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Short communication

A comparison of two sampling techniques in the study of submersed macrophyte richness and abundance

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Abstract

Sampling procedures represent a critical component of plant community studies, particularly for deep-water submersed species that are not easily observed. Here, two methods of submersed macrophyte sampling are compared for their accuracy and consistency. During 2 years of study, in-water sampling produced higher values of total species richness (nine species compared with eight in 1996 and 14 species compared with 10 in 1997), mean species richness in quadrats (2.3 compared with 1.4 in 1996, 2.2 compared with 1.1 in 1997) and frequency for all species than the boat surveys did. Small species were particularly vulnerable to underestimation in boat surveys. In-water sampling was also less variable, producing higher mean-to-variance ratios.

Keywords: Aquatic plants; Community structure; Species richness; Tidal wetland

1. Introduction

Sampling methods are the foundation of plant community studies (Wade and Bowles, 1981; Golterman et al., 1988), and the appropriateness of a particular method can be judged by its power to answer the questions being asked accurately and unambiguously (Wiegleb, 1988). Until the middle of the 20th century, aquatic plant communities were studied primarily by wading in shallow water or, in deeper water, by observing plants from a boat and retrieving samples with a grapnel or rake (Denniston, 1922). Wading produced satisfactory results for studies of shallow rivers and remains a standard procedure for such habitats

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(Wright et al., 1981; Ham et al., 1982). However, the results of studies of deep-water plants, which are not easily observed from the surface, have been less satisfactory. Rakes and grapnels used in boat sampling can lose plant material, and results vary depending on the homogeneity of stands (Golterman et al., 1988), bottom texture (Wood, 1963), stem density (Sheldon and Boylen, 1978; Golterman et al., 1988) and other factors.

Various dredges and other sampling devices have been developed (Forsberg, 1959), but none were completely satisfactory (Westlake, 1969; Sheldon and Boylen, 1978), and they appear to be used only occasionally. In the 1950s and 1960s, snorkeling (Swindale and Curtis, 1957) and SCUBA equipment (Wood, 1963) were adopted for the study of submersed plant communities, and these 'in-water' techniques have been used to gather quantitative data on community structure, succession and competition. However, the results of work done using these techniques rarely have been compared quantitatively with results obtained using in-boat sampling techniques. In this study, the ability of two sampling methods to estimate species richness and abundance, both major quantitative components of community structure, is evaluated. Specifically, the quality of data obtained by boat sampling techniques is compared with data obtained with in-water study.

2. Methods

The study was carried out in Whalebone Cove (41°25′N, 72°25′W), CT, USA, a freshwater tidal wetland. The cove is in excess of 350,000 m^2 in area and lies on the east side of the Connecticut River, 16 km north of its mouth. Sampling was performed at 41 locations selected to represent all parts of the cove and all habitat types, including areas with deep water and strong currents and more shallow areas with little water movement. At each sampling site, a submersed frame constructed of 1.25 in. diameter PVC pipe was used to create an array of 16 quadrats, each 1 m^2. Eight quadrats were sampled from a boat, using a long-handled rake. The remaining eight quadrats were censused in the water, using snorkeling equipment. Alternate plots were sampled using the two methods. At every sampling location, the frame was oriented in a north/south direction, and the position of the northeast corner was recorded with Global Positioning System equipment (Pathfinder Pro XL, Trimble Navigation Co., Sunnyvale, CA) so the frame could be returned to the same location in the future, using a differential correction unit (Trimble Pro Beacon). The first survey was conducted from June to August 1996, and the procedure was repeated from June to August 1997.

In boat sampling, all plants present in a quadrat were identified by observation from the boat and by retrieving specimens with the rake. Plants were identified to species, and their presence was recorded. During in-water sampling, using snorkeling equipment, the identity of each species in each quadrat was recorded. Only submersed angiosperms were considered in boat and in-water sampling. Total species richness, based on both boat sampling and in-water censuses were calculated for each of the 2 years of data. Mean quadrat richness levels were calculated for both years, and the significance of differences in means was calculated using two-sample *t*-tests assuming unequal variance. Variability of richness estimates obtained with the two sampling methods was assessed by calculating the mean-to-variance ratios. The frequency of occurrence of each species was also calculated, based on the percentage of quadrats in which it was found with each sampling method.

Table 1
Species richness compared for boat-based and in-water sampling[a]

	1996		1997	
	Boat sampling	In-water sampling	Boat sampling	In-water sampling
Total species richness	8	9	10	14
Mean quadrat richness	1.4	2.3***	1.1	2.2***
Range of quadrat richness	0–4	0–6	0–5	0–7

[a] All values represent numbers of species.
*** $p<0.001$.

3. Results

Sampling by both boat and in-water inspection was possible at 33 sites in 1996. In other locations, the water was too deep to permit retrieval of rake samples or too turbid to permit viewing of submersed plants. Sampling in 1997 was conducted at 31 locations, using both the methods for all of them. Results are presented only for those quadrats where both sampling methods were used, so differences in results can be attributed confidently to sampling methods, not to differences in sampling locations.

Values of total species richness obtained by in-water inventories were higher for both years than richness values obtained by boat sampling (Table 1). In 1996, eight species were recorded in boat sampling, compared to nine with in-water surveys. In 1997, 10 species were recorded in sampling from the boat; these and four additional species were recorded in water-based surveys. That the boat sampling richness estimate increased from 1996 to 1997 indicates that there is little likelihood that the first-year sampling biased the second-year estimate by causing vegetative destruction in those quadrats. In both years, mean richness of quadrats was significantly higher with in-water inventories than in-boat sampling ($p<0.001$ both years). Boat sampling produced more variable richness estimates for both years, which resulted in lower mean-to-variance ratios. The mean-to-variance ratio for in-water richness estimates was 1.7:1 in 1996, compared to 1.4:1 for in-boat surveys. In 1997, the mean-to-variance ratios were 1.5:1 for in-water surveys and 1.3:1 for boat surveys.

In 1996, nine of the 16-quadrat plots were recorded as having no submersed vegetation, based on in-boat sampling, but eight of these were found to contain some submersed plants when surveyed in the water. In 1997, two 16-quadrat plots apparently lacked submersed vegetation; however, in-water examination revealed two species in one and four in the other. In plots where only one species was recorded with boat sampling, as many as seven species were found during in-water surveys.

The frequency with which every species occurred in quadrats was higher when determined by in-water censusing than by in-boat sampling for both years (Table 2). The frequency of several species was twice as high when determined using in-water censusing than was indicated by boat sampling.

4. Discussion

Most taxonomic or ecological studies of communities require, at a minimum, an accurate assessment of species richness (Kershaw and Looney, 1985), and this study shows

Table 2
Comparison of the frequency of submersed species in quadrats 1 m^2 as determined by different sampling techniques, for 1996 and 1997

	1996 (*n*=264)		1997 (*n*=248)	
	Boat sampling	In-water sampling	Boat sampling	In-water sampling
Vallisneria americana Michx.	46.2	54.9	48.4	66.1
Potamogeton pusillus L.	30.3	53.8	9.5	31.1
Elodea nuttallii (Planch.) St. John	18.2	35.2	24.8	39.5
Ceratophyllum demersum L.	16.7	31.8	12.4	29.8
Zannichellia palustris L.	17.8	35.2	5.4	25.4
Potamogeton perfoliatus L.	7.6	10.2	4.6	7.7
Najas flexilis (Willd.) Rostk. & Schmidt	1.5	4.2	0	7.7
Potamogeton crispus L.	1.5	2.7	0	0
Potamogeton spirillus Tuckerm.	0	0	0.8	3.2
Potamogeton pectinatus L.	0	0	1.7	2.0
Najas minor Allioni	0	6. 5	0	0.8
Potamogeton epihydrus Raf.	0	0	0.8	1.6
Potamogeton nodosus Poir.	0	0	1.2	1.6
Utricularia vulgaris L.	0	0	0	0.4
Myriophyllum spicatum L.	0	1.9	0	0.4

that sampling from a boat provides less satisfactory results than analyses involving direct inspection of submersed plants in the water. In both years of this study, more species were recorded during in-water censuses than in boat samples. Underwater observations, thus, provided a more complete and accurate reflection of the richness of the community. Earlier researchers reached similar conclusions. Wood (1963) found that sampling from a boat was 68% as effective as in-water surveys in detecting the presence of submersed species. Sheldon and Boylen (1978) found that only 59% of the submersed species present in Lake George were recorded with boat sampling, compared to 96% recorded by divers. Wade and Bowles (1981) reported that, of the three methods compared in surveys of 20 lakes — boat sampling, sampling from the shore with a grapnel and in-water surveys — boat surveys were least efficient in terms of number of submersed species recorded per time allotted, and in-water surveys were most efficient.

Not surprisingly, small species are particularly vulnerable to exclusion in boat-based surveys (Department of the Environment, 1987). In the present study, *Najas flexilis* (Willd.) Rostk. & Schmidt would not have been recorded in 1997 with in-boat sampling procedures alone, although in-water censuses showed the species occurred in 7.7% of the quadrats studied. *Najas minor* Allioni also escaped detection by boat sampling but was recorded with in-water surveys. The species had not been found previously in Whalebone Cove, and its discovery in 1997 represented the first report of the species in the Connecticut River basin (C.B. Hellquist, personal communication).

Frequency data recorded using in-water censusing showed that species also are more prevalent than boat sampling indicated. The frequency of occurrence found by in-water censusing was consistently higher, even for large species, but differences were particularly dramatic with data for small plants. For example, the thread-like *Zannichellia palustris* was recorded in 5.4% of quadrats with boat sampling and 25.4% of quadrats with in-water censusing in 1997. This annual species commonly grows under other plants, including the long-leaved *Vallisneria americana* Michx., and is easily obscured. Inadequate sampling procedures likely contributed to the previous listing of *Z. palustris* as a species of special concern in Connecticut although it has since been found to be abundant and widespread in surveys (including in-water observations of plants) of Connecticut River tidal wetlands (Barrett et al., 1997).

In many communities, dominant, abundant species represent only a fraction of the total species richness (McNaughton and Wolf, 1970), while rare or uncommon species may play important roles in community function (den Hartog and van der Velde, 1988), especially by preserving community integrity during periods of disturbance. Tidal marshes and other aquatic habitats are highly dynamic systems (Wiegleb, 1988), and it is precisely in such dynamic systems that rare species are most likely to become common and/or ecologically important in the future. For these reasons, an accurate assessment of species richness and abundance is particularly important in monitoring the health and dynamics of submersed plant communities. An additional advantage of in-water censusing is that it is non-destructive — an essential quality when working in communities that have or might have rare species (Department of the Environment, 1987). In-water surveys ensure that multiple-year community dynamics studies escape the potential confounding effects of destructive boat sampling, which can cause long-lasting damage and potentially lead to disappearance of some species and the increasing dominance of others.

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