Longevity of Perennial Forbs and Grasses

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Source: *Oikos*, 1974, Vol. 25, No. 1 (1974), pp. 93-96

Published by: Wiley on behalf of Nordic Society Oikos

Stable URL: https://www.jstor.org/stable/3543550

OIKOS 25: 93–96. Copenhagen 1974

Longevity of perennial forbs and grasses

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Treshow, M. and Harper, K. 1974. Longevity of perennial forbs and grasses. – Oikos 25: 93–96.

The life expectancy of representative dominant perennial forbs and grasses of grass-, mountain brush-, aspen-, and conifer-communities was determined. The longevity of these species ranged from three to 65 years with *Balsamorhiza sagittata* and *Agropyron spicatum* the longest lived.

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Определяли вероятную длительность существования представителей многолетних трав и злаков, доминирующих в злаковых, горных кустарниковых, осиновых и хвойных ассоциациях. Продолжительность существования этих видов колеблется в прелелах от 3 до 65 лет, причем, наиболее долго живут *Balsamorhiza sagittata* и *Agropyron spicatum*.

Manuscript accepted 3 September 1973

1. Introduction

Since the onset of the Industrial Revolution, but especially in recent decades, man has added air pollution as an environmental input to which not only crop lands and forests, but the world's remaining natural landscapes and watersheds, must respond. The interaction between pollution and the plant community has been obvious where sensitive dominant species prevailed near smelters or such urban centers as the Los Angeles Basin; but the concentration of ozone from photochemical air pollution continues to extend farther from its source each year, and the global sulfur dioxide concentrations continue to increase. Our studies have been directed toward learning how major ecosystems might be responding to this new input of air pollution (Treshow 1968).

In order to evaluate this interaction, we must first know the natural community composition, the life expectancy of the component species, the successional stability, and turnover rate or degree of flux. Several approaches were taken to better understand the nature of the plant communities studied. In order to anticipate or project possible community compositional changes, it was considered particularly essential to determine the natural life expectancy, or longevity of the principle component species. This information would then be combined with data on community composition, turnover rates and ozone sensitivity, and used in mathematical equations developed to predict the community composition following natural, anticipated future exposure to ozone. Few studies have been made attempting to establish the life span and mortality rate of plants in natural populations. In classic studies of perennial plants in forests and meadows, Tamm (1948, 1956, 1972) counted individuals of selected species in permanent quadrats over a period of years.

Sager (1959) mapped seedlings and rosettes of *Plantago lanceolata* in permanent grassland plots and attempted to follow their fate. This was mapped as life table data which included the number of individuals per m^2 before and after a 2-year period, the net gain or loss, the percentage survival, and the half-life (in years) of the mature plants at the start of the study.

This paper reports the expected life expectancy of the most prevalent species occurring in the plant communities in which air pollution impact studies are being conducted.

2. Methods

Longevity plots were established in representative grass, oak brush, aspen, and conifer communities near permanent plot sites previously selected for long term evaluation of air pollution effects. Plots were selected along a line transect of ca 60 m in length and marked by two large steel reinforcing bar stakes. Plants of the desired species, closest to the line, and on either side of it, were designated by driving a 60 cm length of reinforcing bar into the soil next to the plant. One hundred plants were selected and staked along the line in this way for each transect. Four such transects were sought in similar communities at different locations for each species studied. However, only one good transect of adequate density could be located for *Thalictrum* and *Arnica*, and only two for *Stipa*.

Plants studied included *Stipa comata* Trin. & Rupr., *Agropyron spicatum* (Pursh) Scribn & Smith, *Hedysarum boreale* Nutt., *Astragalus utahensis* (Torr.) T. & G., *Balsamorhiza macrophylla* Nutt., *Balsamorhiza sagittata* (Pursh) Nutt., *Wyethia amplexicaulis* Nutt., *Arnica cordifolia* Hook., and *Thalictrum fendleri* Engelm. These species were selected because of their dominance in the understory of their respective communities. The first six species were among the most prevalent in grass and oak brush communities, *Arnica* was most common in spruce-fir association and *Thalictrum* in the aspen.

The crown diameter of each plant of *Agropyron*, *Stipa* and *Astragalus* was measured at the beginning of the study. The stage of relative ageclass only was recorded for the other species. Plant locations were recorded to scale on graph paper. Transects were established in 1969 and 1970 toward the close of the growing season for the respective species, and reexamined for their presence in 1971 and 1972.

Data were summarized and the rate of maturation, size increase, mortality and survival rate determined. The annual mortality rate for each species was plotted by designating the accumulative percent mortality during the period of study and extending this line to a 100% mortality value. The rate of maturation and mortality data were used to develop a replacement curve or net replacement rate. A linear die-off was assumed since the populations were known to have existed on these sites for some years and were considered stable. Previous work by Harper (1967), analyzing data from Tamm, also indicated that deaths were linear if seedlings were ignored. Harper (1967) recalculated these data and presented them as the change in plant numbers (as logarithms) with time. The relationships of plant disappearance with time were found to be essentially linear, indicating that the chance of an individual dying remained the same through the period of study. It showed elimination, or mortality, as a steady process with some individuals remaining vigorous enough to reproduce throughout their lives. Harper concluded that population changes may be characterized like the decay of a radioisotope, by a "half-life". Yoda et al. (1963) and Sager (1959) also suggested that mortality was a continuing risk through the life of the plant, continually adjusting the numbers in the population in relation to the increasing size of the plants.

In the present study, only established plants were considered; the numbers of seedlings were disregarded. Using only established plants provided further justification for assuming a linear die-off.

Survival rates were calculated for the mature forbs and grasses using the formula:

$$S = \frac{\text{relative abundance 1972}}{\text{relative abundance 1970}}$$

The relative abundance was simply the number of individuals in each transect in 1970 and 1972; the ratio provided an additional way of expressing mortality.

3. Results

The mortality rate of representative, prevalent perennial forbs and grasses in local grass, oak, aspen, and conifer communities was determined. *Agropyron spicatum* and *Stipa comata*, the most prevalent species in the grass communities studied, were the longest lived. Only two of the 400 *A. spicatum* plants examined over three growing seasons, died; and none of the 200 *Stipa comata* plants were missing after three growing seasons (Tab. 1).

Balsamorhiza sagittata was the longest lived of the forbs studied. An average of 3% of the plants examined died each year, with a range of 1–5% among the transects. Considering only the initial plants marked, a population life of 40 years was projected (Tab. 1).

Since the ultimate permanence and stability of the population would depend on replacement of individuals as well as mortality, the replacement rate was calculated. The annual replacement rate of *Balsamorhiza sagittata*, based on the number of individuals maturing each year, and not considering seedling replacement, was 2%. Comparing mortality against replacement rates disclosed a net population loss of 1% per year. The survival rate calculated using mature plants only was found to average 0.97.

Wyethia amplexicaule showed an annual mortality rate of 3.5% with a variation of 1.7–5% among transects. A population life span of 28 years was projected. The replacement rate of *Wyethia* was 1.8% per year which resulted in an average annual net population loss of 1.7%. The survival rate was calculated as 0.94.

Hedysarum boreale had an annual mortality of 5% with a variation of 4.5–6.5% among transects. The population life expectancy was projected to be 20 years. The replacement rate of *Hedysarum* was 3% per year which resulted in a net annual population loss of 2%. The survival rate was calculated as 0.92.

Balsamorhiza macrophylla populations had an average mortality rate of 7% per year with a range of 5–10% among the transects. The projected population life expectancy was 14 years. The replacement rate of *B. macrophylla* was 4% per year which resulted in a net annual population loss of 3% discounting seedling replacement. The survival rate was 0.86.

Arnica and *Thalictrum* both had an annual average population mortality of 7.5% and a projected life expectancy of 12 years. The survival rate was 0.85.

Astragalus populations had an average annual mortality rate of 33% varying from 28–37% among transects. The average projected population life expectancy was less than 3 years. Furthermore, the average size of existing *Astragalus* plants diminished 31% each year. The possible development of new plants was not recorded so a replacement value could not be obtained.

Tab. 1. Longevity, survival, replacement and mortality rates of perennial forbs and grasses.

Species	Life expectancy (years)	Annual mortality (%)	Annual vegetative replacement rate (%)[1]	Survival rate[2]
Agropyron spicatum	65	0.5	21[3]	0.99
Arnica cordifolia	12	7.5	–	0.85
Astragalus utahensis	3	33(28–37)[4]	−31[3]	0.30
Balsamorhiza macrophylla	14	7(5–10)	4	0.86
B. sagittata	40	3(1–5)	2	0.97
Hedysarum boreale	20	5(4.5–6.5)	3	0.92
Stipa comata	Indef.	0	41[3]	1.0
Thalictrum fenderli	12	7.5	–	0.85
Wyethia amplexicaule	28	3.5(1.7–5)	1.8	0.94

[1] Replacement rates were based on the number of plants/100 reaching maturity each year.

[2] $S = \frac{\text{Relative abundance 1972}}{\text{Relative abundance 1970}}$

[3] Based on actual growth increase.

[4] Variation in mortality among stands.

4. Discussion and conclusions

Observations of perennial forbs and grasses in replicated transects over a period of four growing seasons gave an indication of the life expectancy and annual mortality of individual plants, the gross replacement rate, and the net population changes that might be expected.

A few of the perennial species studied appeared to have a remarkably long life expectancy. A population of *B. sagittata* plants, for instance, might be expected to live approximately 40 years, *Wyethia* about 28, and *Hedysarum* 10 years, even if seedling replacement and vegetative reproduction were disregarded. *Balsamorhiza macrophylla*, *Thalictrum* and *Arnica* had life expectancies of 7, 6, and 7 years respectively. *Astragalus utahensis*, on the other hand, was little better than an annual having a life expectancy of less than three years. These values for *Wyethia* and *Balsamorhiza* were roughly confirmed by tap root growth ring counts. Counts showed that the longevity of these species might be even greater than indicated by the transect studies.

Seedling replacement was considered for *Wyethia* and *Balsamorhiza*, but seedlings were extremely difficult to distinguish. This was particularly true with *Balsamorhiza* of which no seedlings were found. Small *Wyethia* plants, in the 2- to 4-leaf stage, comprised approximately 5% of the total population of these stands, but these may have been more than a year old.

The few studies available against which these figures might be compared confirm the extreme variation occurring in the longevity of perennial forbs. Tamm (1972) observed individual specimens of *Primula veris* (L.) Huds. on permanent quadrats from 1943 to 1971. Specimens in one stand maintained their position the whole period; vegetative propagation by branching rhizomes compensated for deaths. The half life of the population was calculated at 50 years. Plants on another site, however, with a closing canopy of ash trees, rapidly decreased the last 12 years of the study and had a half life of only 2.9 years.

Tamm (1948) marked individual plants and watched their development. No plants of *Fragaria vesca*, *Anemone hepatica*, or *Sanicula europaea* died during a period of four years. His conclusion that these species were "very long-lived" was borne out by subsequent studies. He attributed a low rate of renewal to competition for nutrient, water and light in the closed communities. Tamm stated that if "all plants forming a certain plant community are very long-lived, the consequences must be a stability of the community, environmental factors remaining unchanged."

The survival rate of the forbs studied, except for *Astragalus*, ranged between 0.85 and 0.96 which provided another measure of the longevity of the principle forb components of the community. Since the longevity or life expectancy data provide some idea as to how long a particular species population might persist barring some perturbation, it is suggested that longevity data be considered when calculating species stability. It is further suggested that longevity data might have some application to studying community stability provided the life expectancy of key species was known.

Acknowledgement

Financial support was provided by a grant from the Environmental Protection Agency.

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