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Abstract

Lake Fayetteville and Lake Wedington are small reservoirs of about the same size and age that are located in northwestern Arkansas. We collected macrophytes from eleven transects around each reservoir in the autumn of 1993. *Justicia* (waterwillow), *Typha* (cat-tail), *Scirpus* (bulrush), *Potamogeton* (pondweed), and *Zannichellia* (horned pondweed) occur in both reservoirs. *Justicia* occurs most commonly in both reservoirs. The macrophytes of Lake Wedington are organized in a characteristic zonation pattern with bands from shore toward open water of emergent, floating-leaved, then submersed macrophytes. Macrophyte zonation was not as evident in Lake Fayetteville because of the low occurrence of floating-leaved and submersed macrophytes in 1993. Early studies of Lake Wedington found that the dominant macrophytes were *Cyperus, Echinochloa, Lotus,* and *Sagittaria,* all of which were absent during this study. *Potamogeton, Scirpus,* and *Typha* were also found to be dominant during 1952 studies, but occurred in lesser amounts in the current study. Previous studies (1956, 1967, 1977) on Lake Fayetteville stated that *Sagittaria* and *Nelumbo* were dominant macrophytes, but we found none in 1993. *Juncus, Potamogeton, Scirpus,* and *Typha* were common in the early studies but occurred infrequently in our collections. Macrophyte composition in Lake Fayetteville in 1993 was attributable to an herbicide application that occurred in spring, 1992. As for the changes in Lake Wedington, we assume that the *Justicia* has out-competed those macrophytes that were in the reservoir in 1952, or that normal lake ontogeny during the intervening 40 years has altered habitat conditions to now favor *Justicia.*

Introduction

Aquatic macrophytes are an important component of many ecosystems. They are indicators of the existing physical environment, and they are also the agent of many changes to the environment in the water and sediments beneath them. Macrophytes also have important roles as intermediates in many biotic interactions.

Physical factors of the environment affect macrophyte distribution. In a survey of 139 lakes, Duarte et al. (1986) reported that the biomass of emergent macrophytes was proportional to lake size, but biomass of submersed macrophytes was inversely proportional to lake size. Lake basin slope has a negative influence on macrophyte biomass, especially emergent macrophytes (Duarte et al., 1986; Duarte and Kalff, 1990; Rorslett, 1991). Light is most often the limiting factor on submersed macrophyte biomass (Duarte et al., 1986). Rorslett (1991) determined that small fluctuations in water level greatly increased macrophyte diversity perhaps as a result of a supression of a dominant species that might competitively exclude others (Ward and Stanford, 1983). Duarte and Kalff (1990) reported a decrease in macrophyte biomass as wave action increased.

Water chemistry has a strong influence on macrophyte species distribution. Alkalinity, pH, dissolved organic matter, nitrogen, phosphorous, chloride, and sulfate all affect macrophyte species distribution (Pip, 1979). Duarte and Kalff (1990) reported that an incrase in macrophyte biomass corresponded to an incrase in alkalinity. Friday (1987) found that pH was the most important factor limiting macrophyte species diversity in small ponds in Great Britain.

Macrophytes can also effect changes in their abiotic environment. They decrease currents and, as a result, increase sedimentation (Spence, 1982; Carpenter and Lodge, 1986; James and Barko, 1990). The composition of the sediments beneath macrophyte beds differs considerably from other sediments. Nitrogen, phosphorus, calcium and organic compounds are present in higher quantities beneath macrophytes (James and Barko, 1990). The sediments beneath macrophytes are enriched by decaying material from the plant bed (Carpenter and Lodge, 1986). Macrophytes alter the quantity and quality of light beneath them. The reduction in the amount of light causes the water under the macrophytes to be cooler than the surrounding water (Carpenter and Lodge, 1986). Water chemistry is also influenced by macrophytes. Oxygen and carbon dioxide levels fluctuate more in the littoral than the limnetic zone as the macrophytes respire and photosynthesize. Organic and inorganic carbon levels in the water are increased by macrophytes while inorganic nutrient levels are generally reduced (Carpenter and Lodge, 1986).

Aquatic macrophytes play a pivotal role in the biotic interactions of the littoral zone. They provide an area of refuge and forage for fish (Rozas and Odum, 1988). Macrophytes serve as a substrate for periphyton and invertebrates (Carpenter and Lodge, 1986; Cyr and Downing, 1988). Many invertebrates inhabit the rich substrate created beneath the macrophytes (Becket et al., 1992).

Many studies have investigated the trophic links between periphyton, periphyton grazers, macrophytes, and predators (Price et al., 1980; Bronmark, 1985; Cyr and Downing, 1988; Chambers et al., 1990; Hanson et al., 1990; Steinman 1991). Bronmark (1985) found that when grazing snails were present, macrophyte growth increased due to the lesser amounts of epiphyton, but when fish ate the snails, macrophyte growth decreased. Studies by Chambers et al. (1990) and Hanson et al. (1990) were not as conclusive. They found differences in effect between male and female crayfish and species of plant because the crayfish ate snails and macrophytes. Macrophytes serve as a direct food source to many herbivorous invertebrates such as crayfish (Lorman and Magnuson, 1978; Price et al., 1980; Chambers et al., 1990; Hanson et al., 1990), and some fish (Carpenter and Lodge, 1986).

All of the above interactions may affect macrophyte frequency and biomass, but features of the plants themselves will also affect distribution. Some species of macrophytes can exclude other species (Pip, 1979; Grace, 1985). The shape of some macrophytes determines the environment that they may inhabit (Duarte and Roff, 1991). The aquatic macrophytes in the littoral zone of lakes are arranged in specific zones (Spence, 1982; Wetzel, 1983). Emergent macrophytes occur nearest the shore, the floating macrophytes occupy the intermediate zone, and the submersed macrophytes are farthest from shore.

In man-made lakes the succession of invading aquatic macrophytes follows a predictable course (Correll and Correll, 1975). The first aquatic macrophytes to become established are cat-tails (*Typha*) followed closely by bulrush (*Scirpus*). both of these have small wind-blown seeds which make them good colonizers. These macrophytes spread within the reservoir by means of rhizomes that stabilize the substrate and allow colonization by other macrophytes. Therefore, there should be an evident change in macrophyte composition between the early studies on Lakes Wedington (Allman, 1952; Owen, 1952) and Fayetteville (Hulsey, 1956; Browne, 1967; Jackson, 1977) and the present.

In reservoirs each of these zones is inhabited by certain plants (Correll and Correll, 1975). The emergent macrophytes are primarily of the following genera: spike rush (*Eleocharis*), sedge (*Carex*), bulrush, bur-reed (*Sparganium*), cat-tail, water plantain (*Alisma*), and arrowhead (*Sagittaria*). Common floating macrophytes in reservoirs are water shield (*Brasenia*), yellow cow lily (*Nuphar*), water lily (*Nymphaea*), pondweed (*Potamogeton*), water fern (*Azolla*), floating fern (*Ceratopteris*), water hyacinth (*Eichhornia*), and water meat (*Wolffia*). Submersed macrophytes found in reservoirs include water milfoil (*Myriophyllum*), coontail (*Ceratophyllum*), water nymph (*Najas*), *Egeria*, waterweed (*Elodea*), fanwort (*Cabomba*), and the macroalgae *Chara* and *Nitella*.

Previous research on other characteristics of Lakes Wedington and Fayetteville often included a description of the dominant genera or species of plants in the lakes. Hulsey (1956) reported that the only macrophyte found in Lake Fayetteville was watercress (*Rorippa*). Browne (1967) found that in Lake Fayetteville the dominant plant genera were bulrush, cat-tail, rush (*Juncus*) and a few patches of arrowhead. Jackson (1977) reported that his study sites were dominated by yellow lotus (*Nelumbo*) at the shallow sites and pondweed at the deeper sites.

Owen (1952) reported that the macrophyte population in Lake Wedington was dominated by the following genera: *Potamogeton, Lotus, Scirpus, Sagittaria,* and *Typha*. Owen also found that the aquatic macrophytes were most abundant on the western banks, with a lesser number of macrophytes also occurring on the northern shores. Allman (1952) found that the aquatic macrophytes in Lake Wedington grew primarily in the western ends of the coves. He found the following species: *Sagittaria cantata, s. latifolia, s. platyphylla, Echinochloa crusgalli, Cyperus escalenta, Scirpus americanus, Scirpus* spp., and *Eleocharis* spp.

Macrophytes of the littoral zone are important parts of many reservoir environments yet few studies of macrophytes exist for this latitude of North America, and no studies have been done solely on the macrophytes of Lakes Wedington and Fayetteville. The objectives of this study were to compare aquatic macrophytes between Lakes Fayetteville and Wedington regarding:

1) dominant genera, past and present;
2) above-substrate biomass;
3) zonation patterns.

Study Sites

We collected macrophytes from the littoral zones of Lake Fayetteville and Lake Wedington. Both reservoirs are located in Washington County, Arkansas. Lake Fayetteville is located north of Fayetteville and is an impoundment of about 69 ha on Clear Creek that was constructed in 1949-1950 (Hulsey, 1956; Browne, 1967; Jackson, 1977). Lake Wedington is located about 32 km west of Fayetteville. It was impounded in 1937 and covers an area of 33 ha (Allman, 1952; Owen, 1952).

Methods

Macrophytes were collected using methods similar to those used by Lillie (1990). We collected along transects spaced about 500 m apart for a total of eleven transects per lake. One 0.1 m^2 quadrat was sampled every two meters starting at the shoreline and proceeding through the littoral zone. All macrophytes in each quadrat were cut at the level of the substrate and counted, with each plant shoot that grew from one point out of the substrate counted as one plant. Macrophytes were identified to generic level using Correll and Correll (1975). Flowers and fruits were not available for identification to the specific level. The macrophytes were oven-dried for seven days at 55°C to determine biomass/m^2 for each genus. We used occurrence, shoot frequency, and biomass in determining genera dominance. Total biomass for both reservoirs was estimated using shoreline measurements from theses by Hulsey (1956) and Owen (1952), mean distance the macrophytes grew from the shore, and the mean biomass of macrophytes collected.

Results

A total of 11 genera of aquatic macrophytes was collected from both reservoirs. Water willow (*Justicia*), cattails, bulrush, pondweed, and horned pondweed (*Zannichellia*) occurred in both reservoirs. Rushes, coontail, and buttonbush (*Cephalanthus*) were collected only in the littoral zone of Lake Fayetteville. We observed duckweed in the littoral zone of Lake Fayetteville, but none was present in our sampled quadrats. Water lily, spike rush, and smartweed (*Polygonum*) were collected only in Lake Wedington. We observed sedge and coon-tail in the littoral zone of Lake Wedington, although none were present in our samples. The macrophyte composition was very smililar between lakes, with a similarity index of 73%.

The most dominant plant in both reservoirs based on occurrence in quadrats was water willow, occurring in 50% of the quadrats in Lake Wedington and 58% of the quadrats in Lake Fayetteville. Other macrophytes only occurred in 0 to 10.5% of the quadrats (Fig. 1).

Based on shoot frequency, water lily was the dominant macrophyte in Lake Wedington, comprising 72% of the plant shoots, while in Lake Fayetteville the rush was the most frequently occurring plant, making up 66% of the macrophyte shoots. Water willow was the second most frequent macrophyte in both reservoirs, comprising 20% of the plants in Lake Wedington and 27% of the plants in Lake Fayetteville. The other macrophytes represented less than 6% of the shoot frequency (Fig. 2).

Water willow dominated the biomass of Lake Fayetteville, making up 57% of the total. In Lake Wedington cat-tails and water willow accounted for about equal portions of the biomass, 37% and 34% respectively. Cat-tails comprised only a minor portion (6%) of the biomass in Lake Fayetteville. Rushes constituted 18% of the total biomass in Lake Fayetteville, while water lilies made up just under 18% of the biomass in Lake Wedington. The other macrophytes only contributed minor portions of the total biomass (Fig. 3).

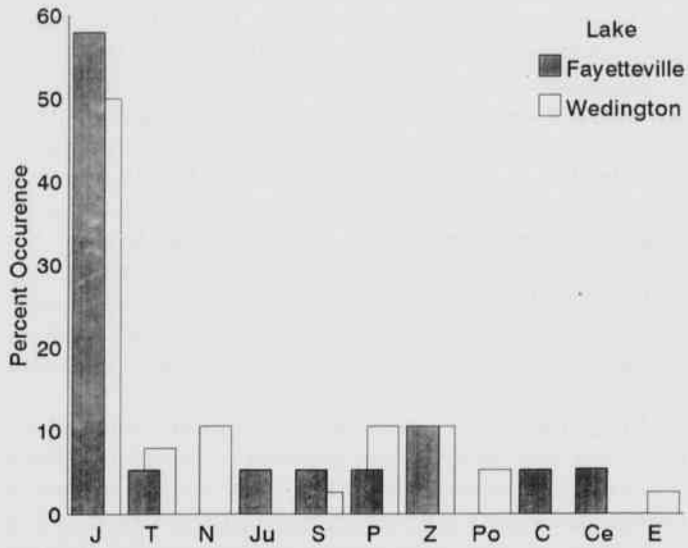

Fig. 1. Percent occurrence of macrophytes in quadrats from Lake Fayetteville and Lake Wedington in October, 1993. J=*Justicia*, T=*Typha*, N=*Nymphaea*, Ju=*Juncus*, S=*Scirpus*, P=*Potamogeton*, Z=*Zannichellia*, Po=*Polygonum*, C=*Ceratophyllum*, Ce=*Cephalanthus*, E=*Eleocharis*.

The shoreline of Lake Fayetteville, as reported by Hulsey (1956), is 8,420 m. The macrophytes in our transects extended to a mean distance of 2.45 m from the shoreline. This yields an estimated littoral zone of 20,667.3 m^2. In our collections we calculated a mean biomass of 110.6 g/m^2, for an estimated total biomass for standing crop of macrophytes of 2,285.8 kg (Table 1).

The shoreline of Lake Wedington is 6,122 m (Owen, 1952) and the macrophytes extended to a mean distance of 3.9 m from shore, yielding a littoral zone of 23,892.8 m^2, roughly equal to that of Lake Fayetteville. We calculated a mean biomass of 143.6 g/m^2 from our quadrats. This gave an estimate for the total standing crop biomass of 3,430.9 kg for Lake Wedington (Table 1).

A pattern of zonation in both reservoirs was obvious (evident to direct observers) but rather weak. Floating-leaved macrophytes occurred in only one quadrat along one transect in Lake Fayetteville. In Lake Wedington floating-leaved macrophytes occurred in only 3 of 11 transects. Submersed macrophytes were also relatively rare occurring in three transects each in Lake Fayetteville and Lake Wedington.

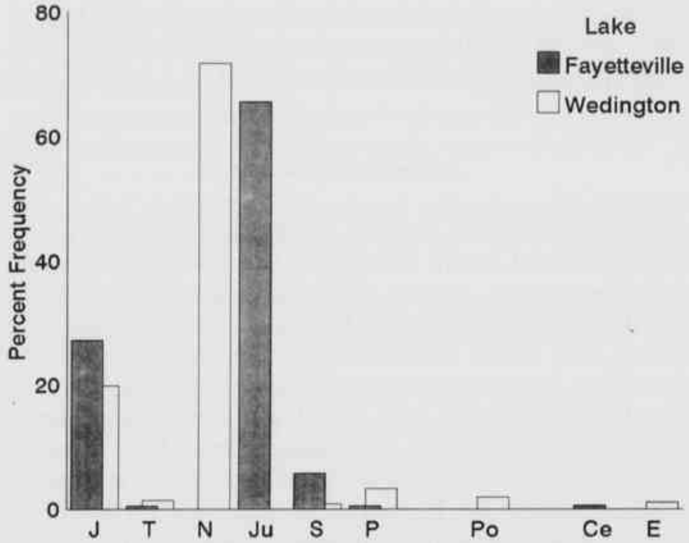

Fig. 2. Percent shoot frequency of macrophytes form Lake Fayetteville and Lake Wedington in October, 1993. J=*Justicia*, T=*Typha*, N=*Nymphaea*, Ju=*Juncus*, S=*Scirpus*, P=*Potamogeton*, Po=*Polygonum*, Ce=*Cephalanthus*, E=*Eleocharis*.

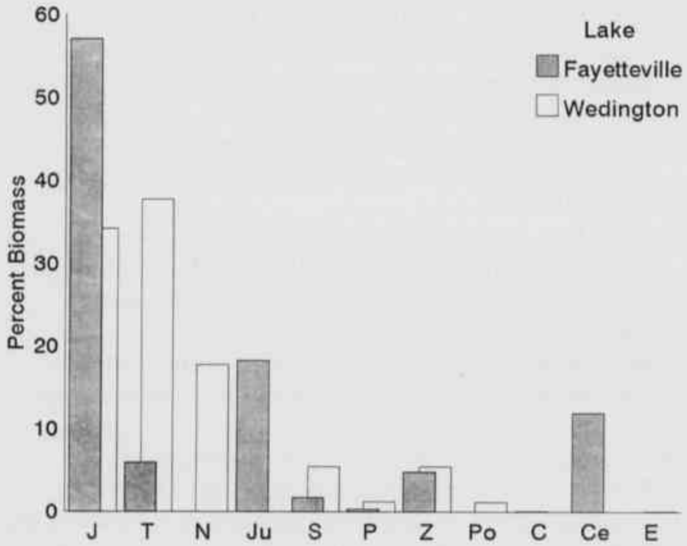

Fig. 3 Percent total biomass of macrophytes in Lake Fayetteville and Lake Wedington in October, 1993. J=*Justicia*, T=*Typha*, N=*Nymphaea*, Ju=*Juncus*, S=*Scirpus*, P=*Potamogeton*, Z=*Zannichellia*, Po=*Polygonum*, C=*Ceratophyllum*, Ce=*Cephalanthus*, E=*Eleocharis*.

Table 1. Littoral characteristics and total macrophyte standing crop biomass for Lakes Fayetteville and Lake Wedington in northwestern Arkansas during October, 1993.

	Wedington	Fayetteville
Surface Area (ha)	33	69
Mean Littoral Extension (m)	3.9	2.45
Shoreline (m)	6,122	8,420
Littoral Area (m2)	23,893	20,667
Mean Macrophyte Biomass (g/m^2)	143.6	110.6
Standing Crop Biomass (kg)	3,431	2,286

Discussion

Water willow was the most dominant macrophyte in both reservoirs. The high frequencies of water lily and rush were the result of a large shoot number occurring in very few quadrats, and is, therefore, over-emphasized in Fig. 2. Even though cat-tails had a low frequency and occurrence, in Lake Wedington they contributed a large amount of biomass. All other macrophytes were of minor importance in comparison to these.

The standing crop biomass of Lake Wedington was much larger than in Lake Fayetteville even though Lake Fayetteville has a larger shoreline and a shallower, potential littoral zone than Lake Wedington. Observations in other recent years indicate that the anomalous results of 1993 could have been caused by the application of an herbicide in 1992 (Hal Brown, pers. comm.).

The pattern of zonation in both reservoirs was weakly developed. In Lake Wedington only three transects contained all three zones, and the reservoir had two areas of extensive water lily growth. In Lake Fayetteville the data from transects did not support the weak zonation pattern observed. Only one floating-leaved macrophyte was collected and submersed macrophytes occurred in only three quadrats.

In Lake Fayetteville we collected four macrophytes (cat-tails, bulrushes, rushes, and pondweed) that were also present in early studies (Hulsey, 1956; Browne, 1967; Jackson, 1977). Macrophytes found in past studies that did not occur in our samples included arrowhead, yellow lotus, and watercress. The most notable macrophyte we collected that was not present in the past studies was water willow. The buttonbush that was growing four meters from the shore in the littoral zone was rooted on a raised tree bole and therefore might not be considered to be a truly littoral plant. However, buttonbush was relatively abundant in the wet soil near the water. The submersed macrophytes, horned pondweed and coontail, may possibly have been present but not detected in the past studies (Table 2).

In Lake Wedington, macrophytes collected that were also present in the studies of 1952 (Allman, 1952; Owen, 1952) include cat-tails, bulrushes, pondweed and spike rush. Macrophytes noted by Owen and Allman that we did not collect were arrowhead, yellow lotus, watercress, and water hyacinth. Macrophytes collected in 1993 that did not appear in the studies of 1952 were water willow, water lily, and smartweed. As with Lake Fayetteville, it is possible that the submersed macrophye, horned pondweed, was present in 1952 but not detected (Table 3).

Table. 2. Comparison between macrophytes found in early studies (Hulsey, 1956; Brown, 1967; and Jackson, 1977) and those found in Lake Fayetteville during October, 1993.

Early	1993
Typha	*Typha*
Scirpus	*Scirpus*
Juncus	*Juncus*
Potamogeton	*Potamogeton*
Sagittaria	*Justicia*
Nelumbo	*Cephalanthus*
Rorippa	*Ceratophyllum*
	Lemna

Table 3. Comparison between macrophytes found in early studies (Allman, 1952; Owen, 1952) and those found in Lake Wedington during October, 1993.

1952	1993
Typha	*Typha*
Scirpus	*Scirpus*
Eleocharis	*Eleocharis*
Potamogeton	*Potamogeton*
Sagittaria	*Justicia*
Lotus	*Nymphaea*
Echinochloa	*Zannichellia*
Cyperus	*Polygonum*
	Carex
	Ceratophyllum

Conclusions

The changes in both reservoirs are at least partially due to recent disturbance events. In the spring of 1992 most of the macrophytes in Lake Fayetteville were eliminated by herbicide poisoning. In the spring of 1991 the water level of Lake Wedington was lowered by 2 meters for a construction project. Both events probably altered the littoral zones, but since Lake Wedington may have been less-severely affected and had longer to recover, it has a greater biomass and was farther along in re-establishing a zonation pattern. Water willow had probably become the dominant macrophyte due to its ability to resist disturbance, supported by its widespread occurrence in Ozark streams which experience frequent harsh floods and droughts. The presence of watercress in these two reservoirs during the early studies (1950s) suggests a lingering stream influence at that time. The abundance of *Justicia* during our study and the disappearance of several other species which were reported earlier suggests that it has displaced some of the earlier species.

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