the region indicated in the title is 398. We may surmise that no less than 500 actually occur.

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NOTES ON METEOROLOGY AND CLIMATOLOGY

PHENOLOGY

PHENOLOGY is the study of the periodic phenomena of plant and animal life in their relation to weather and climate. Phenology is most important in forestry, agriculture, horticulture and ornithology. In spite of the wide application of such data there has been but little phenological observing done in this country. The extent of such work here and abroad is summarized by J. Warren Smith in Monthly Weather Review, Supp. 2, October, 1915, in connection with the remarkably long and extensive records of Thomas Mikesell at Wauseon, Ohio. These Wauseon records began in part in 1869 and are published including 1912; complete data are given concerning 114 kinds of wild plants, 48 forest trees, shrubs and vines, 16 kinds of fruits, 20 field and garden crops (with yields of some), and the temperatures, rainfall, frosts and first and last snows. In parts of Europe similar records though of fewer plants have been taken by many observers in the British Isles for more than 20 years and in Hessen 33 years.[1]. Ihne[2] in charge of the latter has made a map of phenological spring, and also compared the distribution of population with the phenological maps.

The Bureau of Entomology and the Forest Service are studying phenology as an aid in planting and cutting trees and in the control of pests.

Dr. A. D. Hopkins, of the former, has formulated in a general way the law of phenological variation as follows:[3] "The average variation in the dates of a phenological phenomena of a species is in uniform proportion to the variation in the controlling factors of climate." The general average is the only one for drawing reliable conclusions. A variation of 4 days is to be found with a difference of 1° in latitude, 400 feet in altitude, 5° in longitude westward, or 1° F. The longitude variation seems to be connected with the increasing dryness and strength of sunlight for the Central United States, and with the warmth of the Pacific as the west coast is approached. Departures from the theoretical are the result of local factors. Prevailing sunshine, aridity, absence of large bodies of water, warm ocean currents, prevailing warm winds, S., S.E. and S.W. slopes, narrow summits or plateaus of hills and mountains, broad valleys, open forests, barren or sandy and dry soils—these are accelerating; the opposite conditions are retarding. The size of departures are roughly as follows: error in interpretation, 2 days; southern or northern slopes 1 to 4 days, other retarding or accelerating factors, 1 to 4 days, early and late individuals 1 to 8 days, coastal influences 10–14 days.

The results of collection made by the Forest Service of a large amount of phenological data on 72 common trees in the eastern United States is published in Monthly Weather Review, Supp. 2, October, 1915, pp. 5–9 incl., "A Calendar of the Leafing, Flowering and Seeding of the Common Trees of the Eastern United States," by George N. Lamb. The dates are given only for the extreme north and south limits of their ranges. Further cooperation in the collection of such data is desired by the Forest Service.

In agriculture, phenology contributes not only to the control of pests, but also is of use in determining the proper dates for planting certain crops. On the basis of a thorough study of the Hessian fly at one or more control stations in West Virginia, Dr. Hopkins was able to construct a map and table with which if he knew his location and altitude a farmer could plant his winter wheat during a short period immediately after the usual disappearance of the Hessian fly. In the spring, wild plants are used by many to indicate the proper

1 Quart. Jour. Roy. Meteorological Soc., J. E. Clark—13 common plants, 6 birds, 5 insects, more than 100 stations.

2 "Arbeiten der Landwirtschaftskammer für das Grosherzogtum Hessen."

3 "Report on Forest Trees," 1914.

dates for planting. Thus, "when the silver maples begin to put forth their leaves and the catkins appear on the willows and poplars, nature is indicating that the season is right for the planting of such vegetables as lettuce, mustard, onion seeds and onion sets, parsley, the round seeded peas, early Irish potatoes, radishes, spinach and turnips."[4] Ten days later beets, carrots, kohl-rabi and a second sowing of peas can be made.

[4] U. S. Dept. Agric. Weekly News Letter, Mar. 24, 1915.

CLIMATOLOGY OF THE PERUVIAN ANDES

DR. ISAIAH BOWMAN has devoted one sixth of his recent book, "The Andes of Southern Peru" (336 pp., New York, 1916) to a well-illustrated discussion of the perplexing diversities of Peruvian climates. There are four climatic belts: (1) the wet, eastern lowlands, covered with heavy tropical forest; (2) the wet, windward mountain slopes, with mountain forest extending up to the cold timber line at 10,500 feet, and in protected valleys down to a dry timber line at 3,000 feet; (3) semi-arid mountains, plateaus and basins, covered with grass, moss and alpine plants; (4) the arid coastal zone of irrigated valleys, barren except along valley floors and on the seaward slopes of low coast ranges.

On the wet, windward mountain slopes the belt of heaviest rainfall is between 4,000 and 10,000 feet. Summer is rainiest, for the force of the trade wind by day is greatly increased by virtue of the greater contrast between the highland and lowland temperatures. In the deep, shut-in valleys of the eastern mountains, conditions of marked aridity are found. The local climates of the semi-arid mountains, plateaus and basins depend on altitude, and thus differ primarily in temperature and winds. The chapter on "Meteorological Records from the Peruvian Andes," adds the daily touch to the preceding general discussion of climate. Extensive diagrams, including daily temperature maxima, minima, variability, and daily rainfall show a tropical steadiness, but, withal, sudden weather changes and considerable differences between corresponding seasons of different years. The diagrams taken from thermograph tracings show vividly the effect on the temperature of changes of wind, the passing of clouds or the inception of storms. The Yale Peruvian Expeditions with the National Geographic Society still maintain some meteorological stations in Peru.

The climates of the coast are the most difficult to explain. Widely accepted are the general explanations of the coastal desert of northern Chile and of Peru: that the deserts are there because the normal trade winds blow over the mountains and on descending are warming, drying winds; and that the cold coastal water intensifies the dryness because any winds thence have little tendency to yield rainfall over a warm land. This cold water is an adjunct of the prevailing offshore "trades," for the warm surface water blown out to sea is replaced by cold abysmal water. In southern Peru, Bowman distinguishes five zones from coast to mountains: (*a*) zone of coastal terraces, rain once in many years; (*b*) zone of fog-covered mountains, rain at intervals of 5–10 years; (*c*) zone of desert plains, rain at intervals of many years; (*d*) zone of steep valleys, yearly rains; (*e*) zone of lofty mountains and plateaus, frequent rains in summer months.

The sea-breeze is the most important meteorological feature of the coast. By day the heating of the land on a slope tends to make an up-hill wind; the heating of the land next to cold water tends to make a breeze on-shore. Combined, these two factors make a wind which blows so strongly that shipping operations in the afternoon are hindered or rendered impossible. Its coming at or before noon is uncomfortably boistrous and dusty. On the coast the highest temperature occurs just before the sea-breeze arrives. The coast range, where present, makes this wind rise abruptly several thousand feet, which generally causes fog at 2,000 to 4,000 feet elevation, and in winter some rainfall. Beyond the coast range, however, the air is warmed, and mixed rapidly by convection with the high dry air so that no more condensation occurs until it approaches the western Cordillera. There the topographically forced ascent of the air again brings it to the condensation point, and at 8,000 feet, rain may come in summer. The rainfall on the windward side of the coast range occurs in winter, for then the land is more nearly the temperature of the water. In summer, even with the sea-breeze twice as strong, the heated land surface warms the ascending air too rapidly for the occurrence of precipitation. As little moisture is lost in summer on the coast range, the relative humidity is higher in the interior, so that as the strong winds drive up the mountains, there is more moisture available for precipitation. With unusual wind frequency from the north, there are heavy coast rains at intervals of four to ten years, for then the cold coast water is replaced by a warmer current.

Throughout Peru, the trade winds are in control: there is the wet windward slope, the semi-arid interior plateau and the arid leeward coast. The extraordinary inner diversity of climate in the eastern mountains is due to the difference in exposure to the trade winds, and to the differences in altitude. The contrasts within the desert coast region are the result of the effect of the topography on the daily sea-breezes of varying strength blowing off the cold Humboldt current.

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SPECIAL ARTICLES

THE DISTRIBUTION OF ENDEMIC SPECIES IN NEW ZEALAND

THE flora of New Zealand is so exceptionally rich in endemic forms that its study promises interesting results if taken up under the modern conceptions concerning the origin of species. It embraces among the angiosperms 902 endemics confined to New Zealand proper against 399 forms of wider distribution, 98 of which are confined to New Zealand and outlying islands. This consideration has induced J. C. Willis to make a statistical study of this flora[1] and to compare it with the results deduced from his similar treatment of the endemic forms of Ceylon.[2]

Willis has proposed a new principle for explaining the distribution of plants in general, which is that "the area occupied by any given species (taken in groups of twenty or so) at any given time in any given country in which there occur no well-marked barriers depends upon the age of that species in that country." This proposition he calls his hypothesis of "age and area." It is intended to convey the idea that adaptation, although it may be of use in determining the frequency of a species within its area, is not in general a factor of wider operation. No results show in the figures which can be attributed to it. Exceptional instances, where this seems to be the case, are almost always the result of changes in environic conditions, made by man, and it is a well-known fact that such rapidly spreading forms invade a country along its roads and railroads, occupying chiefly waste fields and stirred-up soil.

If, however, we leave these out of consideration and concern ourselves only with ordinary wild species, statistical study seems the only means to get average and reliable results. Taken in small groups of, *e. g.*, 10–20 species these statistical results prove to be the same everywhere and in all the larger families. A general cause must govern this phenomenon, a cause which is, at any rate, independent of morphological and biological qualities.

New Zealand is very convenient for determining the area of its species, for the islands are spread out in a long curve running in general north and south for about 1,080 miles, with an average breadth of 100. Therefore longitudinal range can simply be substituted for area and this can be determined by dividing the country by transverse lines at every twenty miles. Moreover, it consists chiefly of two parts: North Island and South Island, which do not show any essential barriers to the spreading of plants, but are separated by a channel broad enough not to be passed by

[1] Dr. J. C. Willis, "The Distribution of Species in New Zealand," *Annals of Botany*, Vol. 30, No. 119, July, 1916.

[2] See the review in SCIENCE, N. S., Vol. 43, No. 1118, pp. 785–787, June, 1916.