INTERNAL REPORT 78

VARIATION IN PLANT MOISTURE STRESS ASSOCIATED WITH FOREST COMMUNITIES IN THE H. J. ANDREWS EXPERIMENTAL FOREST

Donald B. Zobel, Glenn M. Hawk,
W. Arthur McKee and C. T. Dyrness
Oregon State University and USFS, Corvallis

Abstract

Measurement of plant moisture stress of 1-2 m understory conifers was made in "reference stands" on the H. J. Andrews Experimental Forest in 1970-1972. Maximum stress each year (measured between midnight and dawn) is closely correlated with the position of each community along one axis of an ordination of the vegetation. In some stands, stress decreases during rainless periods, for uncertain reasons. Apparently, use of different species in different plots does not, of itself, lead to differences in stresses measured at the plots.

Introduction:

In the vicinity of the H. J. Andrews Experimental Forest in the Western Cascades of Oregon, twenty-three plant communities have been described (Dyrness et al., 1972). These communities have been analyzed by a two-dimensional ordination technique. The resulting classification of communities provides a useful and sensitive method of stratifying the landscape in the Experimental Forest for sampling and modeling of ecosystem structure and processes. Measurements of environment and observations of plant phenology in these communities will make such a stratification more useful and provide some insight into the environmental relationships of the different communities. To obtain such measurements, "reference stands" were established, representing approximately the modal characteristics of several widespread or contrasting plant communities.

A major determinant of community distribution in Oregon vegetation is moisture (Waring, 1969; Minore, 1972), and a major axis of the ordination of vegetation on the H. J. Andrews is interpreted as being associated with moisture conditions (Dyrness et al., 1972). This paper reports the relationship between plant moisture stress of understory conifer saplings and the type of plant community in which they occur for several contrasting "reference stands" on the H. J. Andrews Experimental Forest.

Methods:

Moisture stress of 1 to 2 m tall coniferous saplings was measured. These trees should reflect moisture conditions of a given site more accurately than measurements of soil moisture or of plant stress of large trees (Waring and Cleary, 1967). Stress was measured on twigs with a pressure chamber (Scholander et al., 1965). Such measurements are at least fairly well correlated with leaf water potential of some conifers (Boyer, 1967; Kaufmann, 1968; Waring and Cleary, 1967). The actual value measured is the pressure potential of the xylem sap, which in most cases is very close to water potential of the xylem sap (Boyer, 1967). Values of sap pressure potential are negative, and as they become more negative moisture stress of the plant increases. In this paper we will refer to "stress", not pressure potentials.

Stress determinations were made between midnight and first light to estimate a minimum stress for each day, when plant moisture stress was closely related to the moisture condition of the soil. At some sites, daily stress patterns were also obtained. Reference stands (R.S.) used, with the community represented at each, are listed in Table 1. The approximate positions of these communities in the vegetational ordination and their relationship to the unsampled communities are shown diagramatically in Figure 1. Three to seven saplings of the most important understory conifers were used. Reproduction of overstory dominants was preferred, but where these were sparse *Taxus brevifolia* was sampled (Table 2).

The locations of two reference stands were changed between the 1970 and 1971 sampling periods. Reference stand 6 (Tshe/Cach) was established in 1971. Data for 1970 (R.S. 6*) were obtained in a similar stand at a different location. Reference stand 7 (Tshe/Pomu-Oxor) was not established until 1971. The 1970 measurements were in a stand (R.S. 7*) representative of the Tshe/Pomu community, which occupies slightly drier sites that the Tshe/Pomu-Oxor community, according to the vegetation ordination.

Usually a single determination was made on each tree, although occasional duplicate samples were taken as a check. Readings much different than expected in the particular situation were repeated. Within each year, the same trees were measured at a given site. However, long-term use of some seedlings was restricted by their sparse branching habit.

Readings were made by Glenn M. Hawk in 1970 and 1972 and by W. Arthur McKee in 1971.

Rainfall data presented are from the U.S. Forest Service "Climatic Station" located at 500 m elevation between Reference Stands 2 and 7.

Results:

Species differences:

This study was designed to examine differences between communities, and the data are ambiguous when examined for species differences. In some years there were definite differences in predawn stress between species sampled at the same site. Three *Abies amabilis* had higher stress than a *Tsuga heterophylla* at R.S. 4 on all five sample dates in 1972. In three other site-years there were no real differences between these species. In a fifth comparison the opposite relationship appeared in late season.

Comparisons of *Tsuga heterophylla* and *Taxus brevifolia* for five site-years show *Tsuga* to have equal or higher stress in two cases, to be no different in two others, and to be lower in the fifth. Therefore, our data do not indicate that the use of different species on different sites for inter-community comparisons would consistently bias data for a particular community. However, the hypothesis that there are no species differences has not been rigorously tested.

Diurnal patterns:

Daily variation in plant moisture stress is shown for three contrasting sites in mid-August, 1970 (Figure 2) and in 1971 (Figure 3). Daily variation in plant moisture stress ranges from 7 to 11 bars for sites moister than -10 bars, and decreases to 6 bars in drier situations. On most sites stress steadily increases in the morning, gradually reaching an afternoon maximum. Reference Stand 4 (Figure 2) is on a steep northwest slope and solar radiation may reach seedlings only in the afternoon, resulting in the rapid but delayed rise in stress. Late-morning haze on the sample date also may have affected the pattern.

In four of eight daily patterns measured, stress decreased (by 0.5 to 2.5 atm) after the initial pre-dawn reading. This suggests that stress measured from midnight to predawn does not always represent the actual daily minimum. All sites in Figure 2 and 3 had a west to north aspect, delaying the time when direct sunshine reaches the slope compared to sites with an east aspect, and extending the period for recovery from the previous day.

All sample days (except R.S. 4 in 1970) were clear with high temperatures of 81 - 89°F and lows of 49 - 55°F.

Seasonal patterns:

Averages of predawn moisture stress for each site and date are given in Table 3. Variation among trees on a given site and day was usually less than 3 bars except on drier sites such as R.S. 1, 6, and 8, where ranges of 5 to 9 bars were not uncommon. Occasional large within-site differences occurred elsewhere.

Yearly maximum predawn moisture stress of Tsuga heterophylla Zone communities is highly correlated with their vegetational composition (Figure 4), especially in drier years, 1970 and 1972. In Figure 4 the median X-axis coordinate of each community is chosen from the plant community ordination of Dyrness et al. (1972) for the Tsuga heterophylla Zone, and yearly maximum predawn stress is plotted against it. The correlation is best, and very similar, in the two drier years. One transition zone community (R.S. 3) did not fit the relationship except in 1972. The change of its relative position from 1970-71 is perhaps due to a spring 1972 salvage cutting within 70 m of the stand, increasing its exposure to the north-northwest and somewhat to the west.

The slope of the regression varies, being +0.319 (±.024) bars per X-axis unit in the dry years but only +0.207 (±.036) in the wetter year.

The only community replicated in reference stands measured is represented by R.S. 2 and 17 (Tshe/Rhma/Bene). On August 25, 1972, they were at 8.9 and 8.1 bars, respectively.

Except for R.S. 4, communities in the Abies amabilis Zone (R.S. 4, 12, 13, 14) were seldom sampled. At R.S. 4 greater stress did develop than at some Tsuga heterophylla Zone communities, specifically R.S. 3 and 7 in 1970 and 1971 and R.S. 7 in 1972. In two comparisons, R.S. 14 was drier (by 1 and 3 bars) than R.S. 4, in agreement with the community ordination (Dyrness et al., 1972, Figure 4). The only comparison of these four stands was in August, 1971. All had stresses of -3.6 to -4.5 bars, allowing no useful comparison of moisture stress and vegetation type.

Discussion:

A number of sources of error could be present in our data. Differences in investigators, or investigator fatigue, could cause small discrepancies. Use of different species at different sites did not appear to introduce consistant bias, but the data are not sufficient to determine this with certainty. Microsite differences in stress are probably present, and thus choice of which individual saplings to sample in a given year could influence readings.

Our data for some sites could represent conditions other than those of undisturbed forest. We have documented a 5 bar stress increase at R. S. 3 from 1970 to 1972, when other sites were similar, apparently associated with partial cutting of a neighboring forest. What influence roads or cutting, which are moderately close to several other sites (e.g. R. S. 2, 4, 5, 10), may have is uncertain. The situation at R. S. 1 and 8 is more extreme. A reservoir extends 150 m west and several km south and southwest of the base of the watershed where these sites are located. The presence of the reservoir probably does not increase insolation on these sites, which are high on the slope, but certainly should ameliorate temperature and humidity (and thus moisture stress) when it is full. However, it is partially drained at a variable time each summer, leaving dry ground. This bare soil probably has the opposite effect on climate of the surrounding slopes and on plant stress. In 1970 and 1972 draining started before moisture stress measurements, while in 1971 it began during the measurement period. Although sites 1 and 8 undoubtedly have much more stress than the others, their relative position may be changed by the reservoir. The reservoir has been present only since 1969.

Although seasonal stress development was influenced by summer rains in 1971 and 1972, a tendency of moisture stress to decrease on certain sites during rainless periods was observed. In 1970 stress at R. S. 2 and 4 decreased markedly (5-7 bars) from early to mid-August even though there was no rain. R. S. 1 and 3 decreased slightly (less than 1 bar) during the same period. From July 21 to August 4, 1972, stress decreased more than a bar on R. S. 2, 7, and

9. This may be related to continuing movement of ground water into the sites (sites 2, 4, 7, and 9 are all at the base or mid-slope on protected and rather steep slopes). It may also be related to plant characteristics. *Pseudotsuga* keeps its stomata open at night under low moisture stresses in early summer. Thus when stomata finally begin to close each night, the minimum stress might possibly be lower than it was early in the summer. There is some indication that *Abies amabilis* on R. S. 4 does act this way (R. H. Waring, personal communication). Also, the lower minimum stress may be related to maturation of the new foliage, such as cuticle development and increasing stomatal control. These sites produce new foliage later than most but not all other sites. The decrease in stress at some sites in the absence of precipitation seems to be real, but is presently unexplained.

In the *Tsuga heterophylla* Zone, the correlation of maximum moisture stress of each community with its "Moisture" axis coordinate of the vegetation ordination was excellent in the drier years of 1970 and 1972, and even fairly strong in 1971. Even though this close agreement may be somewhat fortuitous, given the extraneous influences on moisture stress discussed above, there seems little doubt that vegetation variation on the X-axis of the Dyrness *et al*. (1972) ordination is related to moisture stress.

Dyrness et al. present species distribution diagrams for the *Tsuga heterophylla* Zone, using the axes from their vegetation ordination (their Figure 10). The linear (or almost linear) relationship between maximum predawn stress and their x-coordinate increases the usefulness of these diagrams. Most species shown are fairly widely distributed. However, over 3% cover of *Oxalis oregana* should indicate maximum stress less severe than -16 bars and that of *Holodiscus discolor*, more severe than -16 bars. *Rubus nivalis* is not found between -10 and -21 bars. Use of these diagrams is subject to error, however, since only median X-axis values for each community were used to construct Figure 3. There is considerable variation in X-axis position among stands classified within the same community.

Using single-stand samples to represent communities which contain considerable variation also has certain drawbacks. Each sample-of-one may misrepresent its particular type, and we have no check by replication to discover such problems. However, use of stands showing modal vegetation for a given community should help assure that our reference stands do indeed represent the type we chose them for. With limited resources, we felt it was better to sample sparingly throughout the full range of vegetation (and moisture) conditions on the H. J. Andrews, rather than replicating communities to more precisely characterize a very few types of forest communities.

Ranges of maximum stress in Oregon vegetation mosaics have been measured in the eastern Siskiyou Mountains (Waring, 1969) and in the South Umpqua Basin of the Oregon Cascades (Minore, 1972). Waring found -5 bars to be the late summer nighttime stress of small Douglas fir on several communities at mid- to high-elevations. Black oak communities were at -26 bars. Minore, measuring only *Abies grandis*, found communities with >-3 to -21 bars stress. He worked in 1969, a year of lower moisture stresses than was 1970 in the H. J. Andrews area (Zobel, 1972). On the H. J. Andrews communities measured, stress ranged from -8 to -27 bars. Higher stresses have been measured around the H. J. Andrews Forest, however. Five Abies grandis saplings on both a cobbly river terrace at 350 m and in open vegetation on a rocky slope at 1370 m averaged between -25 and -30 bars at the end of the 1970 dry season, both drier than R. S. 1 (Zobel, 1972).

In Waring's, Minore's and this study, relatively few communities had maximum predawn moisture stress drier than -16 bars. At less stress, segregation of communities appeared to depend on factors other than water stress or closely related factors.

In the Tsuga heterophylla Zone, highest plant moisture stresses were in communities which occur on moderate to steep slopes having south or southwest aspects, at low elevations, and with shallow and well-drained soils. Low stresses were on sites with deeper, more poorly drained soils of finer texture, at the base of slopes with north to northwestern aspect.

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Table 1. Elevation and Forest Community of Each Reference Stand:

Ref. Stand	Elevation (m)	Forest Community	Abbreviation
1	490	Pseudotsuga menziesii/Holodiscus discolor	Psme/Hodi
2,17	490, 490	Tsuga heterophylla/Rhododendron macrophyllum-Berberis nervosa	Tshe/Rhma/Bene
3	945	Tsuga heterophylla - Abies amabilis/Linnaea borealis	Tshe-Abam/Libo
4	1310	Abies amabilis/Tiarella unifoliata	Abam/Tiun
5	880	Tsuga heterophylla - Abies amabilis/Rhododendron macrophyllum/Berberis nervosa	Tshe-Abam/Rhma/Bene
6	610	Tsuga heterophylla/Castanopsis chrysophylla	Tshe/Cach
7	460	Tsuga heterophylla/Polystichum munitum - Oxalis oregana	Tshe/Pomu-Oxor
8	490	Pseudotsuga menziesii - Tsuga heterophylla/Corylus cornuta var. californica	Psme-Tshe/Cococa
9	460	Tsuga heterophylla/Acer circinatum/Polystichum munitum	Tshe/Acci/Pomu
10	610	Tsuga heterophylla/Rhododendron macrophyllum/Gaultheria shallon	Tshe/Rhma/Gash
11	1010	Pseudotsuga menziesii/Acer circinatum/Berberis nervosa	Psme/Acci/Bene
12	1010	Abies amabilis/Vaccinium alaskense/Cornus canadensis	Abam/Vaal/Coca
13	1310	Abies procera/Clintonia uniflora	Abpr/Clun
14	1430	Abies amabilis - Tsuga mertensiana/Xerophyllum tenax	Abam-Tsme/Xete

Table 2. Species sampled at each site for the years 1970-1972

Ref. Stand	1970				1971				1972			
	Psme**	Tshe	Abam	Tabr	Psme	Tshe	Abam	Tabr	Psme	Tshe	Abam	Tabr
	No. of Trees Sampled											
1	3			1	4				3			
2		1		3		4				2		2
3		3		1		2	2			3		
4		2	2				4			1	3	
5						4				3		
6		1*		2*	3	2			4			
7		3*				4				3		
8					4				3			
9						3		2		3		
10						4				3		
11						4						
12						3	3					
13						3	4					
14							4				3	
17										3		

* Site differs from that used in 1971-72. See text.

**Psme = _Pseudotsuga menziesii_, Tshe = _Tsuga heterophylla_, Abam = _Abies amabilis_, Tabr = _Taxus brevifolia_

Table 3. Average stress of saplings at each site for each set of measurements.

Ref. Stand	Community	1970 Aug 5-6	Aug 12-14	Aug 19-20	Sept 3	1971 Jul 7-9	Jul 23-25	Jul 28-30	Aug 17-20	Aug 24-27
		- - - - - - - - - -Bars- - - - - - - - - - - - - -								
1	Psme/Hodi	19.1	18.4	20.9	23.3	6.4	7.2	9.3	16.1	13.8
2	Tshe/Rhma/Bene	15.0	-	8.1	8.3	9.2	4.0	3.7	6.1	6.0
3	Tshe-Abam/Libo	7.9	-	7.6	9.8	4.4	-	3.7	3.7	-
4	Abam/Tiun	11.2	10.6	5.7	8.3	5.1	-	3.0	3.6	-
5	Tshe-Abam/Rhma/Bene	-	-	-	-	6.0	-	4.4	6.3	-
6	Tshe/Cach	*16.2	-	*17.5	*20.0	6.4	-	4.8	8.1	-
7	Tshe/Pomu-Oxor	* 5.5	*6.2	*8.2	*9.2	4.2	2.7	3.4	4.4	4.2
8	Psme-Tshe/Cococa					9.7	-	7.2	10.5	-
9	Tshe/Acci/Pomu					4.1	-	5.2	6.3	-
10	Tshe/Rhma/Gash					4.7	-	4.6	9.4	-
11	Psme/Acci/Bene					4.4	-	3.0	5.3	
12	Abam/Vaal/Coca					3.3	-	2.7	4.0	
13	Abpr/Clun								4.2	
14	Abam-Tsme/Xete								4.5	
17	Tshe/Rhma/Bene									
Rain since last measurement (mm)		-	0	0	0	-	2.5	0	0.3	13.7

*Sites different than 1971-72 sites.

Table 3. Average stress of saplings at each site for each set of measurements. (Continued).

Ref. Stand	Community	1972 Jul 21	Jul 26	Aug 4	Aug 11	Aug 25	Aug 31	Sept 6
		Bars						
1	Psme/Hodi	18.2	–	24.3	26.4	24.3	26.6	–
2	Tshe/Rhma/Bene	10.8	–	9.3	12.0	8.9	15.4	–
3	Tshe-Abam/Libo	7.7	–	9.6	14.2	12.5	15.0	–
4	Abam/Tiun	–	3.0	7.1	7.9	6.9	8.8	–
5	Tshe-Abam/Rhma/Bene	8.2	–	–	13.8	11.5	–	–
6	Tshe/Cach	–	–	–	–	–	–	14.4
7	Tshe/Pomu-Oxor	6.0	–	5.2	6.9	6.4	8.2	–
8	Psme-Tshe/Cococa	12.5	–	18.9	21.2	17.6	19.4	–
9	Tshe/Acci/Pomu	10.4	–	7.8	9.2	7.8	6.2	9.6
10	Tshe/Rhma/Gash	11.7	–	14.4	17.2	10.9	13.0	–
11	Psme/Acci/Bene			–		–		
12	Abam/Vaal/Coca			–		–		
13	Abpr/Clun			–		–		
14	Abam-Tsme/Xete			10.0		–		
17	Tshe/Rhma/Bene					8.1		
Rain since last measurement (mm)		–	0	0	0	27.2	0	0.8

*Sites different than 1971-72 sites.

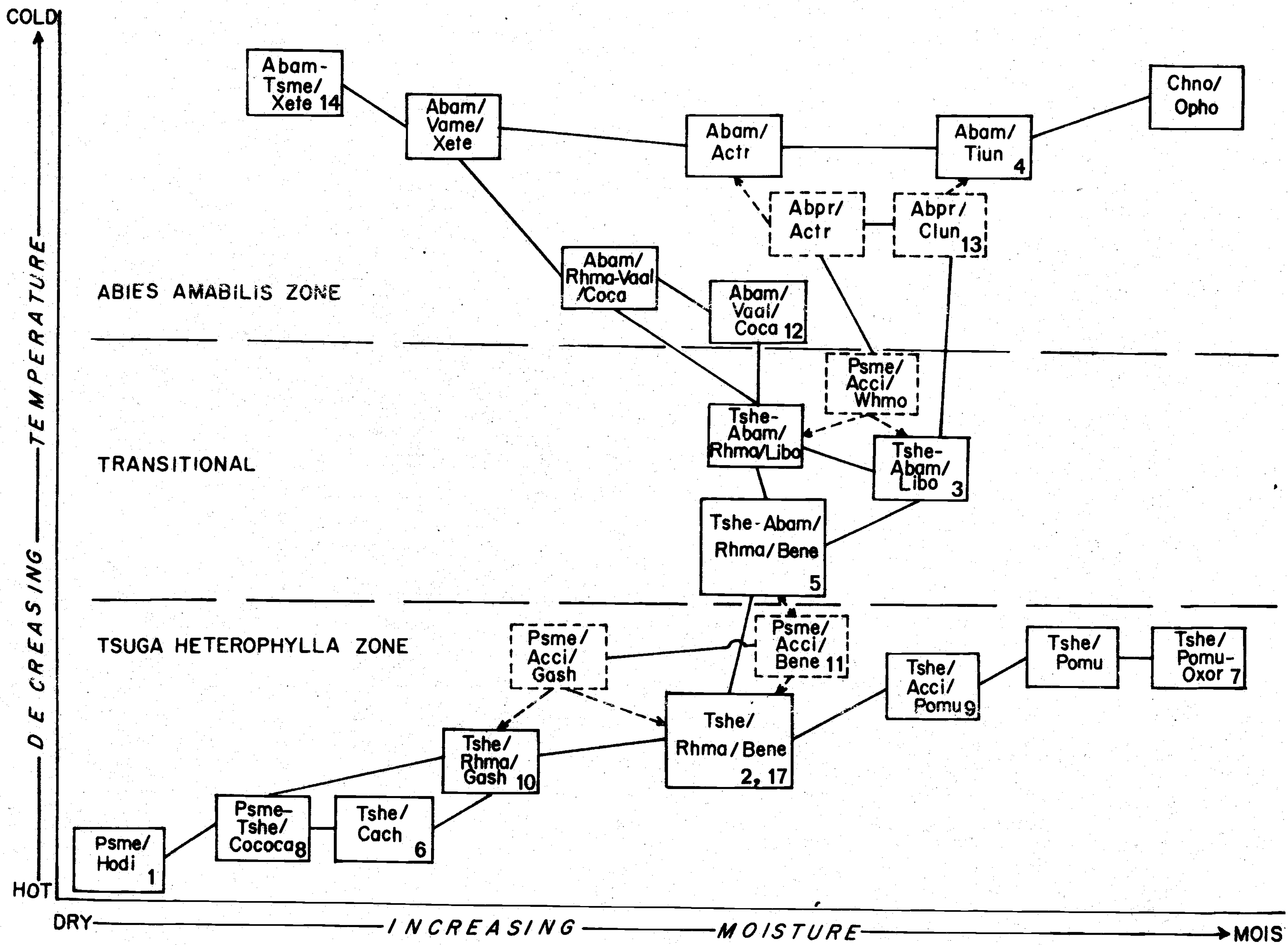

Figure 1. Diagramatic representation of the vegetation ordination of Dyrness *et al*. (1972). Communities sampled in this study are identified by a reference stand number in the box. Communities enclosed with dotted

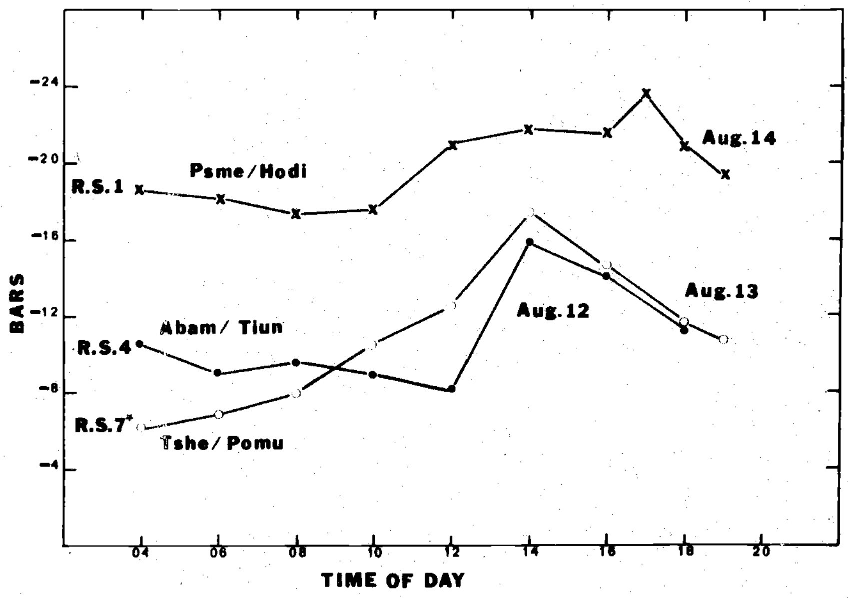

Figure 2. Diurnal patterns of plant moisture stress in 1970.

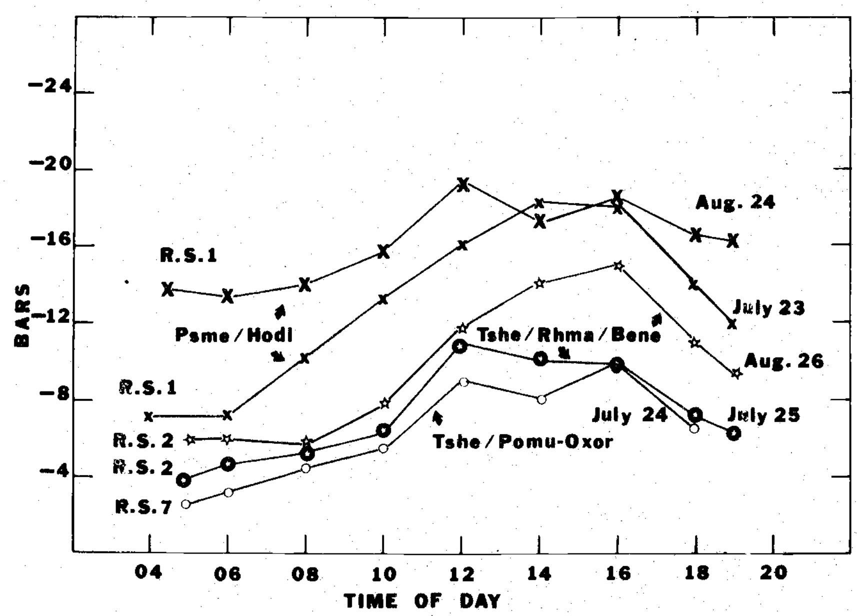

Figure 3. Diurnal patterns of plant moisture stress in 1971.

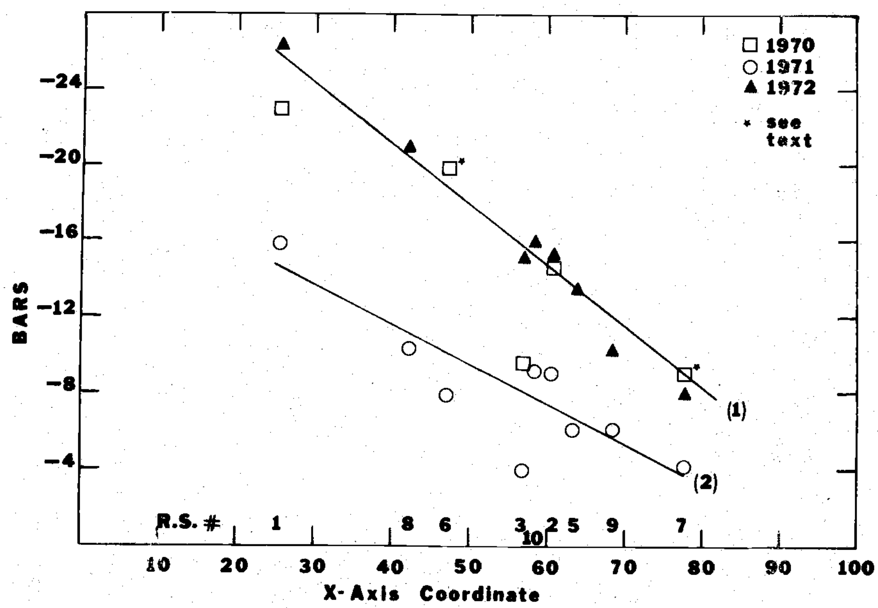

Figure 4. Relationship of maximum yearly predawn moisture stress to position of the community on the X-axis of the vegetation ordination of Dyrness et al. (1972). The community represented by each reference stand is listed in Table 1. Linear regressions: (1) 1970 + 1972. $Y = -33.96 + 0.319 X$, $r^2 = .95$; (2) 1971. $Y = -20.00 + 0.207 X$, $r^2 = .83$. (Data from R.S. 3 were excluded from the regression equations.)

Appendix

Common Names of Species Mentioned in the Report

Trees:

Abies amabilis	Pacific silver fir
A. grandis	Grand fir
A. procera	Noble fir
Pseudotsuga menziesii	Douglas fir
Tsuga heterophylla	Western hemlock
T. mertensiana	Mountain hemlock

Shrubs and small trees:

Acer circinatum	Vine maple
Berberis nervosa	Long-leaved Oregon grape
Castanopsis chrysophylla	Golden chinkapin
Corylus cornuta var. californica	California hazel
Gaultheria shallon	Salal
Holodiscus discolor	Ocean-spray
Rhododendron macrophyllum	Pacific rhododendron
Vaccinium alaskaense	Alaska blueberry

Herbaceous plants:

Clintonia uniflora	Queen-cup bead-lily
Cornus canadensis	Bunchberry
Linnaea borealis	American twinflower
Oxalis oregana	Oregon oxalis
Polystichum munitum	Sword fern
Tiarella unifoliata	Western coolwort
Xerophyllum tenax	Bear grass