, RIC, and CRL (note scale change for CRL; see text for maximum values)

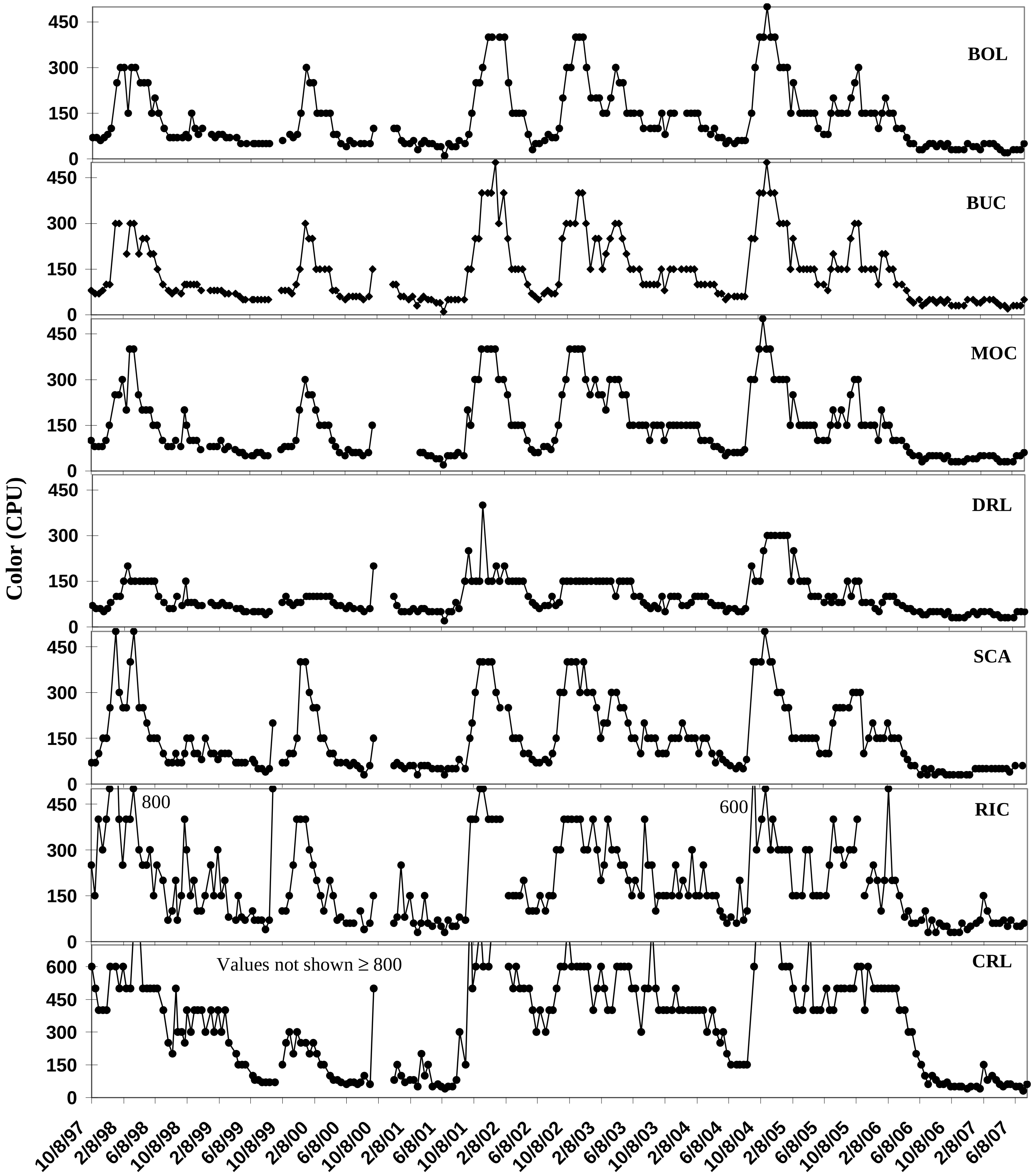


Figure 36: Bi-monthly TSS values, between October 1997 – July 2007, for BOL, BUC, MOC, DRL, SCA, RIC, and CRL

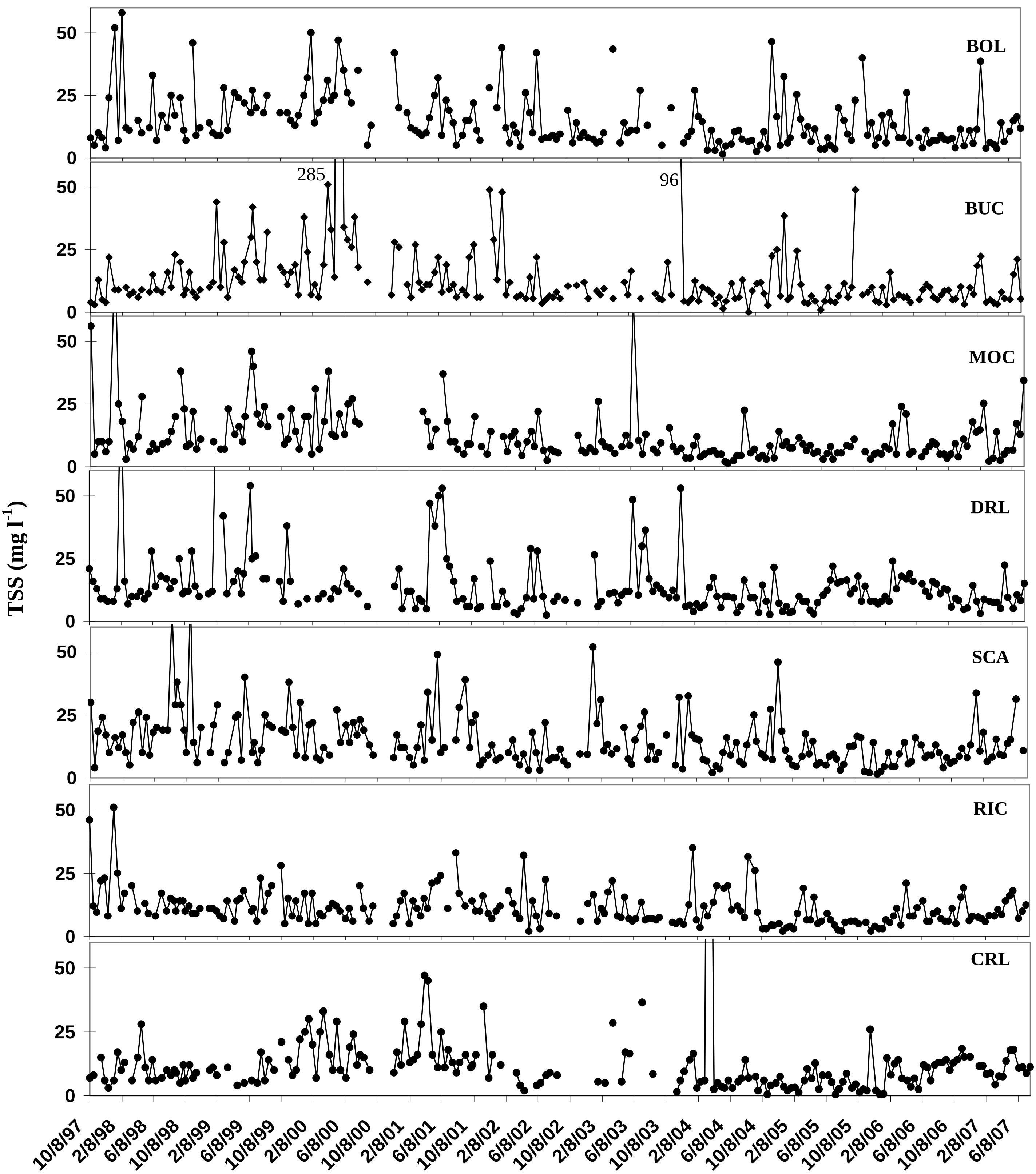


Figure 37: Bi-monthly turbidity values, between October 1997 – July 2007, for BOL, BUC, MOC, DRL, SCA, RIC, and CRL

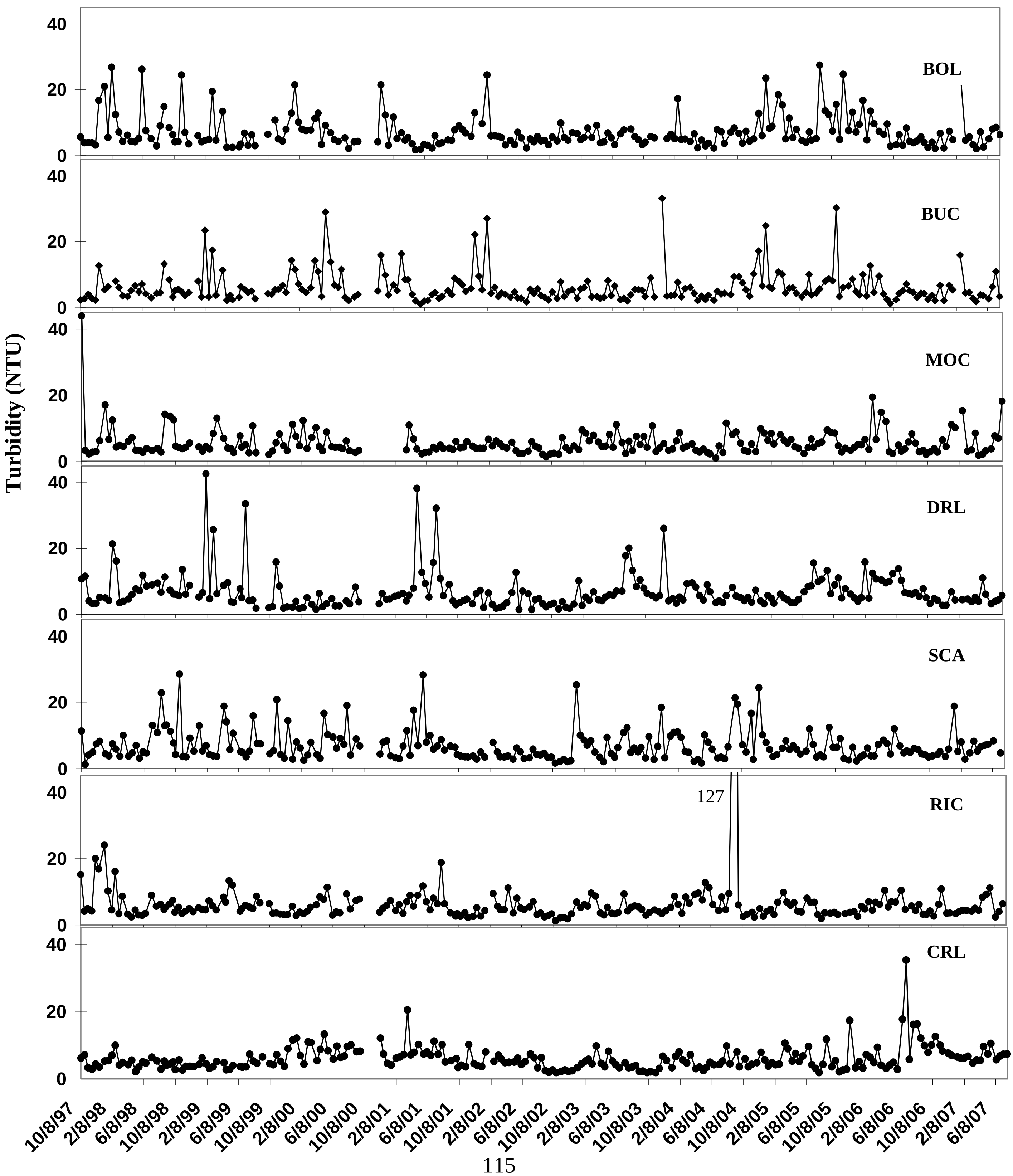


Figure 38: Bi-monthly Kd values, between October 1997 – July 2007, for BOL, BUC, MOC, DRL, SCA, RIC, and CRL

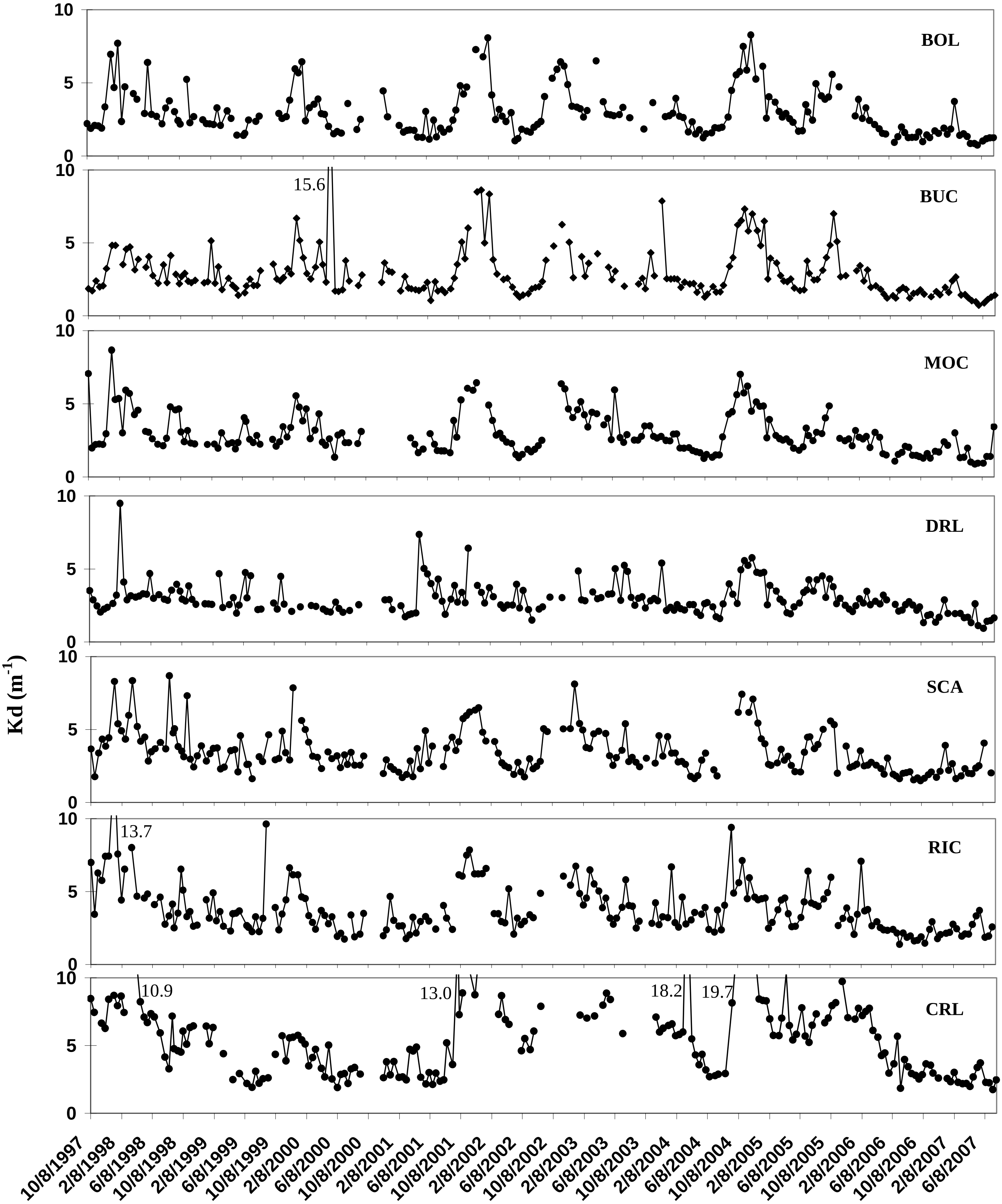


Figure 39: Mean seasonal SAV cover as compared to mean seasonal (A) Chl-a, (B) color, and (C) Kd. Water quality means represent an average of values taken the 3 months preceding SAV surveys. Data from PMN sites: BOL, BUC, MOC, SCA, RIC (Taken from Sagan 2006a)

A

B

C

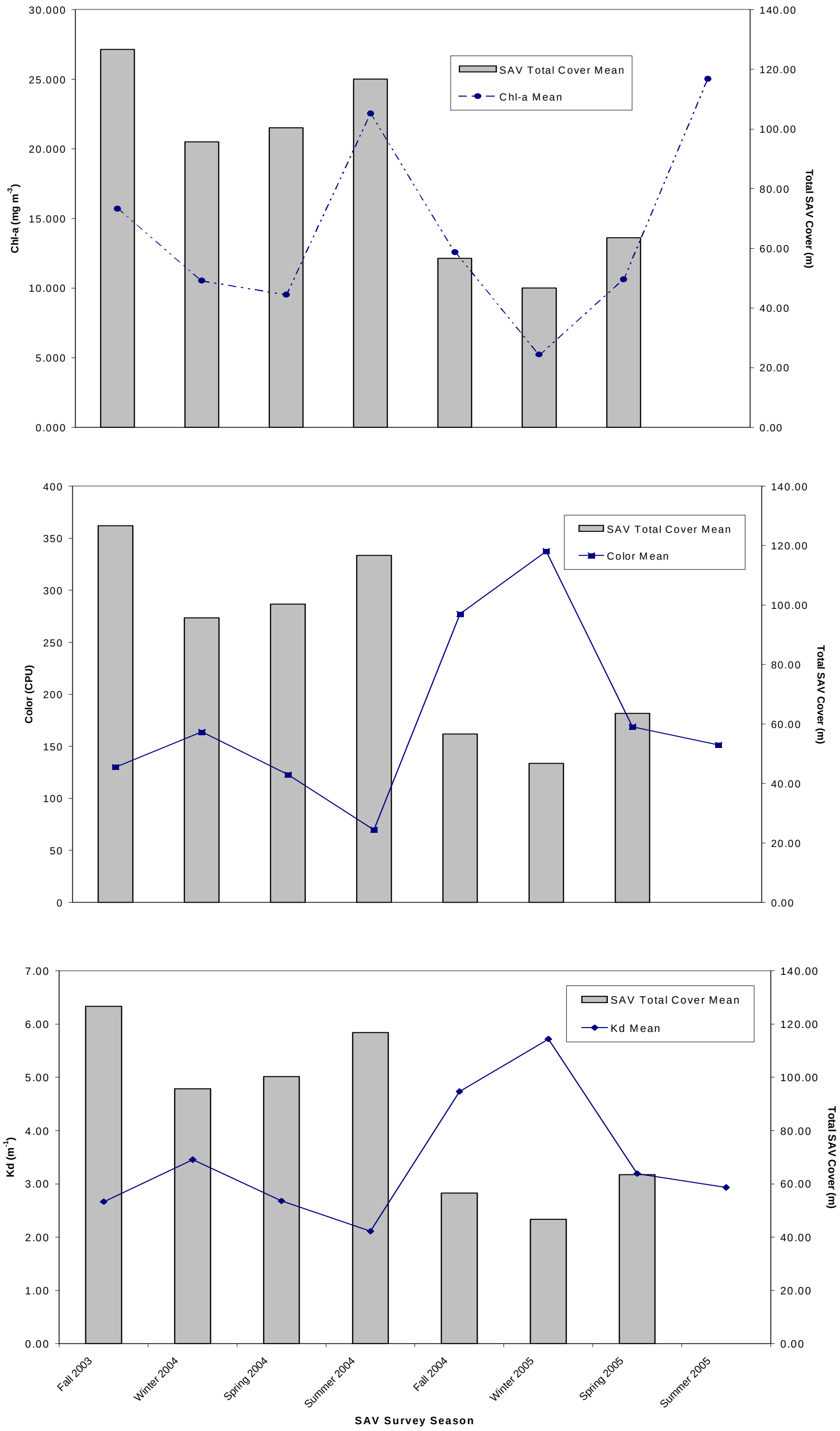


Figure 40: Mean seasonal SAV cover as compared to mean seasonal (D) TSS and (E) Turbidity. Water quality means represent an average of values taken the 3 months preceding SAV surveys. Data from PMN sites: BOL, BUC, MOC, SCA, RIC (Taken from Sagan 2006a)

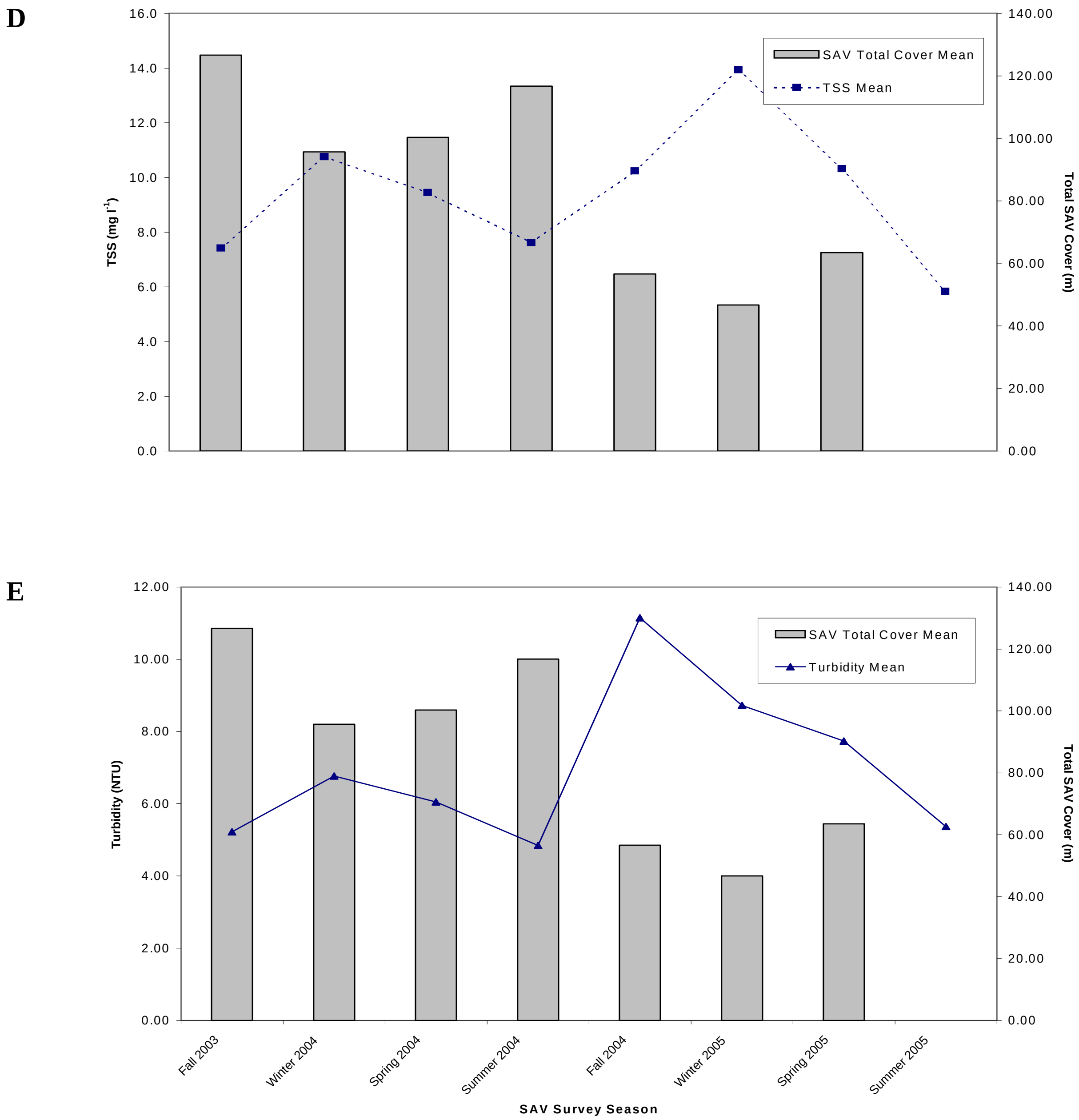


Figure 41: The See Saw Effect: Monthly (n = 5) comparison of total SAV cover for years 2000 - 2007 between upstream (RIC) and downstream sites (BUC)

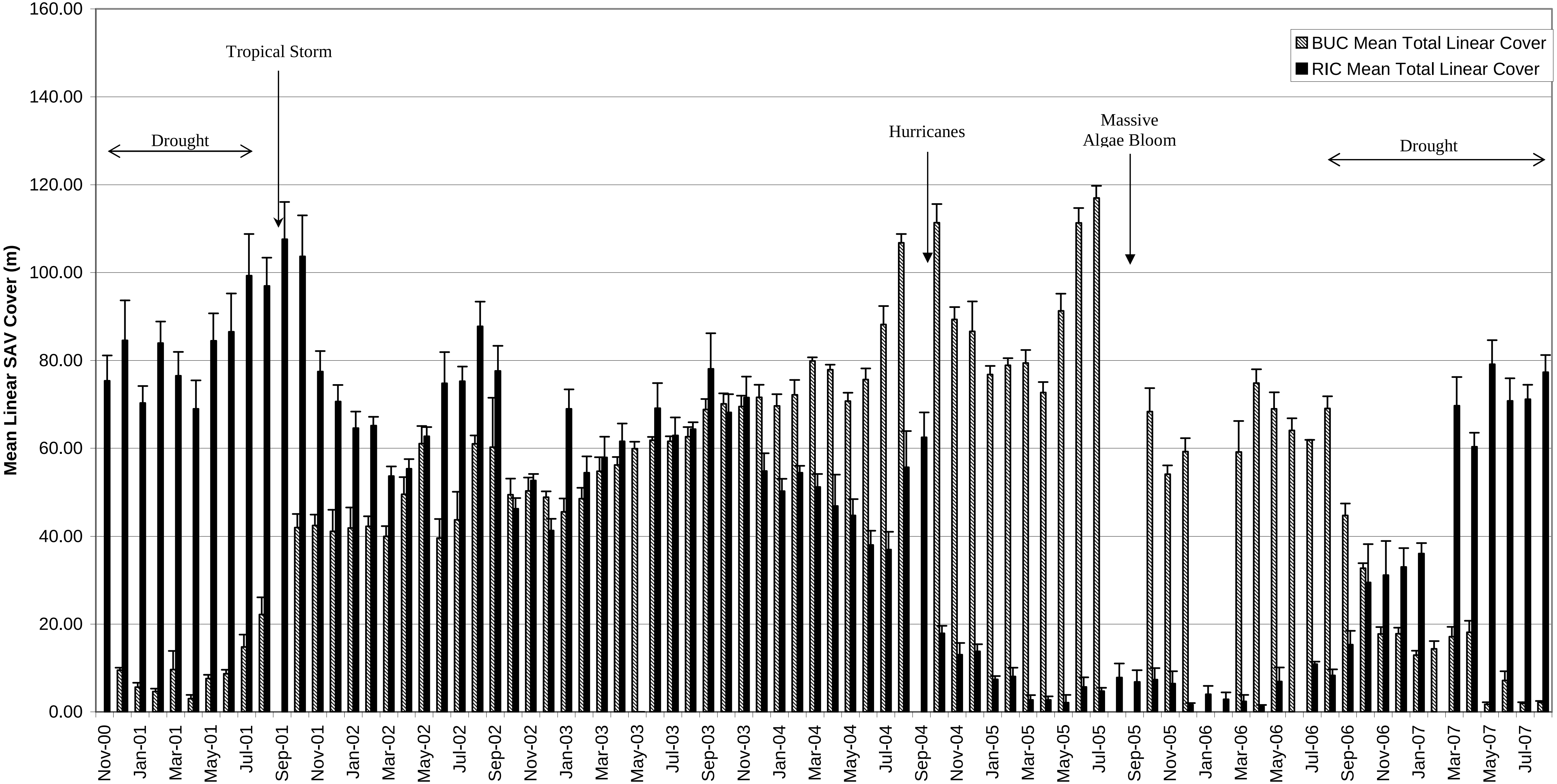


Figure 42: Macroalgal bloom in LSJR – Spring of 1997 (Courtesy SJRWMD)

Figure 43: Macroalgal bloom at Experimental Docks, Eagle Point, LSJR – May 2000
(Courtesy Alicia Steinmetz, BCI Engineers and Scientists, Inc.)

Figure 44: Detached Algal Mats at Buckman Site (August 19, 2003): Floating (above) and Entangled with SAV (below). Embedded in nearshore algal mats is the floating plant, *Salvinia* sp.

Table 1: Permanent Monitoring (PMN) Station Descriptions as of 2007

Site	Access	Latitudinal Coordinate	Longitudinal Coordinate	Maximum SAV Bed Length from Shore	Species Diversity	Sampling Frequency	Direction Survey Tape Pulled between Benchmarks
Bolles School	Land Private	30°14′26″	81°37′53″	93 m	+	Quarterly	Upstream
Buckman	Land Private	30°10′25″	81°38′51″	92 m	++	Monthly	Downstream
Moccasin Slough	Boat	30°07′46″	81°41′31″	177 m	++	Quarterly	Upstream
Doctors Lake	Boat	30°06′38″	81°44′54″	75 m	++	Quarterly	North
Orangedale	Land Public	30°00′15″	81°36′49″	76 m	+++	Quarterly	Downstream
Scratch Ankle	Land Private	29°50′18″	81°36′08″	250 m	+++	Quarterly	Upstream
Rice Creek	Boat	29°42′36″	81°38′23″	98 m	+++	Monthly	Downstream
Crescent Lake	Boat	29°30′12″	81°30′15″	99 m	+	Quarterly	East

Table 2: SAV Data Collection Summary Fall 1995 - Summer 2001

Sites in Latitudinal Order	Fa95	Wi96	Sp96	Su96	Fa96	Wi97	Sp97	Su97	Fa97	Wi98	Sp98	Su98	Fa98	Wi99	Sp99	Su99	Fa99	Wi00	Sp00	Su00	Fa00	Wi01	Sp01	Su01
Pt. La Vista											C				C				C					
Saddler Pt.											C								C					
Bolles	B L	B C L		B C L	B C L				C		C				C		C		C		C L	C L	C L	C L
Mulberry Cove											C				C				C					
Buckman				B C L	B C L				C		C				C				C		mC L	mC L	mC L	mC L
Doctors Lake											C				C		C		C		C L	C L	C L	C L
Moccasin Slough	B L	B C L		B C L	B C L				C		C				C				C		C L	C L	C L	C L
Old Bull Bay	B L	B C L		B C L	B C L						C				C		C		C					
Fleming Island	B L	B C L		B C L	B C L				C		C				C				C					
Hallowes Cove																			C					
Orangedale	B L	B C L		B C L	B C L				C		C				C				C					
Bayard Pt.	B L	B C L		B C L	B C L						C				C				C					
Ferriera Pt.	B L	B C L		B C L	B C L						C				C				C					
Scratch Ankle	B L	B C L		B C L	B C L				C		C				C				C		C L	C L	C L	C L
Federal Pt.	B L	B C L		B C L	B C L						C				C				C					
Rice Creek	B L	B C L		B C L	B C L				C		C				C		C		C		mC L	mC L	mC L	mC L
Mullis Dock	B L	B C L		B C L	B C L				C		C				C				C					
FPL	B L	B C L		B C L	B C L				C		C				C									
Browns Landing																	C		C		C L	C L	C L	C L
Buffalo Bluff																								
Crescent Lake									C		C				C		C		C		C L	C L	C L	C L
Lake George																			C					

B	SAV data collected = biomass & root:shoot
C	SAV data collected = canopy height
L	SAV data collected = line intercept
m	SAV data collected monthly
	Denotes contiguous seasons in which biweekly WQ was collected at site
	Denotes seasons during which quarterly WQ was collected at site

Table 2b: SAV Data Collection Summary Fall 2001 - Summer 2007

Sites in Latitudinal Order	Fa01	Wi02	Sp02	Su02	Fa02	Wi03	Sp03	Su03	Fa03	Wi04	Sp04	Su04	Fa04	Wi05	Sp05	Su05	Fa05	Wi06	Sp06	Su06	Fa06	Wi07	Sp07	Su07
Pt. La Vista																								
Saddler Pt.																								
Bolles	C L	C L	C L	C L	C L	C L	C L	C L	C L	C L	C L	C L	C L	C L	C L	C L	C L	C L	C L	C L	C L	C L	C L	C L
Mulberry Cove																								
Buckman	mC L	mC L	mC L	mC L	mC L	mC L	mC L	mC L	mC L	mC L	mC L	mC L	mC L	mC L	mC L	C L	mC L	C L	mC L	mC L	mC L	mC L	mC L	mC L
Doctors Lake	C L	C L	C L	C L	C L	C L	C L	C L	C L	C L	C L	C L	C L	C L	C L	C L	C L	C L	C L	C L	C L	C L	C L	C L
Moccasin Slough	C L	C L	C L	C L	C L	C L	C L	C L	C L	C L	C L	C L	C L	C L	C L	C L	C L	C L	C L	C L	C L	C L	C L	C L
Old Bull Bay																								
Fleming Island																								
Hallowes Cove																								
Orangedale																				C L	C L	C L	C L	C L
Bayard Pt.																								
Ferriera Pt.																								
Scratch Ankle	C L	C L	C L	C L	C L	C L	C L	C L	C L	C L	C L	C L	C L	C L	C L	C L	C L	C L	C L	C L	C L	C L	C L	C L
Federal Pt.																								
Rice Creek	mC L	mC L	mC L	mC L	mC L	mC L	mC L	mC L	mC L	mC L	mC L	mC L	mC L	mC L	mC L	C L	mC L	C L	mC L	mC L	mC L	mC L	mC L	mC L
Mullis Dock																								
FPL																								
Browns Landing	C L	C L	C L	C L	ND	C L	C L	C L	C L	C L	C L	C L	C L	C L	C L	ND	C L							
Buffalo Bluff	CL	CL	CL	CL	CL	CL	C L	C L	C L	C L	C L	C L	C L	C L	C L									
Crescent Lake	C L	C L	C L	C L	C L	C L	C L	C L	C L	C L	C L	C L	C L	C L	C L	C L	C L	C L	C L	C L	C L	C L	C L	C L
Lake George																								€

B	SAV data collected = biomass & root:shoot
C	SAV data collected = canopy height
L	SAV data collected = line intercept
m	SAV data collected monthly
(hatched)	Denotes contiguous seasons in which biweekly WQ was collected at site
(grey)	Denotes seasons during which quarterly WQ was collected at site

Table 3: SAV Coverage and Species Diversity by Year and Ecozone

Year	Ecozone	Number of Transects surveyed	Percent of Transects without SAV	Coverage (m) of Total SAV	Coverage (m) of *Vallisneria americana*	Coverage (m) of *Ruppia maritima*	Mean Number of Species
1998	1	39	0%	63.28	47.44	1.33	4
	2	38	0%	50.57	29.51	1.50	4
	3	ND	ND	ND	ND	ND	ND
	CRL	ND	ND	ND	ND	ND	ND
2000	1	11	9%	22.98	17.51	5.34	2
	2	25	4%	44.70	26.29	1.70	4
	3	15	20%	9.05	4.73	0.00	2
	CRL	ND	ND	ND	ND	ND	ND
2001	1	25	12%	38.29	29.26	7.18	2
	2	25	4%	68.02	35.36	6.00	5
	3	21	29%	8.75	6.61	0.00	2
	CRL	4	25%	26.45	21.34	0.00	2
2002	1	25	20%	32.06	27.30	4.43	2
	2	25	4%	55.91	30.82	3.50	6
	3	21	24%	6.17	5.51	0.00	1
	CRL	4	25%	7.20	6.74	0.00	1
2003	1	25	12%	71.00	55.35	5.05	4
	2	25	4%	53.60	32.92	2.27	7
	3	21	29%	4.79	3.83	0.00	4
	CRL	4	100%	0.00	0.00	0.00	0
2004	1	25	8%	98.64	63.58	3.74	4
	2	25	4%	71.69	38.80	1.87	6
	3	21	57%	0.64	0.44	0.00	1
	CRL	4	50%	2.36	2.25	0.00	1
2005	1	25	12%	59.44	37.25	1.99	4
	2	25	8%	32.04	18.55	0.94	5
	3	21	95%	0.09	0.01	0.00	0
	CRL	4	100%	0.00	0.00	0.00	0
2006	1	25	8%	53.80	34.97	5.36	4
	2	24	8%	40.94	16.89	4.21	5
	3	21	90%	0.22	0.08	0.00	0
	CRL	4	100%	0.00	0.00	0.00	0
2007	1	25	16%	19.30	14.54	4.22	2
	2	25	8%	65.05	34.97	5.55	6
	3	21	33%	6.03	4.17	0.00	2
	CRL	4	25%	23.24	19.64	0.00	2

Table 4: Yearly Mean Water Quality (± S.E.) Preceding SAV Annual Surveys (taken from Sagan 2003a)

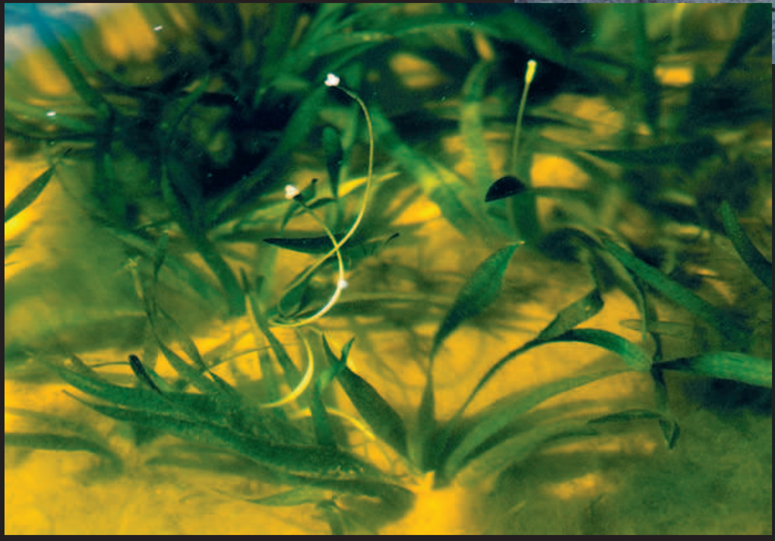
Section	Year*	Chlorophyll-a (mg m^{-3})	Color (CPU)	Salinity (ppt)	Turbidity (NTU)	TSS (mg l^{-1})	Secchi (m)	Kd (m^{-1})
1	1998	11.431 ± 1.824	188 ± 12	0.68 ± 0.15	7.81 ± 1.05	15.5 ± 2.4	0.63 ± 0.02	3.61 ± 0.18
	1999	21.864 ± 2.291	88 ± 3	2.46 ± 0.35	9.45 ± 1.25	20.4 ± 2.4	0.66 ± 0.02	3.17 ± 0.15
	2000	14.429 ± 0.906	110 ± 8	4.91 ± 0.48	9.17 ± 0.70	28.5 ± 3.5	0.61 ± 0.02	3.24 ± 0.13
	2001	11.105 ± 0.917	58 ± 3	7.58 ± 0.47	8.41 ± 0.96	21.2 ± 2.4	0.71 ± 0.02	2.52 ± 0.12
	2002	8.907 ± 0.656	172 ± 14	3.78 ± 0.55	9.26 ± 1.06	22.2 ± 2.6	0.57 ± 0.02	3.42 ± 0.19
	2003	9.164 ± 0.922	219 ± 12	1.52 ± 0.34	5.88 ± 0.40	11.7 ± 1.1	0.61 ± 0.02	3.35 ± 0.10
2	1998	22.499 ± 2.665	272 ± 20	0.24 ± 0.02	6.83 ± 0.80	16.9 ± 2.3	0.58 ± 0.02	4.19 ± 0.20
	1999	38.503 ± 3.645	118 ± 7	0.54 ± 0.11	7.81 ± 0.63	16.8 ± 1.5	0.60 ± 0.02	3.62 ± 0.12
	2000	23.798 ± 2.152	157 ± 13	0.82 ± 0.11	6.71 ± 0.59	15.8 ± 1.4	0.58 ± 0.02	3.42 ± 0.11
	2001	22.318 ± 1.637	70 ± 4	1.41 ± 0.18	7.38 ± 0.57	14.5 ± 1.0	0.67 ± 0.02	2.87 ± 0.10
	2002	22.425 ± 2.8	202 ± 18	0.58 ± 0.05	5.61 ± 0.44	13.1 ± 1.3	0.54 ± 0.02	3.50 ± 0.11
	2003	17.46 ± 1.43	257 ± 13	0.50 ± 0.10	4.85 ± 0.40	10.4 ± 0.9	0.56 ± 0.02	3.76 ± 0.10
3	1998	ND	ND	ND	ND	ND	ND	ND
	1999	ND	ND	ND	ND	ND	ND	ND
	2000	25.788 ± 2.135	134 ± 21	0.44 ± 0.02	6.36 ± 1.40	14.4 ± 2.5	0.61 ± 0.02	3.21 ± 0.24
	2001	29.766 ± 2.215	43 ± 4	0.56 ± 0.02	6.34 ± 0.93	12.1 ± 1.8	0.74 ± 0.03	2.41 ± 0.11
	2002	31.539 ± 5.409	185 ± 30	0.50 ± 0.03	4.80 ± 0.70	10.1 ± 1.4	0.53 ± 0.03	3.32 ± 0.11
	2003	19.173 ± 2.407	217 ± 23	0.39 ± 0.02	3.44 ± 0.42	11.9 ± 3.5	0.62 ± 0.03	3.17 ± 0.12

*1998 represents average of data from October 1997 – May 1998; 1999 represent average of data from June 1998 – May 1999; 2000 represents average of data from June 1999 – May 2000; 2001 represents average of data from June 2000 – May 2001; 2002 represents average of data from June 2001 – May 2002.; 2003 represent average of data from June 2002 – May 2003.

Appendix A: Guide to Measuring Submerged Aquatic Vegetation in the Lower St. Johns River

A Guide to Measuring Submerged Aquatic Vegetation

in the Lower St. Johns River



St. Johns River Water Management District

P.O. Box 1429

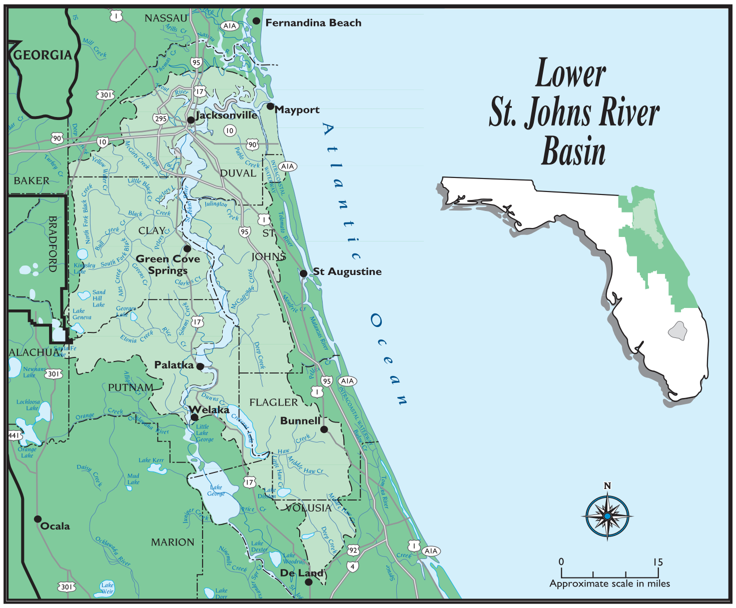
Palatka, FL 32178-1429

Contents

Why do we monitor submerged aquatic vegetation?

The St. Johns River has many hundreds of miles of grassbeds — or submersed aquatic vegetation (SAV) — along its shores. SAV provides important sources of food and habitat for a variety of wildlife, including fish, bluecrabs, waterfowl and manatees. SAV also acts as a nursery for juvenile fish.

Closer observation of submersed grassbeds reveals a thriving micro-community. The grassbeds provide a surface for smaller organisms to attach to, organisms such as snails, algae and insects. The grassbeds add dissolved oxygen to the water, which enables aquatic animals to breathe. The grassbeds also act as our "canaries in the coal mine": their health is indicative of the health of the river. We monitor SAV because if grassbed communities begin to decline, many aquatic organisms may also begin to decline.



To monitor the health of the grassbeds, the Watershed Action Volunteers of the St. Johns River Water Management District collect data on the grassbeds along the lower basin of the river, from Jacksonville to Crescent Lake. This monitoring effort is called the Submersed Aquatic Vegetation Monitoring Project.

While water quality monitoring data are collected from many water bodies from throughout the District's 18-county region of north and east-central Florida, the information in this guide is particular to the lower basin of the St. Johns River. The lower basin is the last 100 miles of the river, from near Lake George to Mayport at the river's mouth.

How do you monitor submerged aquatic vegetation?

Data from each grassbed site are collected quarterly. The data collection process consists of identifying the type of plants present, measuring representative plant height (also called canopy height), characterizing SAV density and the study-plot sediment, measuring water depth and noting the presence of plants or animals growing on the SAV.

SAV data are used to quantify changes, if any, in the SAV bed at each site. A change such as a decline in the SAV bed is most likely due to poor water quality conditions that prevent light from reaching the submerged plants. Other conditions also affect the growth of SAV. The District's Division of Environmental Sciences measures water quality characteristics such as water color, light penetration, nitrate/phosphate levels, algae concentration, dissolved oxygen, pH and salinity on a biweekly basis. This information will demonstrate how water quality characteristics affect SAV growth and distribution.

Volunteers Eva-Maria Schwartz and Kathy Schneider (right) identify submersed aquatic vegetation (SAV).

A typical day monitoring

What should you expect when you volunteer to monitor SAV? Volunteers and the project coordinator usually meet at the study site at 9 a.m. Depending on the size of the grassbed, it may take a few hours or it may take all day to complete data collection. For really large grassbeds, it may take up to three days to finish data collection. It's possible you may be spending up to seven hours on the site, so you should bring plenty of water, a lunch, sunscreen and anything else that will keep you comfortable throughout the day.

We are in ankle- to waist-deep water all day, so you must like getting wet if you are to join us. Also, when working at the deep end of the SAV bed, one volunteer from each group will have to dive under the water in order to view or retrieve plants. Volunteers who have diving goggles or masks should bring them.

Depending on the time of year, appropriate dress can vary from bathing suits to wetsuits with a rain coat. However, on overcast or windy days, it can be chilly even in the summer, so volunteers should always bring a long-sleeved shirt (good for protection against the sun too) and a raincoat. If it rains and there is no threat of lightning, we will still collect data. Having a raincoat and a hat will offer protection throughout the day, whatever the weather brings. Some form of closed-toe shoes should always be worn. Sunglasses and hats are a good idea year-round.

One of the exciting aspects of volunteering is that you will get to visit some beautiful, pristine sites. You'll get a real taste of "wild" Florida. Volunteers are routinely treated to sightings of osprey, manatees, shorebirds and waterfowl, and fish; however, we are also sharing habitat with alligators and snakes. As you would in any natural area, stay alert — give wild animals a chance to retreat from you, as they invariably will if given the opportunity.

What to bring/wear:

Water
Lunch
Sunscreen
Hat
Sunglasses
Closed-toe shoes
Raincoat
Emergency medication

Protocol for data collection of submersed aquatic vegetation: measuring and recording plant height data

1. Work in groups of two or three. One person records while the other(s) measures.
2. Find the benchmark at your site (normally a green stake with an attached “Study Plot”sign). Stake the beginning (the 0-meter [m] end) of a 50-m transect tape at the benchmark (refer to Figure 1 for steps 2–4).
3. Check with District personnel or the District contractor to find out if the tape is to be pulled upstream or downstream. Pull the tape in a straight line parallel to the shore and stake the 50-m end by wrapping the tape around a tent stake and placing the stake securely in the sediment.
4. Use 100-m tapes to create five transects perpendicular to the shore at 0 m, 12 m, 25 m, 38 m, and 50 m from the benchmark. You will be creating a transect grid. Set up only as many transects as you can finish in a day with the number of people on the team. Each perpendicular transect runs from the shoreline (the point where water and land meet), crosses the 50-m tape and continues to the end of the SAV. Stake the tape at both ends as you did with the 50-m tape. If your grassbed runs longer than 100 m, a second 100-m tape should be pulled where needed, beginning at the end of the first tape. Keep the transects as straight as the wind and the tide will allow.
5. Fill out the information at the top of the data sheet (site name, transect number, date, start time and names of volunteers), as shown on page 5.
6. Start at the beginning of the first transect (0 m). Use a meter stick to measure the water depth and plant height at every red meter mark on the tape (e.g., 0, 1, 2, 3)(refer to the sample data sheet); record other observations also.
   a. Record water depth in centimeters (cm) from the sediment surface to the water surface to the nearest 0.5 cm. Be careful not to push the meter stick down into any soft mud. Correct for wave action.
   b. Identify each species of plant at each meter mark within a 25- by 25-cm sampling area. A plastic square (quadrat) is provided for determining the sampling area. Some species can be inconspicuous, so check the area within the quadrat thoroughly for plants.
   c. Measure a plant of each rooted species to the nearest 1 cm. Randomly pick the plant to be measured, but do not pick the tallest or shortest plant. Measure the plants from the sediment surface to the tip of the tallest leaf. Pull a plant to measure it, if necessary. If a plant is pulled, measure from just above the roots to the tip of the tallest leaf. For plants with roots at different points along the stem (e.g., *Najas*), find where the plant enters the sediment and measure from that point. Any uprooted plants should not be recorded. If no rooted SAV is found at the meter mark, circle “Bare” under the observation column of the data sheet.
   d. Record the density of the SAV growth within the quadrat — sparse (S), medium (M) or heavy (H). Sparse equals one plant to one-third coverage, medium equals one-third to two-thirds coverage, heavy equals two-thirds to full coverage.
   e. Record the presence of each floating species or species without roots (e.g., *Ceratophyllum*, *Lemna*), each emergent species (e.g., cattails), filamentous algae and overhanging trees, using the plant name code (Table 1).
   f. Record sediment type (e.g., S = sandy, MS = mucky sand, M = mucky).
   g. Record any interesting or unusual observations at the site (e.g., flowering SAV, plant or animal growth on the leaves of SAV, manatees).
7. Continue measuring the water depth and plant height until you come to the end of the SAV. Always wade at least 10 m out past the last “Bare” entry to make sure that the plants are no longer present.
8. Record the end time as each data sheet is completed. If an additional data sheet is used, record the new start time at the top of the sheet.

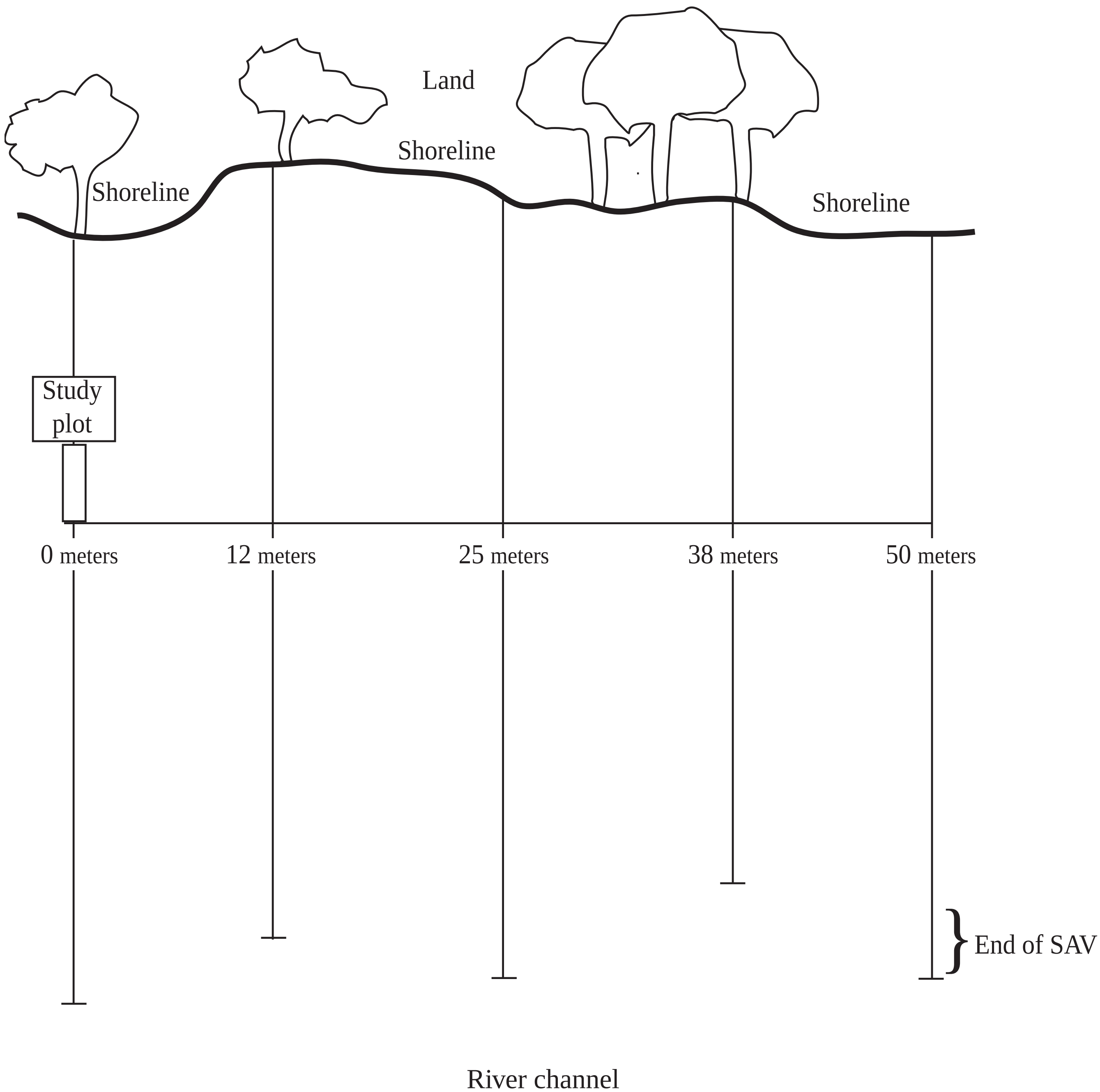


Figure 1. Creating a transect grid

Sample SAV Data Sheet

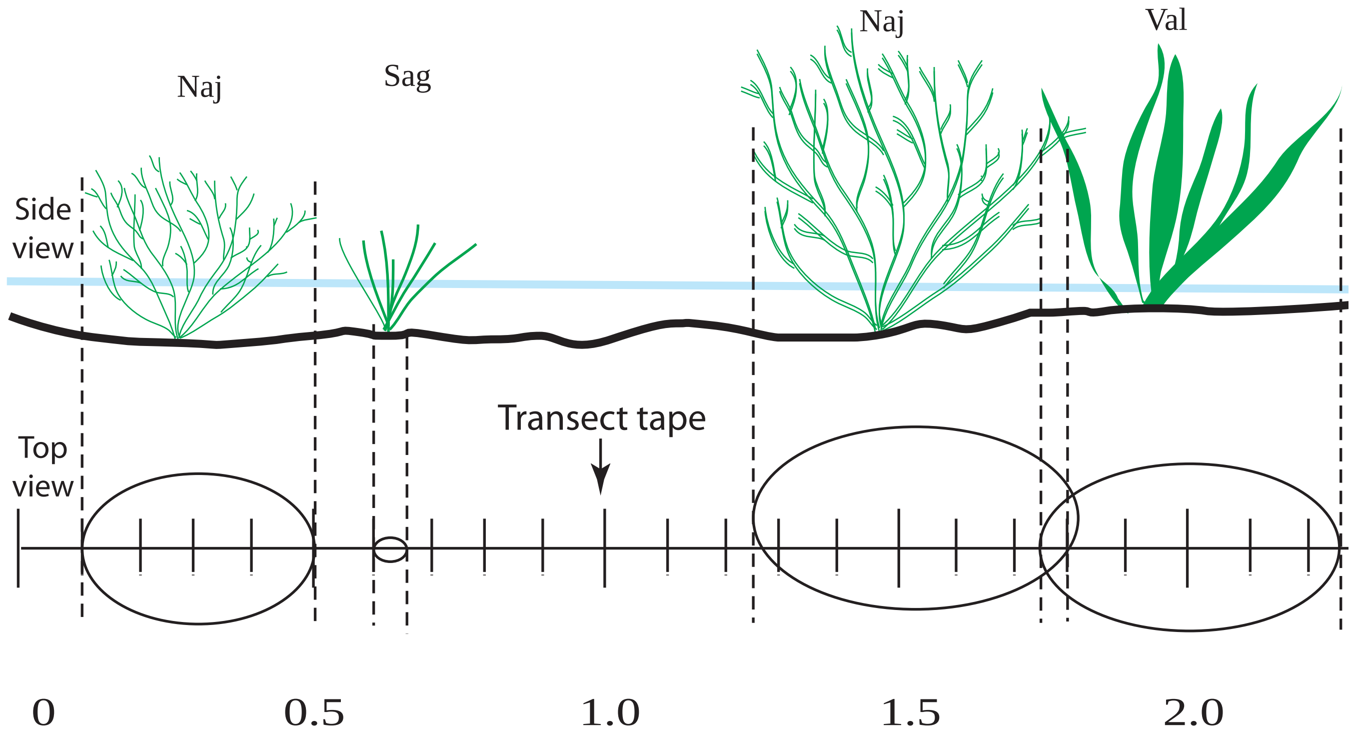
Site: Buckman
Start Time: 9:00
Transect #: 1
Date: 10/23/00
End Time:
Transect @ Meter: 0
Names: Sarah Bioman, Andrew Waters

Meter Mark	Water Depth (cm)	Canopy Height (cm)	Observations
0	0	Val-a: ___ Pot-pu: ___ Sag-s: ___ Hyd-v: ___ Pot-pe: ___ Ele-*: ___ Naj-g: ___ Rup-m: ___ Cha-*: ___ Mic-*: ___ Zan-p ___	(B) S M H Cypress tree, Iris S MS (M)
1	2	Val-a: ___ Pot-pu: ___ Sag-s: ___ Hyd-v: ___ Pot-pe: ___ Ele-*: ___ Naj-g: 4 Rup-m: ___ Cha-*: ___ Mic-*: ___ Zan-p ___	B (S) M H Cattails S MS (M)
2	6	Val-a: ___ Pot-pu: ___ Sag-s: ___ Hyd-v: ___ Pot-pe: ___ Ele-*: ___ Naj-g: 4 Rup-m: ___ Cha-*: ___ Mic-*: 5 Zan-p ___	B (S) M H Algae on SAV leaves S MS (M)
		Val-a: ___ Pot-pu: ___ Sag-s: ___ Hyd-v: ___ Pot-pe: ___ Ele-*: ___ Naj-g: ___ Rup-m: ___ Cha-*: ___ Mic-*: ___ Zan-p ___	B S M H S MS M
		Val-a: ___ Pot-pu: ___ Sag-s: ___ Hyd-v: ___ Pot-pe: ___ Ele-*: ___ Naj-g: ___ Mic-*: ___	B S M H
		Val-a: ___ Hyd-v: ___ Naj-g: ___ Mic-*: ___	
		Val-a: ___ Hyd-v: ___ Naj-g: ___ Mic-*: ___	

Protocol for data collection of submersed aquatic vegetation: measuring and recording line intercept data

1. Work in groups of two or three. One person records while the other(s) measures.
2. Find the benchmark at your site (normally a green stake with an attached "Study Plot" sign). Stake the beginning (the 0-meter [m] end) of a 50-m transect tape at the benchmark (Figure 1).
3. Check with District personnel or the District contractor to find out if the tape is to be pulled upstream or downstream. Pull the tape in a straight line parallel to the shore and stake the 50-m end by wrapping the tape around a tent stake and placing the stake securely in the sediment.
4. Use 100-m tapes to create five transects perpendicular to the shore at randomly chosen meter marks between 0 m and 50 m from the benchmark. Set up only as many transects as you can finish in a day with the number of people on the team. Each perpendicular transect runs from the shoreline (the point where water and land meet), crosses the 50-m tape and continues to the end of the SAV. Stake the tape at both ends as you did with the 50-m tape. If your grassbed runs longer than 100 m, a second 100-m tape should be pulled where needed, beginning at the end of the first tape. Keep the transects as straight as the wind and the tide will allow.
5. Fill out the information at the top of the data sheet (site name, transect number, date, start time and names of volunteers).
6. Start at the beginning of the first transect (0 m). Note if any plants or their leaves or stems cross over the transect tape (see Figure 2). Record the plant type on the data sheet under the SAV column. Record the number on the tape where the plant first crosses the transect under the Begin column. Record the number on the tape where the plant stops under the End column. If no plants are present, write "Bare" under the SAV column and record the first and last occurrence of the bare patch under the Begin and End columns. Plants may overlap on the transect. Continue to record where each individual plant begins and ends.
7. Continue the line intercept data until you come to the end of the SAV. Always wade at least 10 m out past the last "Bare" entry to make sure that the plants are no longer present.
8. Record the end time as each data sheet is completed. If an additional data sheet is used, record the new start time at the top of the sheet.

Figure 2. Recording line intercept data



Sample Data Sheet for recording Line Intercept Data

Site: Scratch Ankle Start Time: 9:30 Transect #: 1

Date: 7/08/00 End Time: 13:10 Transect @ Meter: 6

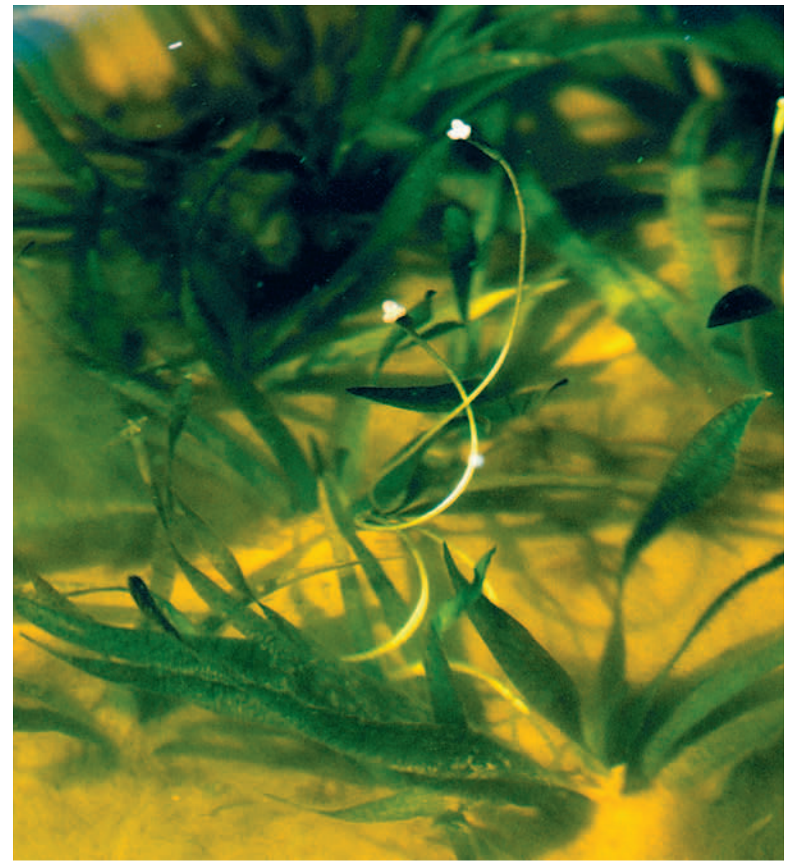
SAV	Begin	End	SAV	Begin	End
Bare	0	0.1			
Naj	0.1	0.5			
Bare	0.5	0.6			
Sag	0.6	0.65			
Bare	0.65	1.25			
Naj	1.25	1.8			
Val	1.75	2.25			

List of aquatic and wetland plants

Scientific Name	Common Name	Code for Data Sheet
Alternanthera philoxeroides	Alligatorweed	Alt-p
Aster spp.	Aster	Ast-*
Azolla spp.	Mosquito fern	Azo-*
Cephalanthus occidentalis	Buttonbush	Cep-o
Ceratophyllum demersum	Coontail	Cer-d
Chara sp.	Muskgrass	Cha-*
Colocasia esculenta	Wild taro	Col-e
Eichhornia crassipes	Waterhyacinth	Eic-c
Eleocharis sp.	Spikerush	Mic-*
Hydrilla verticillata	Hydrilla	Hyd-v
Iris spp.	Iris	Iri-*
Lemna spp.	Duckweed	Lem-*
Lobelia cardinalis	Cardinal flower	Lob-c
Ludwigia spp.	Water primrose	Lud-*
Micranthemum sp.	Baby tears	Mic-*
Najas guadalupensis	Southern naiad	Naj-g
Nuphar luteum	Spatterdock	Nup-l
Nymphaea mexicana	Yellow water lily	Nym-m
Nymphaea odorata	Pond lily	Nym-o
Pistia stratiotes	Waterlettuce	Pis-s
Pontederia cordata	Pickerelweed	Pon-c
Potamogeton illinoensis	Illinois pondweed	Pot-i
Potamogeton pectinatus	Sago pondweed	Pot-pe
Potamogeton pusillus	Slender pondweed	Pot-pu
Ruppia maritima	Widgeon grass	Rup-m
Sabatia spp.	Marsh pink	Sab-*
Sagittaria lancifolia	Duck potato	Sag-l
Sagittaria subulata	Dwarf arrowhead	Sag-s
Salvinia spp.	Water fern	Sal-*
Saururus cernuus	Lizard's tail	Sau-c
Scirpus spp.	Giant bulrush	Sci-*
Typha spp.	Cattail	Typ-*
Vallisneria americana	Tapegrass, eelgrass	Val-a
Zannichellia palustris	Horned pondweed	Zan-p

***Vallisneria americana* with stalked fruit**

***Vallisneria americana* in habitat**



Vallisneria americana

- Teeth on edge of leaves
- Leaves flat, tape-like; 0.5–4 cm wide
- Leaves taper at tip
- No obvious stem
- Height: 4–90 cm (a small one can be confused with *Sagittaria subulata*)

Vallisneria americana **(small — 4 cm)**

Vallisneria americana **seed pod**

Vallisneria americana **male flower**

Vallisneria americana **female flower**

***Eleocharis* sp.**

***Eleocharis* sp.**

- No teeth on leaves
- Leaves round, pencil-like; 1–3 mm wide
- Leaves as broad at tip as at base
- Height: 1–5 cm

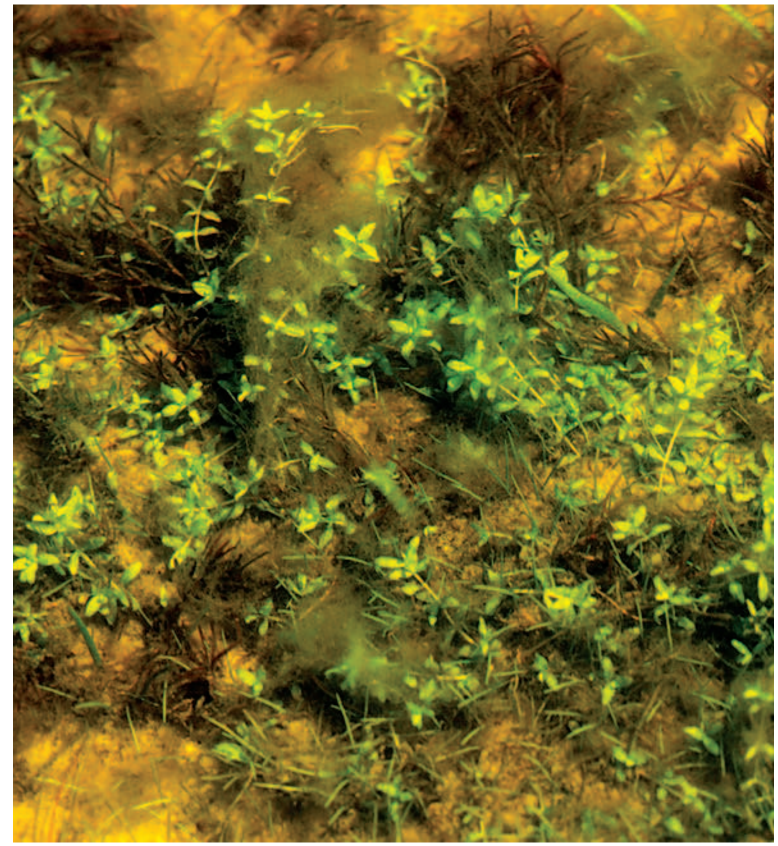
Sagittaria subulata

Sagittaria subulata
- No teeth on leaves
- Leaves triangular, spongy; 3–8 m wide
- Leaves taper at tip
- Height: 1–5 cm

***Sagittaria subulata* in habitat**

***Micranthemum* sp.**

***Micranthemum* sp. in habitat**

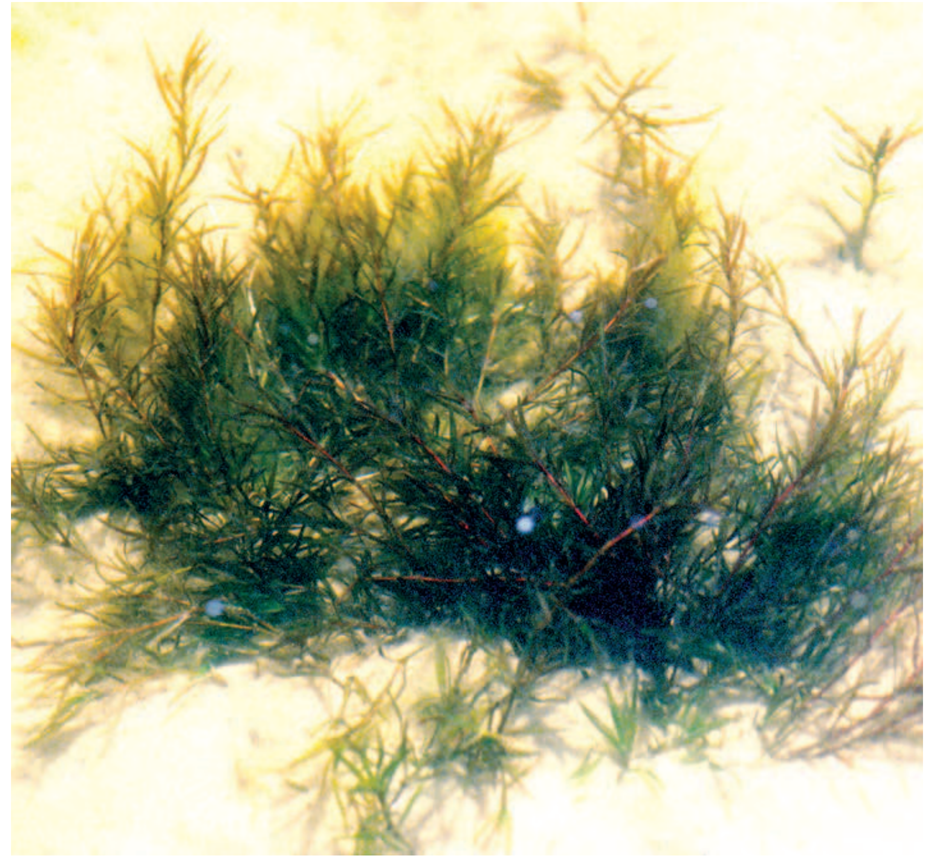


***Micranthemum* sp.**

- Leaf whorls not tightly packed
- Leaf opposite, in whorls of three to four leaves
- No teeth on leaves
- Leaf tip rounded; 2–4 mm wide
- Height: 2–15 cm

Najas guadalupensis

Najas guadalupensis in habitat

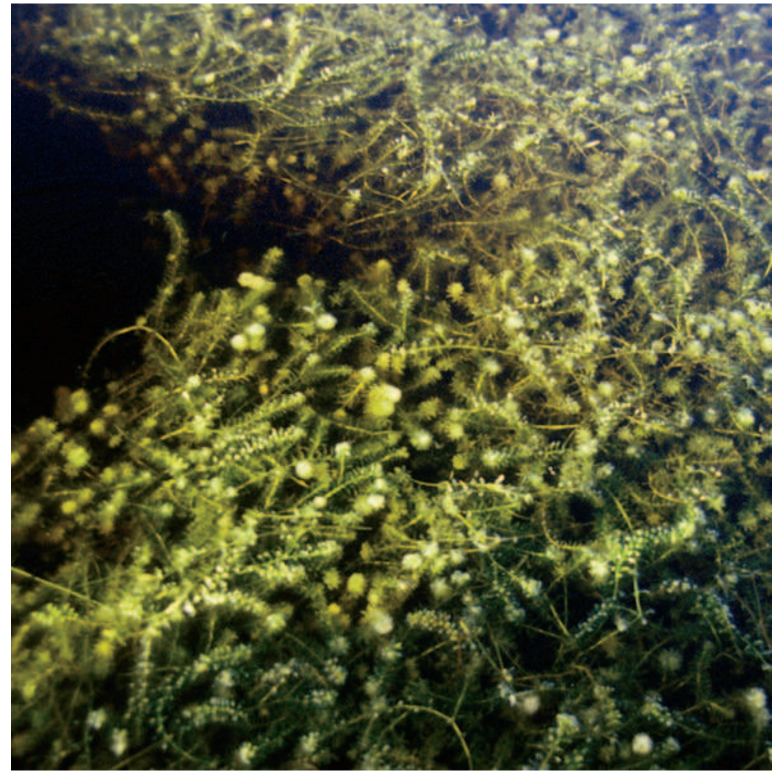


Najas guadalupensis

- Leaf whorls not tightly packed
- Leaf pairs/whorls separated by large spaces on stem
- Leaves opposite, usually in pairs, sometimes in whorls of three
- Leave with teeth (must look closely); 2 mm wide

Hydrilla verticillata

***Hydrilla verticillata* in habitat**



Hydrilla verticillata

- Leaf whorls tightly packed
- Leaves opposite, in whorls of four to eight leaves
- Leaves with conspicuous teeth, making plant scratchy to touch
- Leaf tip pointed; leaves 2–4 mm wide
- Height: 5–15 cm

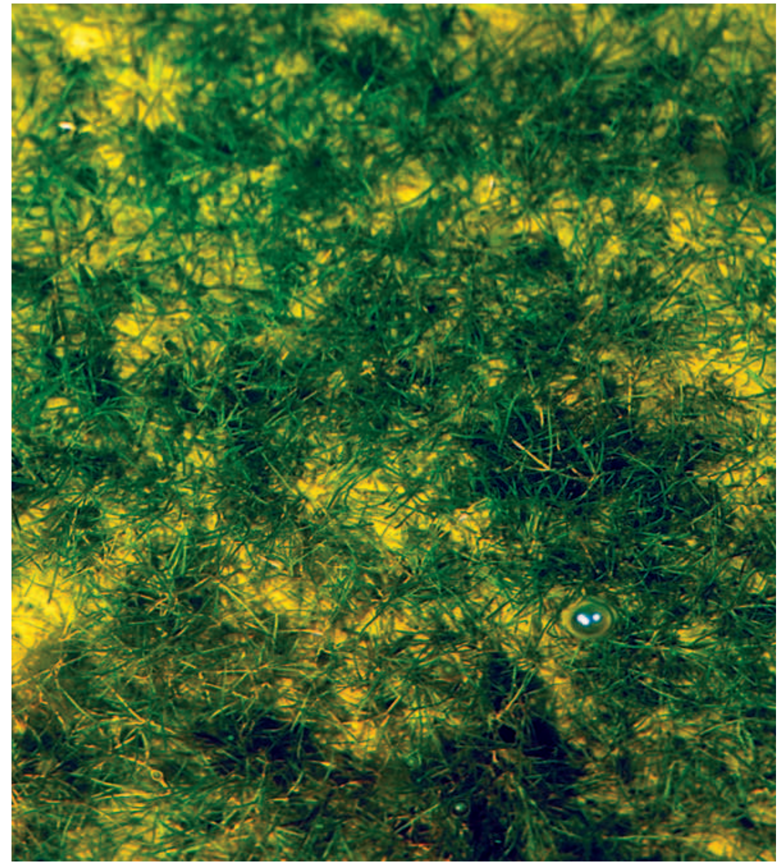
Ceratophyllum demersum

Ceratophyllum demersum
- Leaf whorls tightly packed together
- Leaf forked at tip
- Leaves pliable and scratchy to touch
- Height: 10–20 cm

***Ceratophyllum demersum* in habitat**

Zannichellia palustris

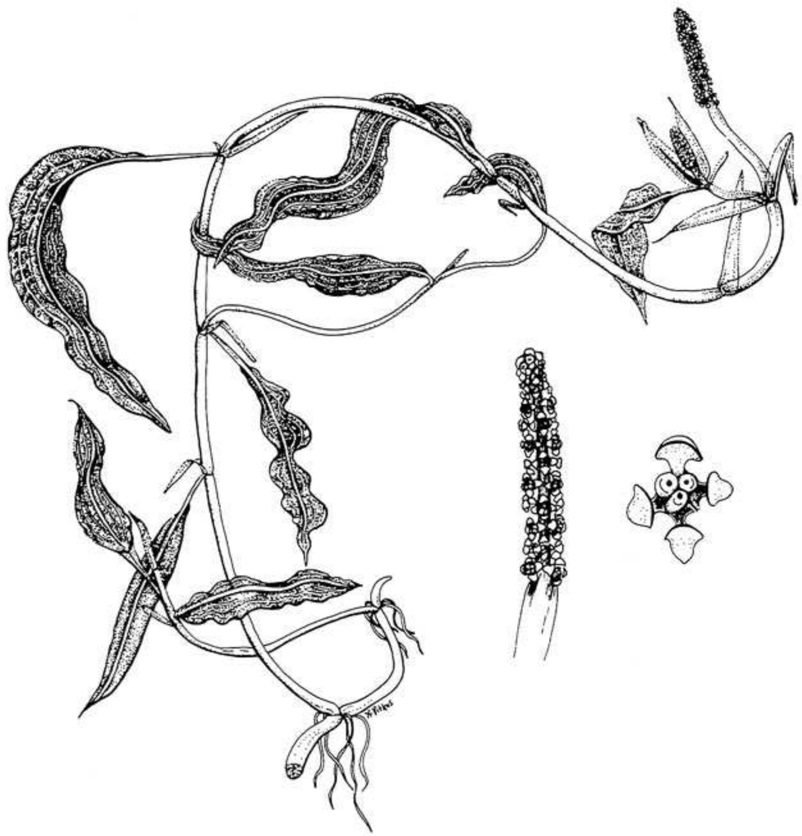
Coin and plants are shown approximately actual size



Zannichellia palustris

- Leaves opposite
- No teeth on leaves
- Long narrow leaves with blunted tips
- Stems thread-like
- Often seen with kidney-shaped fruit
- Height: 1–8 cm

Potamogeton illinoensis



Potamogeton illinoensis

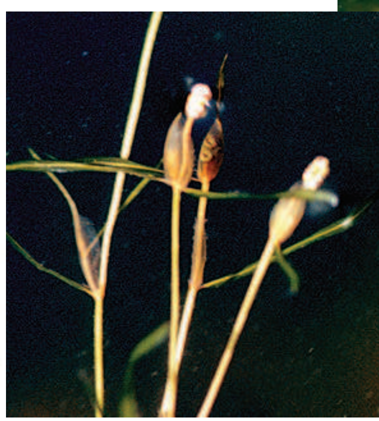
- Leaves alternate; 0.5–4.5 cm wide
- Leaf edges wavy
- Some leaves floating
- Stems thick
- Height: 10–25 cm

Potamogeton pectinatus

Potamogeton pectinatus

- Leaves alternate; 0.5–4.5 cm wide
- No teeth on leaves
- Leaves long and narrowing with pointed tips
- Stems thread-like
- Height: 5–20 cm

Potamogeton pusillus



***Potamogeton pusillus* in habitat**

Potamogeton pusillus

- Leaves alternate; 0.5–3 mm wide
- No teeth on leaves
- Leaves long and narrow with blunted or rounded tips
- Stems thread-like
- Height: 5–20 cm

***Ruppia maritima* with fruit**

Ruppia maritima
- Leaves alternate, tapering at end
- Leaves thread-like; 0.5 mm wide
- Height: 4–20 cm

Ruppia maritima (small — 4 cm)

Ruppia maritima in habitat

Typical SAV along the lower St. Johns River

The following pages depict submerged aquatic vegetation types that are easily confused with one another.

Potamogeton pusillus **and** ***Zannichellia palustris***

Chara **sp. and** ***Ceratophyllum demersum***

Hydrilla verticillata, Najas guadalupensis and Micranthemum **sp.**

Sagittaria subulata and Eleocharis **sp.**

Small ***Vallisneria americana*** **and** ***Sagittaria subulata***

Potamogeton pusillus

Potamogeton pusillus

- Leaves alternate; 0.5–3 mm wide
- No teeth on leaves
- Leaves long and narrow with blunted or rounded tips
- Stems thread-like
- Height: 5–20 cm

Zannichellia palustris

Zannichellia palustris

- Leaves opposite
- No teeth on leaves
- Long narrow leaves with blunted tips
- Stems thread-like
- Often seen with kidney-shaped fruit
- Height: 1–8 cm

***Chara* sp.**

***Chara* sp.**
- Leaf whorls separated by conspicuous spaces
- Leaf not forked
- Leaves stiff and scratchy to touch
- Height: 2–8 cm

Ceratophyllum demersum

Ceratophyllum demersum
- Leaf whorls tightly packed together
- Leaf forked at tip
- Leaves pliable and scratchy to touch
- Height: 10–20 cm

Hydrilla verticillata

***Micranthemum* sp.**

Najas guadalupensis

Hydrilla verticillata

- Leaf whorls tightly packed
- Leaves opposite, in whorls of four to eight leaves
- Leaves with conspicuous teeth, making plant scratchy to touch
- Leaf tip pointed; leaves 2–4 mm wide
- Height: 5–15 cm

***Micranthemum* sp.**

- Leaf whorls not tightly packed
- Leaves opposite, in whorls of three to four leaves
- No teeth on leaves
- Leaf tip rounded; 2–4 mm wide
- Height: 2–15 cm

Najas guadalupensis

- Leaf pairs/whorls separated by large spaces on stem
- Leaves opposite, usually in pairs, sometimes in whorls of three
- Leaves with teeth (must look closely); 2 mm wide
- Leaf tip pointed
- Height: 4–20 cm

Sagittaria subulata

Sagittaria subulata
- No teeth on leaves
- Leaves triangular, spongy; 3–8 m wide
- Leaves taper at tip
- Height: 1–5 cm

***Eleocharis* sp.**

***Eleocharis* sp.**
- No teeth on leaves
- Leaves round, pencil-like; 1–3 mm wide
- Leaves as broad at tip as at base
- Height: 1–5 cm

Vallisneria americana

Vallisneria americana

- Teeth on upper edge of leaves
- Leaves flat, tape-like; 0.5–4 cm wide
- Leaves taper at tip
- No obvious stem
- Height: 4–90 cm (a small one can be confused with *Sagittaria subulata*)

Sagittaria subulata

Sagittaria subulata

- No teeth on leaves
- Leaves triangular, spongy; 3–8 m wide
- Leaves taper at tip
- Height: 1–5 cm

Emergent Plants

Alternanthera philoxeroides

Aster spp.

Cephalanthus occidentalis

Colocasia esculenta


Lobelia cardinalis


Pontederia cordata


Iris spp.


Ludwigia spp.

Sagittaria lancifolia

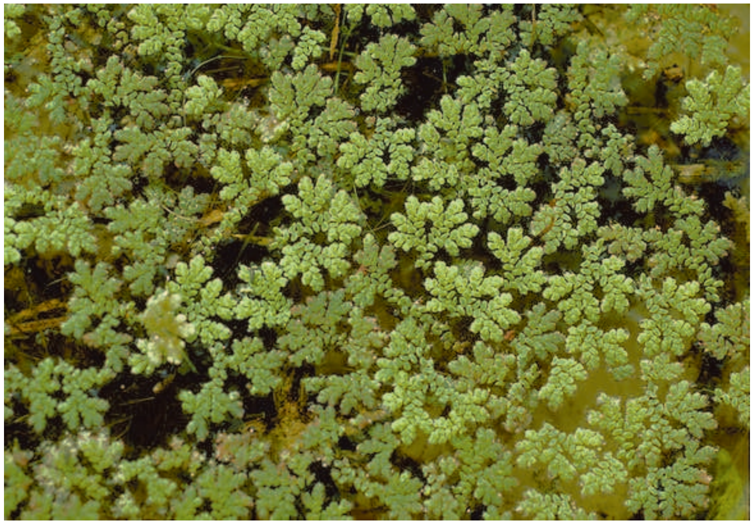
Saururus cernuus

Scirpus spp.

Typha spp.

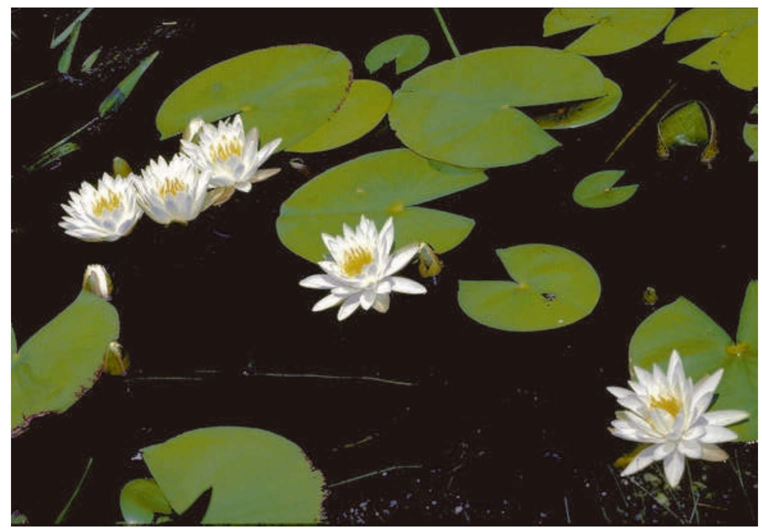
Free-Floating and Floating-Leaved Plants

Azolla spp.



Lemna spp.

Eichhornia crassipes



Nymphaea odorata

Pistia stratiotes

Salvinia spp.

Nuphar luteum

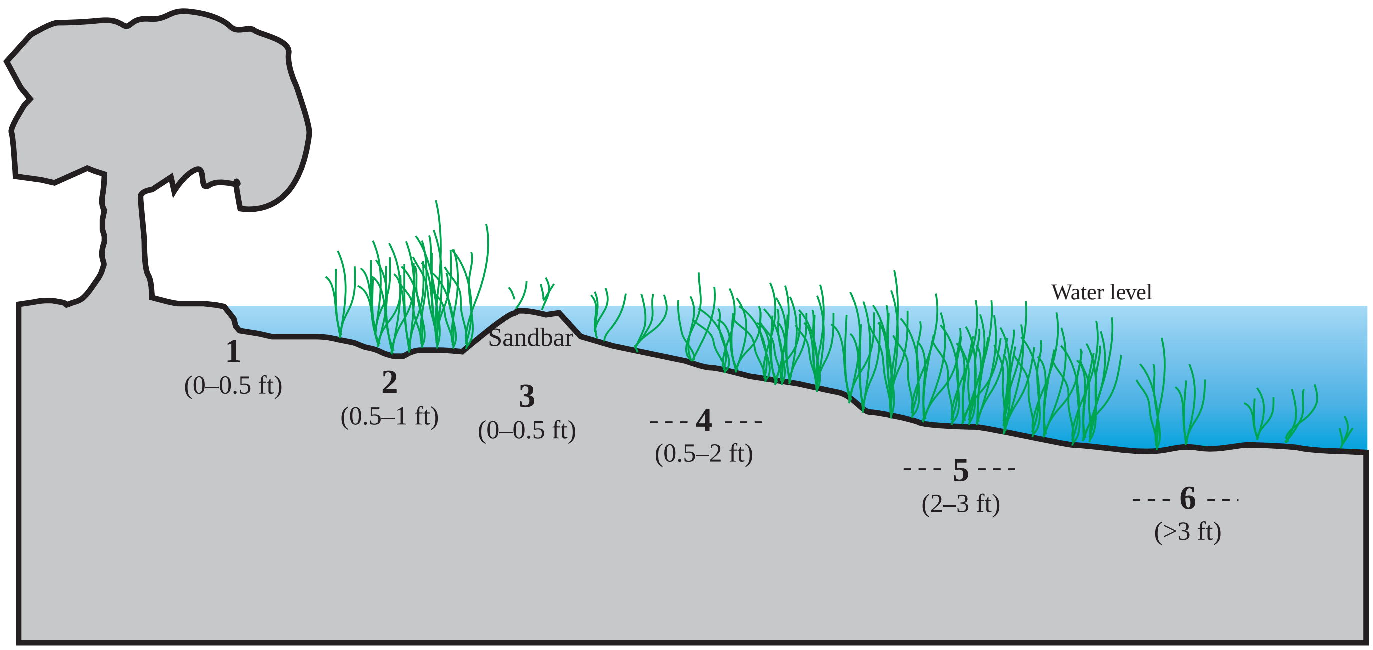
Algae

Macroalgae (*Chara* sp.)

Planktonic algae

Filamentous algae

Plant distribution by water depth contour



1. No SAV, but floating plants

2. Algae, emergent and floating plants, *Chara*, *Eleocharis*, *Najas*

3. Sandbar: Algae, *Eleocharis*, *Najas*, *Ruppia*, *Sagittaria subulata*

4. Algae, *Ceratophyllum*, *Chara*, *Micranthemum*, *Hydrilla*, *Najas*, *Potamogeton*, *Ruppia*, *Sagittaria subulata*, *Vallisneria*

5. *Najas*, *Ruppia*, *Vallisneria*

6. *Najas*, *Vallisneria*

Notes

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