An Approach To Estimating The Standing Crop Of Waterhyacinth

I. W. FORNO and A. S. BOURNE

Entomologist, Division of Entomology and Statistician,
Division of Mathematics and Statistics,
CSIRO Long Pocket Laboratories,
Brisbane, Queensland 4068, Australia

ABSTRACT

The standing crop of waterhyacinth [*Eichhornia crassipes* (Mart.) Solms.] can be determined from samples dried to constant weight. This paper describes an alternative method in which plants are categorized into two groups according to the distribution of the leaves over a number of classes defined by the lengths of the petioles. An equation for each group giving estimates within 10% of values obtained by weighing dried material is developed.

INTRODUCTION

Waterhyacinth has become a major problem in many freshwater ecosystems throughout the world. In Australia the plant first appeared as an ornamental a little before 1895 (1) and today it hinders the commercial and recreational use of water along the east coast from north Queensland to central New South Wales. Infestations also occur in the Gingham watercourse of western New South Wales, near Perth in the south-west of Western Australia, Mt. Isa in western Queensland, and near Darwin in the Northern Territory. With further impounding of water throughout Australia, the area infested with waterhyacinth may increase unless some long term effective control measure is implemented.

A program for the biological control of waterhyacinth was commenced in 1975 with the introduction of the weevil [*Neochetina eichhorniae* Warner]. During field evaluation studies of any biological control agent the seasonal variation in the growth of waterhyacinth must be considered and a measure of the standing crop is an important parameter.

Little has appeared in the literature on the estimation of the biomass and standing crop of perennial aquatic plants. Del Viso *et al.* (2) proposed a method for biomass estimation of waterhyacinth in which they distinguished four groups of plants within their area of study. These groups were identified by the average height of the plant as measured from the surface of the water to the height attained by the leaf tip. Their groupings were as follows: (a) $<$20 cm, (b) 20-50 cm, (c) 50-70 cm, (d) $>$70 cm and they attempted to find empirically the factor of proportionality for different heights on the assumption that for the same average height the biomass was proportional to the number of leaves. Del Viso *et al.* (2) were able to construct a series of linear graphs whereby the dry organic matter in g per m^2 could be expressed as a function of the number of leaves with a particular average height. Though their method claimed an accuracy of 20%, their technique did not give satisfactory results when applied to these field studies in Australia. We suggest that greater accuracy may be possible if the variation in the length of the petioles in the sample is considered.

MATERIALS AND METHODS

Three lagoons in separate districts in south-eastern Queensland were chosen for this study. At each lagoon there were three distinct zones of waterhyacinth; the zone along the shore-line where the plants were frequently stressed as the water level receded, a middle zone where the plants were densely packed and were often rooted to the substrate and the inner zone of small floating plants. Due to the instability of both the inner and outer zones of plants, observations were confined to the middle zone where area and the seasonal variation in the standing crop with change in plant growth were monitored. As a high proportion of the resources available was being devoted to measuring the standing crop by drying samples to constant weight and weighing, it was proposed that if this parameter could be estimated to within 10% of this value a satisfactory measure of the standing crop would be obtained for a smaller allocation of the resources.

In this paper standing crop is defined as the dry weight of leaf material per unit area and biomass as the dry weight of leaf and root material per unit area. The standing crop included all leaves which possessed any living tissue and since successful biological control agents were expected to reduce the leaf mass per unit area, a measure of the standing crop was considered to best reflect the activities of these agents.

From preliminary sampling it was determined that four samples of 0.25 m^2 gave an actual measure of the standing crop with a standard error of 10% of the mean. Therefore, at each sampling date, four samples each of 0.25 m^2 were randomly selected from within the middle band of waterhyacinth. The leaves of each plant were then separated from the rhizome and divided into five classes according to the length of the petiole. The ranges of petiole lengths in each class were 0-10 cm, 10-20 cm, 20-40 cm, 40-60 cm, >60 cm and the leaves in each class were counted, dried to constant weight at 70C and weighed. From these values a measure of the mean dry weight per leaf in each class was obtained.

By denoting the number of leaves in each class as C_1, C_2, C_3, C_4, C_5 respectively, the obvious equation for estimating the standing crop was

$$\text{Standing crop} = a_1C_1 + a_2C_2 + a_3C_3 + a_4C_4 + a_5C_5$$

where $a_1 \ldots a_5$ are estimates of the dry weight of a leaf in each class.

The initial data consisted of 66 samples (Set 1) collected at monthly intervals from each of the three lagoons. From the data, it was apparent that a relationship existed between the mean leaf weight and the length of the petiole. However, within any one class, there was a substantial variation in the mean leaf weights of the different samples and there was a need to improve this simple equation to account for the variation.

Examination of the data suggested that the proportional allocation of leaves to each class might be important. The number of leaves in a sample varied from 150 to 700. By grouping the leaves into classes, determined by the petiole length, a frequency distribution for each sample was produced. Figure 1 shows typical frequency distributions experienced in this study. These can be divided into two types, a 'peaked' distribution where most leaves were of the same length and a 'non-peaked' distribution where the leaves covered a range of lengths and were more evenly spread over the classes. The number of classes over which the leaves in any one sample were distributed, varied from two to five.

Actual dry weighting of the material sampled was continued until a further 56 samples (Set 2) became available. The samples of Sets 1 and 2 were combined and then divided into two groups by the 'peaked' and 'non-peaked' classification. A simple method of separating the 'non-peaked' group from the remainder was to use a ratio of actual leaf weight to estimated leaf weight. Estimated leaf weights were obtained from the equation

$$\text{Standing crop} = 0.276\ C_1 + 0.422\ C_2 + 0.783\ C_3 + 1.53\ C_4 + 2.63\ C_5$$

where the estimated mean leaf weight per class was derived from the 122 samples (Set 1 and Set 2). For samples in the 'non-peaked' group the ratio actual leaf weight to estimated leaf weight was greater than one and for the 'peaked' group the ratio was less than one. The number of samples possessing leaves with petioles in excess of 60 cm (class 5) was very small and hence classes 4 and 5 were combined.

In this way the data were divided into two groups (Table 1). Once this division of the samples had been made a simple formula based on leaf numbers could be applied to each group using different constants i.e. estimates of weight per leaf for each class. The constants were calculated weighted means using all the samples within the group and the following prediction equations were derived.

Group A:

$$\text{Standing crop} = 0.339\ C_1 + 0.685\ C_2 + 1.002\ C_3 + 1.848\ C_4 + 3.077\ C_5.$$

Group B:

$$\text{Standing crop} = 0.218\ C_1 + 0.409\ C_2 + 0.730\ C_3 + 1.313\ C_4 + 2.485\ C_5.$$

The technique for estimating the standing crop was thus to determine the group of the sample from the distribution of its leaves and then to select the appropriate equation.

RESULTS AND DISCUSSION

These equations gave good estimates of the standing crop. When 52 new samples became available (Set 3) the estimated mean leaf weight on any sampling date was, on average, within 10% of the mean leaf weight obtained by drying and weighing each sample.

A brief consideration of the growth of waterhyacinth may help to explain the need for the two equations. Peak growth of waterhyacinth is attained towards the end of summer and at this time the plants in the zone of this study are tall and vigorous. Frequently, frost or near frost conditions occur early in winter and these low temperatures cause severe damage to the tall leaves. As a consequence, these leaves remain turgid at the base of the petioles but the extremities dry out and the leaves bend away from the crown of the plant. The resultant increased light penetration to the center of the plant apparently stimulates the plant to produce shorter leaves with more bulbous petioles. These new leaves have a higher dry weight than their more slender counterparts and since both the newly formed leaves and the older frosted leaves are eligible for inclusion in the estimation of the leaf weight, these plants often have a higher than average mean leaf dry weight.

When attempting to construct an equation to fit data, the technique of pseudo-replication, that is random division into two half samples has been advocated (3). This method

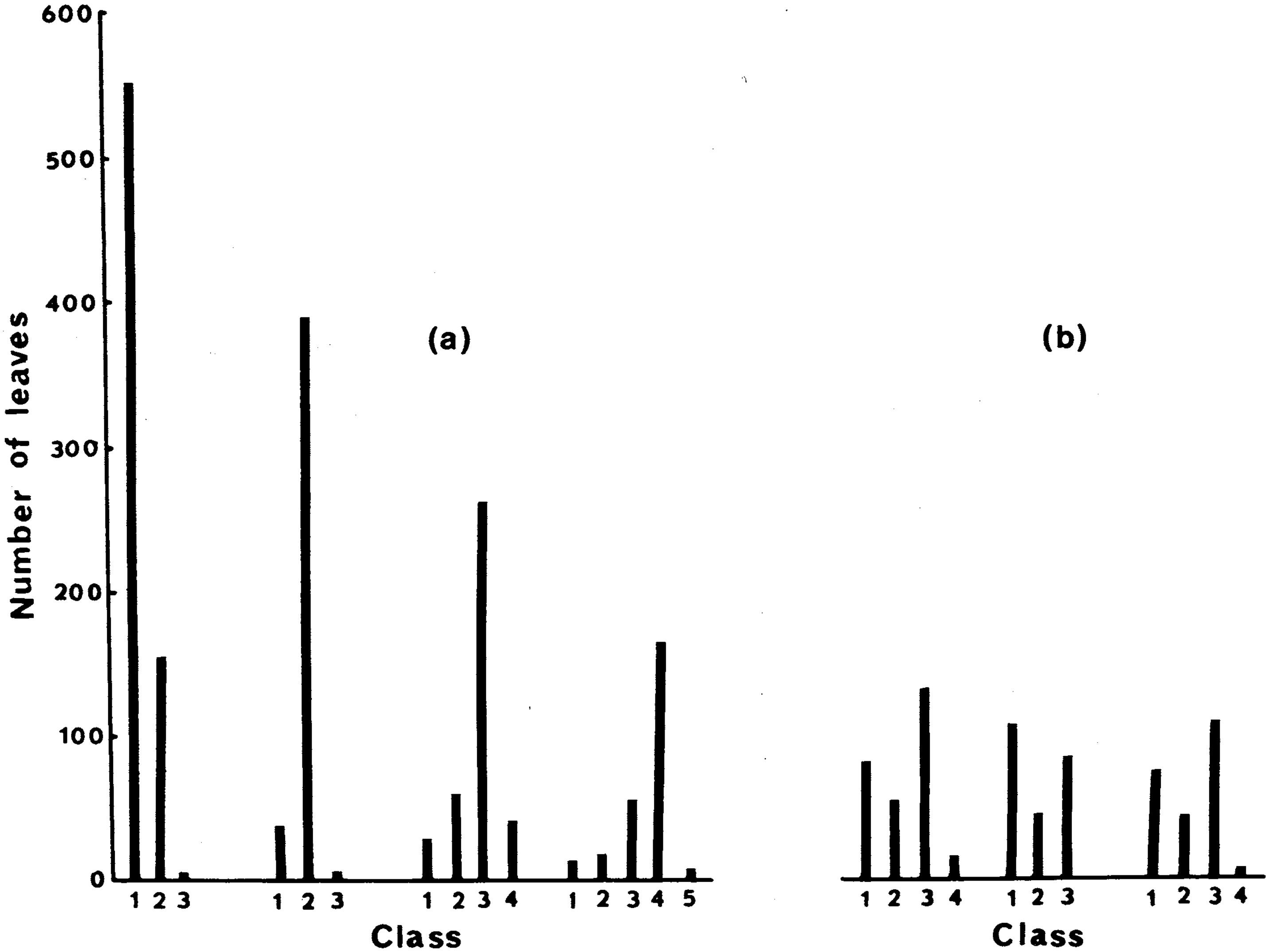

Figure 1. Frequency distributions of the leaves in a sample 0.25 m^2 of waterhyacinth. Each class is defined by a range of petiole lengths: (1) 0-10 cm, (2) 10-20 cm, (3) 20-40 cm, (4) 40-60 cm, (5) >60 cm. (a) 'Peaked' distributions; (b) 'Non-peaked' distributions.

TABLE 1. LEAF NUMBER WITHIN EACH CLASS OF PETIOLE LENGTH FOR 'NON-PEAKED' AND 'PEAKED' DISTRIBUTIONS.

Class	Petiole length cm	Non-peaked	Peaked
1	0-10	<200	≥200
2	10-20	<100	≥100
3	20-40	<160	≥160
4	40-60	<100	≥100

is suitable when the sample is a random sample of the entire population. However, it is not appropriate to extend it to the case where the sample is taken at one point in time and the equation is to be applied to subsequent samples. In the approach outlined here two completely new sets of data were used to test the equations and the successful outcome of these tests does more to validate the equations within the limits of their proposed usage than any subdivision of the original sample.

This simple method of classing leaves by their petiole length and of categorizing plants by the distribution of leaves over these classes has been used for a period of seven months at each of the three study sites. It has proved most satisfactory for estimating the standing crop of waterhyacinth. At regular intervals the estimated values have been tested against the actual weights obtained by drying to constant weight and values have consistently fallen within 10%. However, should insect attack substantially alter the growth of waterhyacinth, it may be necessary to modify the existing prediction equations.

In particular, the application of these equations to estimating the standing crop of waterhyacinth may be limited where the classes of plant height are smaller or larger than the range considered here and where the distribution of the numbers of leaves over these classes is substantially different.

LITERATURE CITED

1. Aston, H. I. 1973. Aquatic Plants of Australia. pp. 264-266 (Melbourne University Press).
2. Del Viso, R. P., N. M. Tur, and V. Mantovani. 1968. Estimacion de la biomasa de hidrofitos en cuencas isleñas del Parana medio. Physis 28:219-226.
3. McCarthy, P. J. 1976. The use of balanced half sample replication in cross-validation studies, J. Am. Stat. Assoc. 71:596-604.