J. Aquat. Plant Manage. 36: 130-137

Using Videotaped Transects to Estimate Submersed Plant Abundance in Fall River, California

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ABSTRACT

Using an underwater viewing device, we videotaped transects of submersed aquatic plants during two years in Fall River, California. Less than eight hours on the river were required to videotape more than 50 transects in an eight km (5 miles) section of the river. Videotapes were viewed upon return to the laboratory and plant frequency determined. Viewing required about 50 hours, but could be done at the laboratory instead of in the field. This technique yielded very clear pictures of the plants and the river bottom and distinguishing plant species was not difficult. Using this technique in conjunction with a global positioning system, we were also able to develop vegetation maps. Species frequency values were comparable to those collected by other

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workers using different techniques and sensitive enough to reveal year to year differences when analyzed using 2 × 2 contingency tables.

Key words: Sampling methods, aquatic plant frequency, vegetation map.

INTRODUCTION

Assessing aquatic plant abundance and the effectiveness of various management techniques, often requires quantitative data in the form of plant coverage, distribution, and biomass. Several methods including line intercept-transects, aerial photography, and direct biomass sampling have been used to estimate submersed macrophyte abundance. Direct methods like biomass sampling (Sabol 1984, Osborne 1984, Sliger et al. 1990, Madsen 1993, Marshall and Lee 1994a), however, may be costly, labor intensive, and may be unsuitable when large areas must be sampled (Schloesser and Manny 1984). Remote sensing techniques utilizing color and infrared aerial photography have been used successfully for emergent and floating aquatic macrophytes (Almkvist 1975, Shima et al. 1976) but have not been extremely successful for determining the abundance of submersed vegetation (Spooner 1969, Benton and Newman 1976). More recently, Marlyn et al. (1986) and Marshall and Lee (1994b) report that boundaries of plant beds and estimates of plant cover can be successfully obtained from aerial photography; however, obtaining detail at species level for submersed plants is problematic (but see Andrews et al. 1984). Recording fathometers have been used to rapidly determine coverage of the submersed plant hydrilla in Lake Baldwin, Florida (Maceina and Shireman 1980, Maceina et al. 1984) and a mixed community dominated by *Potamogeton, Vallisneria,* and *Nitella* in Lake Saint-Pierre in Quebec (Fortin et al. 1993). Vegetation maps may also be useful (Raschke 1984). Harvey et al. (1988) used an automated positioning system to construct vegetation maps.

Line transect sampling methods (Brower and Zar 1984) often provide a practical basis for quantitative, nondestructive sampling of submersed aquatic plants. In aquatic sites, a weighted nylon or lead core line, usually marked off in meters, is laid out along a compass line between two known points, to obtain the transect. In deeper water, divers may lay the line directly on the bottom. Numbers of plants occurring along the line, presence of each species within an interval, or linear distance occupied by each plant along the line are recorded. This type of transect is tedious and time consuming to conduct, especially in underwater surveys. There are also problems in deciding what lies under a line (Raschke and Rusanowski 1984). Use of line transect methods in lakes has been recently reviewed by Titus (1993), who identified the following additional restrictions on the use of these methods 1) limited visibility due to surface glare, low water transparency, water depth, easily suspended sediments, or SCUBA gear obscuring peripheral vision, and 2) reduced maneuverability of the SCUBA diver or boater within weed beds. Despite these problems, transect methods have been used for quantifying aquatic vegetation in streams and rivers (Madsen and Adams 1985, Bouchard and Madsen 1987, and Getsinger et al. 1997) as well as lakes.

As part of an assessment of the aquatic plant community of Fall River in northern California, we conducted line transects within the river. We modified the line transect procedures described above by using a glass-bottomed underwater viewer in conjunction with a hand-held light weight video camera to make videotapes of transects. We report here our experiences with the modified technique, as well as comparison of macrophyte abundance during two years using this technique.

MATERIALS AND METHODS

Fall River is located in northern California in the northeastern corner of Shasta County about 97 km northeast of Redding (Figure 1). Fall River is a moderately sized, slow flowing, meandering meadow stream. It varies in width from 15 m near its headwater to 92 m in the lower reaches; depth ranges from approximately 0.6 m to an estimated 6 m in the deeper pools. The average gradient is less than 0.2 m/km. Fall River is surrounded by land that is used primarily for agriculture (42%) and forested grazing land (34%) (Rode and Weidlein 1986). In recent times, the wild trout fishery of the Fall River has become known as one of the finest places for dry fly fishing in North America (Rode and Weidlein 1986). Fall River is

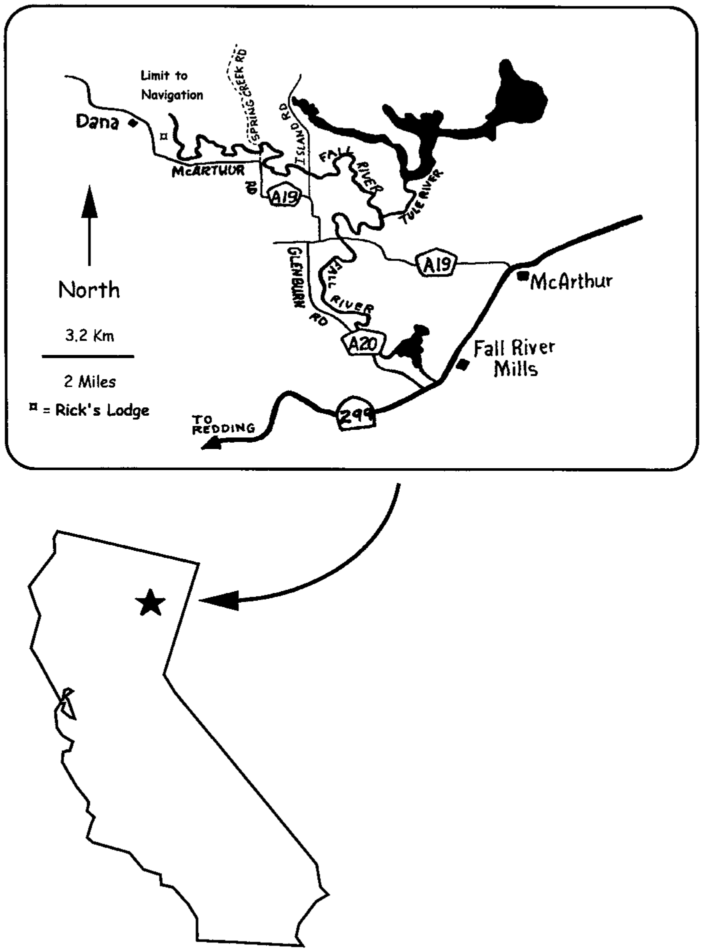

Figure 1. Map of upper Fall River and vicinity.

a unique natural resource for the State of California and plays an important role in the economy of the Fall River Valley.

Prior to our sampling efforts, we made preliminary trips down Fall River by boat to assess general habitat characteristics and to become familiar with landmarks and navigation hazards. On July 23 and 24, 1996, we performed transects across the river at 56 locations in the portion of the river downstream of the "limit to navigation" and upstream of Island Road Bridge (Figure 1). The locations of the transects were picked at random as we proceeded upstream in this 8 km (5 miles) section of the river.

Each transect consisted of the following procedure. An underwater viewing device was lowered into the water (only a few cm) on the sunny side of the boat. The viewer was shaped like an Erlenmeyer flask. It was 59 cm tall and had a 17-cm diameter glass bottom. An 8 mm video camera (Sony Model CCD-TRV1 1) was held above the viewer and the river bottom was videotaped as the boat was directed across the river. The video camera recorded the time, including seconds, directly on the videotape. Verbal comments on the aquatic plants present as well as other pertinent information were also recorded on the tape. We recorded the starting and ending location using a Garman Model 75 GPS unit, operating on version 2.32 software. This procedure was repeated on July 22 and 23, 1997, when we obtained data from 53 transects.

For these transects we used a boat equipped with a 4 horsepower outboard engine and used the slowest possible speed given the engine size. Since engine speed may not be constant we attempted to measure its variation in the following manner. In 1997 we estimated the length of each transect using a Bushnell Yardage Pro 400 Laser Rangefinder. With these data we calculated the average length of an interval by dividing the transect length by the number of intervals (= seconds) in the transect. We also evaluated the effect of mean interval length on the mean number of plant species recorded in each transect using linear regression to determine if variation in boat speed influenced the number of species that were recorded for each transect.

To further evaluate the reliability of this new procedure, we recorded one transect 10 separate times. The transect was located just downstream from Fletcher's Bridge. We calculated the frequency of each species and for all vegetation for each transect. We then combined the data from all the transects and estimated frequency again. We calculated the coefficient of variation (CV) for frequencies from the 10 repeated transects. Calculations and statistical procedures are described below, except that we used χ^2 (Chi-square) from a 2 × 10 contingency table to test the null hypothesis that there is no difference among the frequencies (i.e., proportions) in the 10 transects (Zar 1996).

On September 19, 1996, we executed a single transect beginning at Read's Bridge and continuing down the river to a point midway between Whipple Bridge and Mack Bridge. This longitudinal transect was generally down the center of the river. On a separate trip, we videotaped the screen of the GPS unit to record our relative latitude and longitude and we tracked a similar route down the river. We combined these two data sets to construct vegetation maps of individual species in Fall River.

Upon returning to the laboratory at Davis, the videotapes were played back with a video recorder (Sony, Stereo Cassette Recorder Model EV-C100) capable of pausing at each second within a transect. The picture on the screen at each second was treated as a transect interval and the presence/absence of a particular species was recorded. We only considered plants in the center of the picture, since changes in water depth influence the width of the field of view. The frequency of each species was calculated according to equation 1:

$$f_j = j_i/k \qquad (1)$$

where f_i is the frequency of species i; j_i is the number of intervals containing species i; k is the total number of intervals within each transect or river section. Although we recorded the presence/absence of species for each interval, only values from every other interval were used to calculate species frequencies. Using the presence/absence value for each transect interval would result in nonrandom sampling since the intervals were contiguous (Titus 1993). Skipping every other interval resulted in a stratified random sampling design, as data from each interval are independent of other intervals. Grieg-Smith (1983) cited results that indicate that the accuracy of frequencies from systematic sampling designs (i.e., stratified random samples) was equivalent to that of random samples using the same number of quadrats for artificial grasslands. We used the intervals from several transects within a given river section to calculate aquatic plant frequencies. The river sections were: A, above Fletcher's Bridge; B, Fletcher's Bridge to the New Bridge; C, New Bridge to Spring Creek Bridge; and D, below Spring Creek Bridge (refer to Figures 2 and 3).

Data recorded in this manner (presence/absence) can be used to calculate frequency, the proportion of samples in which a species (or all species) occurs. Grieg-Smith (1983) makes the following points with respect to statistical treatment of frequency data. Successive sets of random samples from the same population will be binomially distributed. The binomial distribution is very asymmetric unless the sample size is large (> 100) or the proportion close to 0.5. Grieg-Smith (1983) states that it is inadvisable to use the standard error in assessing the accuracy of frequency values unless they are based on a large number of samples. Grieg-Smith (1983) also states that the mean and variance from a binomial distribution are correlated, and further notes the inadvisability of using a t-test to compare two frequencies. Since any data set of plant frequency may include a wide range of values and not just values near 0.5, it is desirable to have a method for statistical analysis that can be applied consistently to all of the data.

Grieg-Smith (1983) recommended using 2 × 2 contingency tables instead. Analysis of contingency tables has commonly used χ^2 (Chi-square) or other statistic to test the hypothesis that observed and expected frequencies are similar. Use of 2 × 2 contingency tables to test for associations is a well established procedure among ecologists (Kershaw 1973, Poole 1974, Pielou 1977, Grieg-Smith 1983, Ludwig and Reynolds 1988), but they have not been widely applied to data from aquatic plant communities (Titus 1983, Madsen and Adams 1985, Bouchard and Madsen 1987, Getsinger et al.

1997). We compared the frequency of aquatic plants in four river sections for two years using 2 × 2 contingency tables (PROC Frequency, SAS Institute 1990). We used Fishers' Exact Test, instead of χ^2, because Zar (1996) indicated that 2 × 2 contingency tables were best analyzed by this procedure. We used a 2-tailed test, since we had no *a priori* reason to expect plant frequency to either increase or decrease between years. Zar (1996) provides sample calculations for Fisher's Exact Test. This procedure can be laborious and use of an appropriate computer program is recommended. We used the procedures described by Zar (1996) to calculate 95% confidence limits for aquatic plant frequency (i.e., proportion).

We collected samples of plants from the river for identification. Taxonomic placement was according to descriptions provided in Hickman (1993). The identification of *Myriophyllum sibiricum* was verified by analysis of flavanoid compounds using the procedures described by Ceska and Ceska (1985).

RESULTS AND DISCUSSION

Table 1 lists the submersed aquatic plants observed in Fall River during 1996 and 1997. Three species were not observed in the transects (*Eleocharis acicularis, Rorippa nasturtium aquaticum,* and *Sparganium emersum*) but are included here for completeness. The species found in Fall River are common in rivers throughout the world (Hynes 1970, Westlake 1975, Haslam 1978), and historically, these species have been collected from geographically widespread freshwater ecosystems in California. None are listed as rare or endangered in the latest edition of The Jepson Manual (Hickman 1993).

Based on the results of the transect down the river, we constructed vegetation maps of the submersed species. The map for *Zannichellia palustris* illustrates this type of map (Figure 2). Such maps show the relative locations of particular submersed plants in Fall River. This single transect consisted of 5654 contiguous quadrats (i.e., frames from the videotape representing each second). Data from this transect produced the following ranking of species frequencies: *Zannichellia palustris,* 0.278 (95% Confidence Interval = 0.268 to 0.288); *Callitriche hermaphroditica,* 0.127 (0.119 to 0.134)*;* *Elodea canadensis,* 0.070 (0.065 to 0.076); *Myriophyllum sibiricum,* 0.025 (0.021 to 0.28); *Chara* sp., 0.0004 (0.00006 to 0.00111); and *Ranunculus aquatilis,* 0.0002 (0.000009 to 0.000839). Combining data for all species present, the frequency of all types of submersed plants was 0.392 (0.381 to 0.403).

TABLE 1. AQUATIC PLANTS OF FALL RIVER, CALIFORNIA.

Species	Common Name
Chara sp.	Muskweed
Elodea canadensis Michx.	Common water weed
Callitriche hermaphroditica L.	Water-starwort
Eleocharis acicularis (L.) Roemer & Schultes	Spikerush
Myriophyllum sibiricum V. Komarov	Northern watermilfoil
Potamogeton foliosus Raf.	Leafy pondweed
Ranunculus aquatilis L.	Water buttercup
Rorippa nasturtium-aquaticum (L.) Hayek	Water cress
Sparganium emersum Rehmann	Bur-reed
Zannichellia palustris L.	Horned pondweed

Figures 3 and 4 show the frequency of submersed plants that were present in the transects, from each of four river sections, sampled in late July during 1996 and again in 1997. As a group, submersed plants were more abundant in sections A and D. The middle sections of the river (B and C) were characterized by somewhat lower plant abundance. Based on the data from the transects, the frequency of all submersed plants was 0.51 in 1996 and 0.44 in 1997. These values are somewhat higher than the value, 0.39, obtained from the single downstream transect in 1996. This difference may be in part due to the fact that the 1996 longitudinal transect generally followed the river channel while the other transects were generally perpendicular to the channel.

Examination of individual species frequencies provides a more detailed view of year-to-year dynamics of species abundance (Figure 3 and 4). *Zannichellia palustris* was most abundant in river section D. In 1996, it was less abundant in other river sections. This species was absent from section B, during 1996. In 1997, *Zannichellia palustris* was still most abundant below Spring Creek Bridge, but its abundance had decreased slightly. *Zannichellia palustris* abundance was not significantly different for the two years in section A, it increased in the two middle sections and declined in section D.

Elodea canadensis was found throughout the river in 1996 and 1997. However, there were significant declines in all river sections in 1997. Large beds of *Elodea canadensis* were present in section C, near the site known as Fish Camp and at a second location just upstream from the influx of Spring Creek. In 1997, the abundance of *Elodea canadensis* was reduced at these sites and it was also apparent that sandy sediments had accumulated in these areas.

Callitriche hermaphroditica was only observed in sections A, B, and C in the transects for 1996 and 1997. Abundance fluctuated somewhat, but was similar for both years. *Myriophyllum sibiricum* was more abundant at the two upstream river sections (A and B). During 1996, it was also present in section C, but it was absent from this section in 1997. Examination of this site indicated that sandy sediments had accumulated here. *Myriophyllum sibiricum* was not observed growing below Spring Creek Bridge during either 1996 or 1997. *Ranunculus aquatilis* was most abundant in section A during both 1996 and 1997. Although it was present in section B in 1996, it was not observed there during 1997.

There is little information about the Fall River aquatic plant community in the published literature. A survey of animals and plants in the Fall River was conducted between 1990 and 1992 and reported by Ellis and Hesseldenz (1993). Ellis and Hesseldenz (1993) used GIS procedures to estimate cover of aquatic vegetation in Fall River. Ellis and Hesseldenz (1993) did not provide information on the variation associated with their cover estimates Their estimates were based on plant presence in 100 m long segments of the river and thus may not be directly comparable to the present results which are estimates of plant frequency. They reported their results for three sections of Fall River which appeared to be defined as follows: uppermost Fall River, above Read's Bridge; upper Fall River, below Read's Bridge; and lower Fall River, below the mouth of the Tule River. In the present study, we sampled primarily between Read's Bridge and the Mack Bridge. Thus our data is most comparable to the data reported by

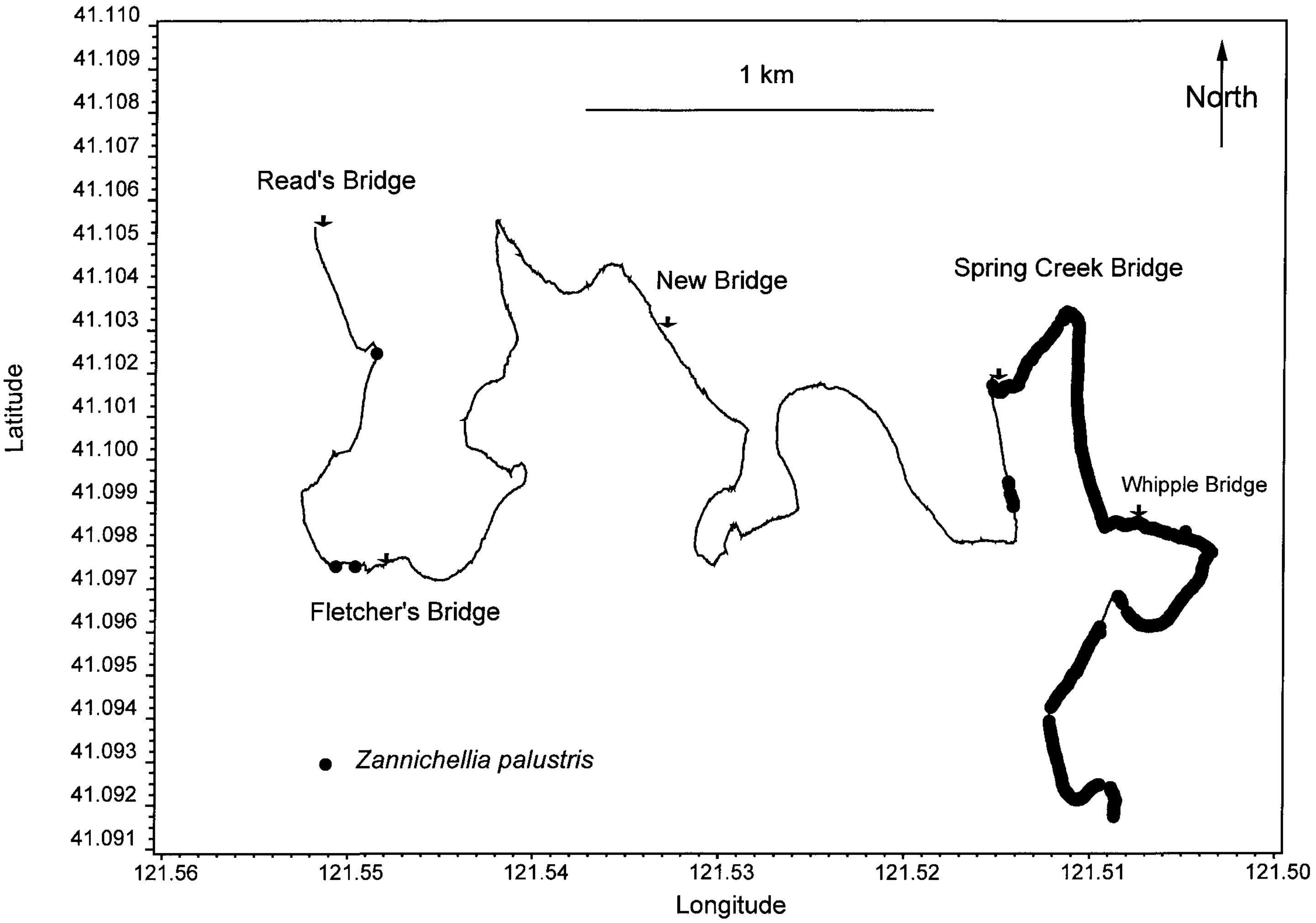

Figure 2. Vegetation map showing the distribution of *Zannichellia palustris* in Fall River in September, 1996. This portion of the river corresponds to Figure 1 just upstream from Island Road.

Ellis and Hesseldenz (1993) for the section they designate as upper Fall River, i.e., the area between Read's Bridge and the mouth of the Tule River. It appears from their dive logs that data from for this section of the river was collected in June and July of 1991 (Ellis and Hesseldenz 1993). For the area below Read's Bridge, Ellis and Hesseldenz (1993) reported that *Elodea* (23% cover) was more abundant than *Zannichellia* (14%) or *Myriophyllum* (3% cover). This ranking of species abundance is different from that obtained from the frequency data reported here. The sum of the values for cover of individual species of submersed aquatic plants given in Table 3 of Ellis and Hesseldenz (1993) is 46%. This is similar to the overall mean frequencies for all plants from our transects in 1996 and 1997. Ellis and Hesseldenz (1993) did not report *Callitriche hermaphroditica* as occurring in Fall River, so the procedures used here were sensitive enough to detect this change in community composition.

Contingency table analysis indicated no statistically significant differences among the 10 repeated recordings of the same transect (Table 2). Comparison of plant frequencies in the 10 repeated recordings of the same transect with the frequencies of the combined data showed that in all cases the 95% confidence intervals of the frequencies from the individual transects overlapped with the 95% confidence intervals of the frequency value for the combined data. (Table 2). Coefficients of variation (CV) for the repeated transects were from 3.2% to 19.5% with the largest values associated with the least abundant species. Such a result would not be unexpected, since slight changes in course when measuring the same transect could lead to scarce species being missed.

We found that the average boat speed for the 53 transects collected in 1997 was 0.6 m/s with a CV of 20%. This variation in boat speed directly influenced the length of each interval within a transect, since each second on the videotape was an interval. However, there was no evidence that this slight variation affected the average number of species per interval. The average number of species per interval was 0.49 with a CV of 72%. The regression of number of species per interval versus interval length was not significant (P = 0.11) and interval length explained little of the variation in the

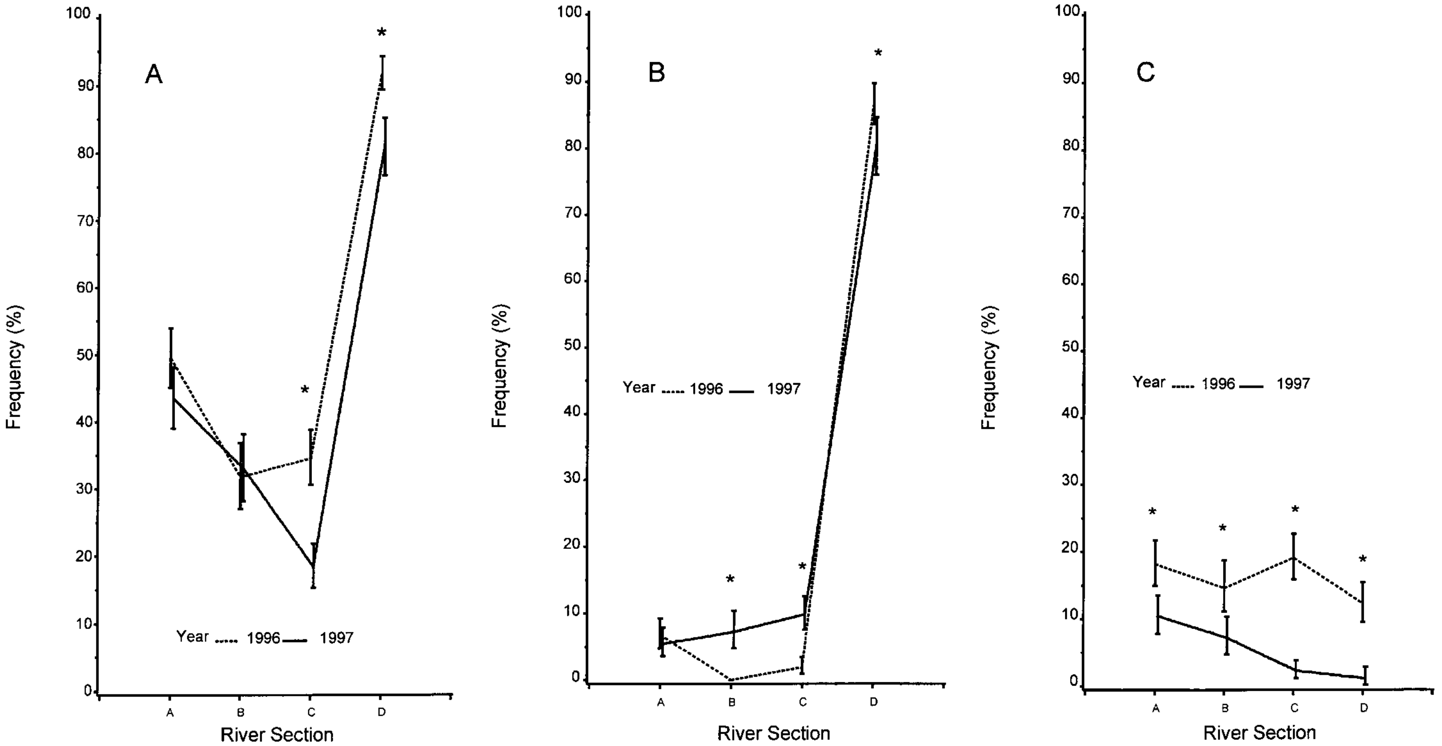

Figure 3. Frequency of all submersed aquatic plants (A), *Zannichellia palustris* (B), and *Elodea canadensis* (C) in four sections of Fall River during two years. The sections are A, above Fletcher's Bridge; B, between Fletcher's Bridge and New Bridge; C, between New Bridge and Spring Creek Bridge; and D below Spring Creek Bridge (see Figure 2). Values plotted are the frequency and 95% confidence limits. An asterisk above a bar indicates that a 2-tailed Fisher's Exact Test comparing the frequencies for both years indicated that the probability of obtaining the observed frequencies by chance alone was less than 0.05, leading to rejection of the null hypothesis that the frequencies were the same.

number of species per interval (R-square = 0.048). It appears that slight variations in boat speed did not result in a significant bias in the frequency data gathered by these techniques.

Using the techniques described above we were able to record data from > than 50 transects in less than two days in both 1996 and 1997, with only about eight hours actually spent on the river. The longitudinal transect down the river required a little less than three hours. The most labor-intensive aspect of this procedure was viewing the videotapes which required about 50 hours of viewing time. One advantage of using videotapes is that the tapes can be viewed repeatedly if there is some doubt as to the species identification or whether it should be considered as under the transect line. This advantage may also increase the time spent viewing the tapes since it is very easy to replay the tapes to make sure of one's decision. Another important advantage is that this technique can be used when certified SCUBA divers are unavailable.

One limitation of using this technique is that the diameter of the field of view (i.e., area) recorded on the videotape changes depending on the water depth over the bottom being recorded. This can be overcome by considering only plants directly in the center of the image as being part of the transect. One way to facilitate this is to place a piece of tape on the inside of the underwater viewer. This marks the center of the field of view and represents the physical transect line. Another potential limitation is water clarity. However, this was not a problem at the time these transects were made in Fall River, which is very clear throughout summer and autumn (mean light transmission through 1 m of the water column was 46%, N = 127, mean turbidity was 0.8 NTU, N = 41). We were also impressed by the sharpness of the videotaped plant images. Distinguishing plant species was not difficult using the videotapes. The majority of these transects were taken in water depths between 2 and 3 m. We were able to discern short-statured *Callitriche hermaphroditica* (generally < 15 cm) as well as taller plants such as *Zannichellia palustris* (present in Fall River as plants ranging from 15 cm to > 150 cm). In one transect taken in an area with 5-m deep water, *Zannichellia palustris*, trailing near the bottom due to the current, was visible. This technique may be particularly suited to rivers, where flow results in canopy movements, which allow understory plants to be recorded. As with any procedure, people wishing to apply it to another aquatic habitat would do well to spend some time evaluating it in that site, prior to embarking on a large scale sampling effort.

ACKNOWLEDGMENTS

This work was possible with the help of a number of people. We would like to thank the Fall River Wild Trout Foundation. Dr. Mike Fitzwater, Mr. Dale Dennis, and Mr. Dennis Jacobsen have been especially helpful. Ms. Linda Whitehand provided valuable assistance with statistical procedures. Dr. Ellen Dean assisted in the identification of Fall River aquatic plants. Ms. Debe Holmberg performed the flavanoid analysis of *Myriophyllum sibiricum* specimens. Dr. Larry Mitich, Dr. Dan Marcum, Dr. Tom Lanini, Dr. John Madsen, and Dr.

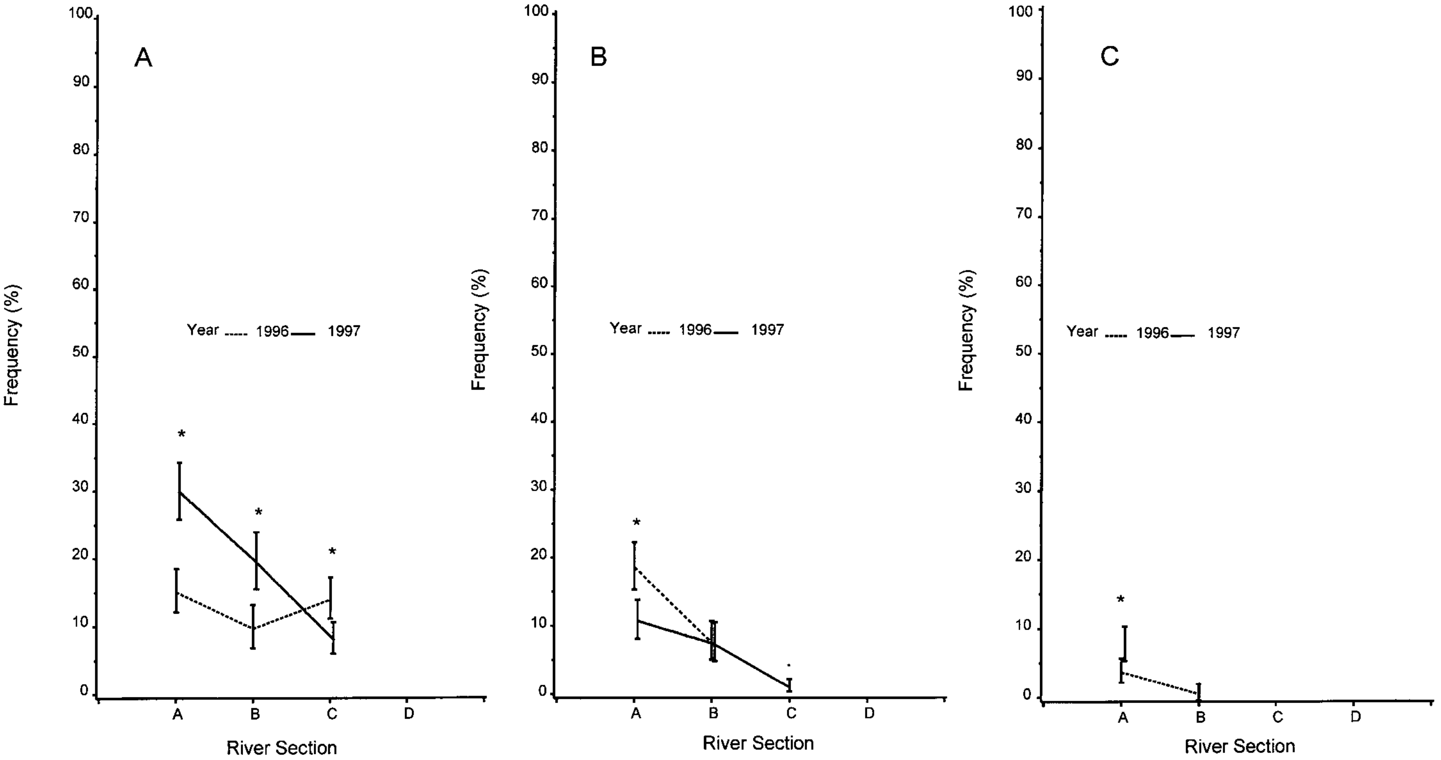

Figure 4. Frequency of all *Callitriche hermaphroditica* (A), *Myriophyllum sibiricum* (B), and *Ranunculus aquatilis* (C) in four section of Fall River during two years. The sections are A, above Fletcher's Bridge; B, between Fletcher's Bridge and New Bridge; C, between New Bridge and Spring Creek Bridge; and D below Spring Creek Bridge (see Figure 2). Values plotted are the frequency and 95% confidence limits. An asterisk above a bar indicates that a 2-tailed Fisher's Exact Test comparing the frequencies for both years indicated that the probability of obtaining the observed frequencies by chance alone was less than 0.05, leading to rejection of the null hypothesis that the frequencies were the same.

TABLE 2. COMPARISON OF PLANT FREQUENCIES (P) IN 10 RECORDINGS OF THE SAME TRANSECT. THE NUMBER IN THE ROW FOLLOWING SPECIES NAME OR "ALL VEG" IS THE NUMBER OF INTERVALS IN WHICH THE PLANT WAS PRESENT. THERE WERE 58 INTERVALS PER RECORDING (TRANSECT). FREQUENCIES WERE CALCULATED BY DIVIDING THE NUMBER OF OCCURRENCES BY THE TOTAL NUMBER OF INTERVALS (I.E., 58 OR 580). 95% CONFIDENCE INTERVALS (LOW CI, UP CI) WERE CALCULATED AS DESCRIBED IN THE TEXT. THE COLUMN LABELED "ALL" SHOWS THE VALUES BASED ON COMBINED DATA FOR ALL 10 TRANSECTS, I.E., THE BEST POINT ESTIMATE. THE COLUMN LABELED "P" SHOWS THE PROBABILITY OF OBTAINING THE χ^2 FROM THE 2 × 10 CONTINGENCY TABLE, TESTING FOR DIFFERENCES AMONG THE 10 FREQUENCIES. CV IS THE COEFFICIENT OF VARIATION FOR THE 10 FREQUENCIES.

	Recording Number												
	1	2	3	4	5	6	7	8	9	10	All	P	CV (%)
All Veg	47	46	45	46	48	46	45	48	50	50	471		
P	0.81	0.79	0.78	0.79	0.83	0.79	0.78	0.83	0.86	0.86	0.81	0.94	3.2
Low CI	0.71	0.69	0.67	0.69	0.73	0.69	0.67	0.73	0.77	0.77	0.78		
Up CI	0.89	0.88	0.86	0.88	0.90	0.88	0.86	0.90	0.93	0.93	0.84		
Callitriche	42	40	37	36	41	39	33	38	39	41	386		
P	0.72	0.69	0.64	0.62	0.71	0.67	0.57	0.66	0.67	0.71	0.66	0.82	5.4
Low CI	0.61	0.58	0.52	0.50	0.59	0.56	0.45	0.54	0.56	0.59	0.63		
Up CI	0.82	0.79	0.74	0.73	0.80	0.77	0.68	0.76	0.77	0.80	0.70		
Myriophyllum	13	14	19	20	18	17	19	16	19	21	176		11.9
P	0.22	0.24	0.33	0.35	0.31	0.29	0.33	0.28	0.33	0.36	0.30	0.84	
Low CI	0.14	0.15	0.23	0.24	0.21	0.20	0.23	0.18	0.23	0.26	0.27		
Up CI	0.33	0.35	0.44	0.46	0.43	0.41	0.44	0.39	0.44	0.48	0.34		
Elodea	13	9	6	9	7	9	9	7	5	8	82		
P	0.22	0.16	0.10	0.16	0.12	0.16	0.16	0.12	0.09	0.14	0.14	0.72	19.5
Low CI	0.14	0.08	0.05	0.08	0.06	0.08	0.08	0.06	0.04	0.07	0.12		
Up CI	0.33	0.26	0.19	0.26	0.22	0.26	0.26	0.22	0.17	0.24	0.17		

Lars Anderson and 3 anonymous reviewers read an earlier version of the manuscript and provided helpful comments. Mention of a manufacturer or product does not constitute a warranty or guarantee of the product by the U.S. Department of Agriculture nor an endorsement over other products not mentioned.

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