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# A fiber optic point quadrat system for improved accuracy in vegetation sampling

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**Summary.** An automated, fiber optic point quadrat system for vegetation sampling is described. Because the effective point diameter of this system never exceeds 25 μm it minimizes the substantial errors which can arise with conventional point quadrats. Automatic contact detection eliminates operator subjectivity, and permits work in dense canopies. Additionally, sampling speed is increased over that of conventional systems.

The point quadrat is a powerful sampling tool in many facets of ecological study including nondestructive assessments of vegetative canopy structure, foliage element inclination, foliage area development and productivity, direct beam solar radiation penetration, and potentially for vegetation architecture in insect habitat analysis (Warren Wilson 1960, 1963a, 1965, 1967; Hatley and MacMahon 1980). The technique can be used both for individual plants and for continuous vegetation canopies (Warren Wilson 1960, 1965). Although the point quadrat is a most versatile and powerful sampling technique, large errors can be encountered and it can extract a considerable toll in labor, especially in the identification of contacts in dense canopies (e.g., Knight 1973). Point quadrat sampling is usually conducted by passing a pin through the vegetation at a prescribed angle and recording all contacts with vegetation. The distance between the point of contact and a reference location, termed pin travel, serves as a means of determining location of the contact in the canopy (Warren Wilson 1960, 1963a).

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The primary source of error in point quadrat sampling, apart from inadequate sampling intensity, is the accuracy with which contacts are recognized. Point quadrats are assumed to be points in a mathematical sense, i.e., without thickness. Very sizable errors are encountered as the effective point size of these quadrats increases (Warren Wilson 1963b). The effective point thickness depends not only on the bluntness of the quadrat tip but also on the ability of the operator to distinguish when the point, rather than the side, of a point quadrat pin contacts a foliage element. To increase accuracy, eliminate subjectivity in recognition of contacts, and increase the speed of the sampling process, we developed a point quadrat system that optically recognizes contacts as a fiber optic probe penetrates the canopy.

In lieu of a pin, this system employs a high resolution fiber optic reflective sensor encased in a stainless steel tube (Fig. 1). An infrared radiation beam emitted by a light-emitting diode (LED) and channeled through fiber optics serves as the point quadrat in this system. This narrow radiation beam exits fiber bundles from the probe tip. When the radiation beam encounters a foliage element, radiation is reflected back to the tip of the probe and is conducted through separate fiber optic bundles to a highly sensitive silicon photodiode sensor. The waveband of radiation is centered at 920 nm with an approximate 100-nm bandwidth which is a region of the spectrum where vegetation is quite reflective. The radiation is pulsed at 1 kHz and a tuned filter is employed so the scanner is only responsive to pulsed radiation and therefore not sensitive to solar radiation or fluorescence from foliage. The sensor system pictured in Fig. 1 is positioned at the end of a motor-driven rod that is passed through the canopy at a prescribed angle. A supporting beam assembly allows the angle, height, and loca-

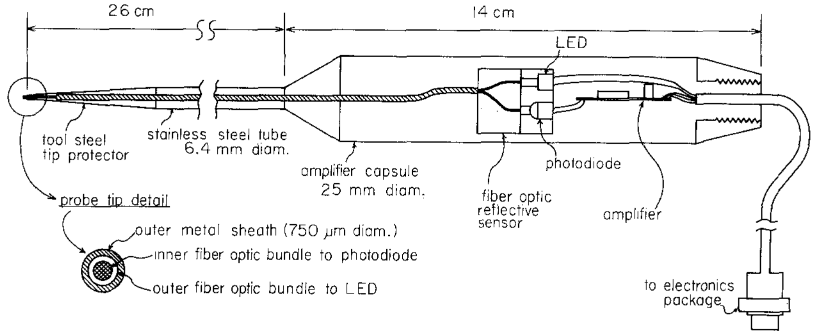


**Fig. 1.** Fiber optic reflective sensor system used as a point quadrat sampling device. Radiation emitting and receiving fiber optic bundles are arranged coaxially for higher resolution. (LED is the infrared light emitting diode; see text)

**Table 1.** Errors in overestimation of foliage area resulting from sampling by point quadrats of different point diameter. These are calculated assuming foliage elements to be elliptical in shape and to be perpendicular to the direction of the point quadrats. Based on theory of Warren Wilson (1963b)

| Elliptical axis dimentions of foliage (mm) | % Error for point quadrat diameters | | |
|---|---|---|---|
| | 2 mm | 1 mm | 25 μm |
| 8 × 30 | 33 | 16 | 0.4 |
| 8 × 3 | 108 | 50 | 1.1 |

tion of the motor-driven rod to be adjusted. When the system senses a foliage element, the motor stops immediately so the operator can record the species and plant part sensed by the quadrat. The tip of the fiber optic probe stops within 1 mm (±0.5 mm) of the foliage element. The pin travel from the supporting beam is measured by a precision potentiometer and registered on a digital liquid-crystal display. The operator then reinitiates operation of the motor to proceed to the next contact in the vegetation.

Errors resulting from thickness of point quadrats depend on the point thickness, dimensions of the foliage elements and angle of incidence of the quadrats with respect to foliage elements (Warren Wilson 1963b). Conventional point quadrat pin tips are seldom much smaller than 2 mm diameter. Tests with a micrometer stage assembly revealed that the effective point diameter of this system never exceeds 25 μm. The sizable errors to be encountered with conventional point quadrats and the advantages of this system are indicated by the calculation of errors for foliage of broad and narrow leaves in Table 1. These errors would be increased if quadrats are striking foliage elements obliquely, or in the case of conventional quadrats, if the side rather than the tip of the pin was scored as a contact. The problems with manually recognizing contacts increase substantially when dense foliage is being sampled. There is no operator subjectivity involved with this new system since contacts are recognized by the sensor.

A secondary advantage of this system is speed of sampling. An application of this quadrat system is contained in a separate paper (Caldwell et al. 1983). In this study we estimated this fiber optic point quadrat system to be approximately twice as rapid as conventional point quadrat analysis even using a motor-driven pin system.

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