

magpies and green woodpeckers are stated to be more common at the present day than was formerly the case, while it is only of late years that the pushing starling has taken to breed in the district. With a bare reference to the account of the author's last sight of a pair of Cornish choughs—possibly the last of their kind—we must take leave of a charming volume.

In any work devoted to outdoor life in Norfolk the element of sport is certain to loom large, next to which birds will probably claim a considerable share of the author's attention, and Mr. Robinson's volume is no exception to this rule. Such subjects as "a royal shoot" and "beside the covert" are, indeed, intercalated with chapters on "panics in bird-land," "the hawk's harvest," and the "birds of autumn," and throughout the portions devoted to the wild life of the county there will be found scattered many observations

RELATION OF RAINFALL TO RUN OFF.

IN NATURE of January 7 (vol. lxxix. p. 226) notice was directed to the attention paid by the Geological Department of the United States to the water resources of the country, and to the series of reports that had been issued relating to the supply available for domestic and business purposes, for power and for irrigation. We have recently received a further series of reports relating to the progress of the stream measurements for the year 1902 carried out on the northern and southern Atlantic coasts, Mississippi River, Great Lakes, Pacific coast and Hudson Bay drainage districts; the hydrography of California and the storage reservoir there; and an account of the irrigation of India.

With the exception of the last, these volumes consist almost entirely of statistical records of the flow



FIG. 1.—Fox cubs. From Tregarthen's "Wild Life at the Land's End."

From a Photograph by C. Reid.

which cannot fail to be of interest to the field-naturalist and lover of the country. A feature of the work is the candid and straightforward manner in which the utility or harmfulness of the mammals and birds generally classed by keepers as "vermin" are discussed, no special pleading being used to afford any of these creatures exemption from destruction when, in the author's opinion, it is well merited. Among the mammals which, according to Mr. Robinson, rightly occupy a place in the "keeper's museum" are the stoat and the hedgehog, the indictment against the latter, from the keeper's point of view, being even heavier than the one in Bell's "British Quadrupeds."

To residents in Norfolk the book should prove specially welcome, but it is also one which can be taken up to while away an idle hour by every reader interested in sport and country life.

R. L.

of streams, and although of great value to American hydrologists, do not call for any special notice.

Paper No. 80 of the series of hydrographic investigations on the relation of rainfall to run off, compiled by Mr. George W. Rafter, contains information which is of value to those interested generally in the question of water supply.

The author of the paper commences by saying that, as the result of many years' study of the problem indicated by the title of the paper, he has come to the conclusion that no general formula is likely to be found expressing accurately the relation of rainfall to the run off of streams, for these vary so widely in their behaviour that every stream is a law unto itself.

Mr. Rafter directs attention to the desirability of the adoption of uniformity or standardisation of the units of measurement, and warns engineers to be very slow to add to the number of standards of measure

for flowing water already in use. In the United States, as in this country, the cubic foot is taken as the unit of volume and the second as the unit of time when measuring flowing water in streams, while here the gallon is generally adopted as the unit when dealing with supplies for domestic purposes. In the United States the million gallons in twenty-four hours appears to be recognised as a standard for city water supply, and an acre in area covered one inch or a foot deep in a month or a year is used for irrigation purposes. The unit of inches of rainfall per acre on the catchment area and the resulting run off in gallons for town supplies, or in cubic feet for drainage, is a measure of very general adoption. In India many irrigation engineers have adopted the term "cusecs" as representing cubic feet per second.

With regard to the proportion of rainfall that finds its way into a stream, the author deprecates the use of averages, and expresses the opinion that safe deductions can only be obtained from using the minimum rainfall and taking into account the longest period such minimums may be expected to occupy. The records of the United States show that this minimum period may be expected frequently to last more than three years.

In this country the general rule is to take the average of the longest period over which the rainfall records of the district extend, from this to deduct one-fifth to allow for the mean annual rainfall of the three consecutive driest years, and from the product further to deduct from eleven to fifteen inches for loss by evaporation, soakage, &c., according to the character of the ground, the remainder giving the quantity available for storing. If compensation water has to be provided, a further deduction of one-third of the available supply has to be made. Fourteen inches is commonly taken as the figure representing evaporation, &c., in this country. For example, with an average annual rainfall of thirty inches, ten inches would be available for run off or storage, or, where compensation water has to be given, 6.67 inches would be available for storage. Taking an inch of rainfall as 3630 cubic feet per acre, 10 inches would give 36,300 cubic feet or 226,300 gallons to the acre of gathering ground.

As a general statement, Mr. Rafter's investigations have led him to the conclusion that the minimum rainfall varies from half to one-fourth the maximum.

The late Mr. Symons's proportion for this country was that the rainfall for the wettest year was half as much more than the mean, and for the driest year one-third less, or, taking the average of three wettest years, one-fifth less than this average.

Mr. Rafter considers that averages derived from a shorter period than thirty-five years are not to be relied on within 2 per cent. The same conclusion was arrived at by Mr. H. R. Binnie in his paper on the average annual rainfall reported in the minutes of proceedings of the Institution of Civil Engineers, 1892. This figure was derived from an examination of rainfall statistics from 153 stations situated all over the world. While short periods like five years' average gave an error of 32 per cent., and thirty years 5.8 per cent., the error for thirty-five year periods was only $2\frac{1}{2}$ per cent., and fifty years came no closer.

Although the annual quantity of rainfall varies very much in different localities and in different countries, the same law universally applies as to the relation of the wettest and driest years to the average fall if taken over a sufficiently long period.

As pointed out by the author of the report, caution is necessary in taking the average of the rainfall as a guide; for storage purposes, where the water has to

be collected in a reservoir a minimum fall derived from an average of years may be a trustworthy guide, but where provision has to be made for carrying off the water in artificial channels for drainage purposes, or where the water has to be pumped, as in low-lying districts, the data to be ascertained is the maximum rainfall that has to be dealt with in a short period. Thus, while the rainfall of the year, or even of the winter months, may not have been excessive, yet floods may have ensued due to heavy rain falling for a few days on ground already saturated. In the Fen districts on the east coast of England, which depend entirely on artificial drainage, the rule is to allow for a discharge equal to a continuous fall of a quarter of an inch of rain during twenty-four hours. The mean daily fall of the rain which caused the twenty-one floods in the Witham district since 1852 was an average of 0.26 inch spread over seventeen days; the average annual fall of the district for the wet period was 32.39 inches, and over a period of seventy years 22.93 inches. The greatest fall during this period averaged 0.41 inch spread over fourteen days, in November, 1885, and also in October, 1883, when there was considerable flooding.¹

The figures given in this paper show that in the eastern States of America with a maximum rainfall of from 20 to 60 inches half the rainfall runs off, and that with a minimum fall from a fourth to a sixth. In the western States, with a fall of about 12 inches, the run off varies from half an inch to an inch.

The total run off of a stream depends very largely on the run off of the storage period. Usually about 0.75 to 0.85 of the total rainfall of this period runs off in the stream, while for the summer, or growing period, not more than about 0.1 of the rainfall appears, this small quantity being due to evaporation and absorption by vegetation. The total run off for the year depends very largely on whether or not the rainfall from December to May is large or small. Whether any given stream is low during the summer months or has then a well sustained flow will depend very largely on the rainfall of the month of May. When the May rainfall is heavy enough to produce full ground water, the flow is likely to be well sustained.

The extent of afforestation seems to have a considerable effect on the run off of streams, catchments with dense forests showing a larger run off for the same rainfall than those which are deforested.

THE ARAPAHO SUN DANCE.²

THE scientific value of the anthropological series of the *Publications* of the Field Columbian Museum, Chicago, has been sustained by the important memoir on the Arapaho sun dance by Dr. G. A. Dorsey, the energetic curator of the Department of Anthropology. Although only very recently published, the work bears the date of June, 1903, which will cause superfluous trouble to bibliographers. Dr. Dorsey witnessed the sun dance in 1901 and 1902, and he has taken great pains to give a clear and minute account of this eight-day ceremony. The description is illustrated with a great wealth of illustrations, there being no fewer than 135 plates, many of which contain two figures; it is probably safe to say that no ceremony has hitherto been so amply illustrated. It is also a matter of congratulation that the description is so detailed, as the significance of a ceremony can only be adequately realised when all the details of the events

¹ "The Fens of South Lincolnshire" (Simpkin, Marshall and Co., Ltd.)
² "The Drainage of Fens and Lowlands" (Spon, Ltd.).

² "The Arapaho Sun Dance; the Ceremony of the Offerings'-Jodge. By G. A. Dorsey. Field Columbian Museum, Anthropological Series. Vol. iv. (Chicago, U.S.A., June, 1903.)