There was a close qualitative correspondence between the zones of sheet and bubble cavitation and those on a $\frac{1}{4}$ -scale model of the propeller, provided the latter was run in aerated water in a cavitation tunnel at a speed rather higher than that nominally corresponding to the ship speed. The blades as photographed in the ship were, however, in positions where the hull wake exerts an important influence, which might account for some of the difference in equivalent speeds.

Although photographs are an invaluable adjunct, visual observation is perhaps even more important. As already mentioned, this can be made at night by using a stroboscopic flash synchronized by a propeller shaft contact, as is the practice in cavitation tunnels. There are, however, many positions on the blade surface which cannot be effectively illuminated by a flash issuing from any of the available ports. If, however, the observations are made in bright daylight, using a hand-operated variable-speed slit stroboscope, it is often possible to observe cavitation at these sites due to their being sufficiently well illuminated by the diffused sunlight below the hull.

Since these preliminary trials were made, observation ports have been fitted to other vessels, and a considerable amount of useful data is accumulating as a result. It has, for example, been found that the arms of an A bracket supporting the propeller shaft may in certain cases show heavy cavitation at high speeds; as is well known, this may be an important cause of structural erosion.

Another problem in which direct observation may prove helpful is that of the 'singing propeller'; it may, for example, be found that certain cases of excited blade vibration are associated with an intermittent tip-vortex cavitation, a combination of phenomena which I once observed when a model propeller in a tunnel was working at both very high slip and high cavitation index.

This article is published by permission of the Admiralty.

¹ Fisher, J. W., *Trans. N.E. Coast Inst. Eng. and Shipbuilders*, 68, p. 20; also *Engineering*, Dec. 7, 1951, p. 729.

THE CHANGING FLORA OF BRITAIN

By J. E. LOUSLEY

IT is perhaps persistence, rather than the changes in the British flora, which first impresses those who interest themselves in field botany. Remarks from older workers that plants have grown in the places where they know them since the days of their youth, and the realization that certain rarities are still to be found in the places whence they were recorded by early botanists, combine to give a false impression of permanence. The fact that local quantitative changes in the vegetation are going on constantly, and are sometimes not difficult to observe, is now well known owing to the work of ecologists over the past half-century. The qualitative changes in our flora generally are not so widely appreciated.

A conference arranged by the Botanical Society of the British Isles was planned to bring together the various approaches to the study of changes in the floristics of Britain. Held at the Royal Horticultural Society's New Hall, during April 4-5, under

the title "The Changing Flora of Britain", the conference was attended by 270 members and guests. It was followed by a field meeting in Kent on April 6 for the study of species discussed in some of the papers.

The president of the Society, the Rev. Canon C. E. Raven, opened the proceedings with a paper on "The Significance of a Changing Flora". He instanced *Eryngium campestre* and *Veronica spicata* as species still to be found in the precise localities recorded by John Ray in the seventeenth century, and directed attention to the relatively small number of the very many aliens added to our lists since his time which have established themselves permanently. He pointed to the vitality and invasiveness of *Spartina townsendii*, like *Poa annua* and *Galeopsis tetrahit* which are likewise now regarded as of hybrid origin, and suggested that further investigation of examples of such amazing efficiency might demonstrate that fertile hybrids have played a not unimportant part in the process of evolution. "While the changes in our flora by invasion give rise to a number of fascinating ecological, physiological and chemical problems which deserve full investigation", Canon Raven pleaded for a wider and deeper study of the changes taking place in our flora by the extreme variability of critical groups and especially of *Rubus* and *Hieracium*. These, he said, present fascinating problems not only to the systematist but also to the general biologist. Botanists should make a greater contribution to the general study of science than has been the case in the past, and this conference, by bringing together so large and varied a group of botanists, might do something to facilitate this by bridging the gap that is always liable to open between the field-worker and the expert, the amateur and the professional.

The historical approach to the theme was introduced by a paper by Dr. H. Godwin (Botany School, Cambridge) on "British Vegetation in the Full-glacial and the Late-glacial Periods". After reviewing the British Late-glacial (between 10,000 and 15,000 years of age) and earlier Full-glacial deposits, and evidence for their correlation with stages of glaciation and with West European deposits, he discussed floristic lists of species identified from beds of these ages. Two species, *Silene calata* Reid and the less-satisfactory *Linus præcursor* Reid, from the Full-glacial, are no longer known as living plants. A number of arctic-alpine plants have become extinct in Britain in the Post-glacial period; but material of twenty-six out of a total of seventy-six in the present British Arctic-Alpine element (as listed by Matthews) has been found in the Full- and Late-glacial deposits. Their distribution in many instances was very much wider than their present range. Of Matthews's other phytogeographical categories there were representatives of the Alpine, Arctic-Subarctic, Northern Montane, Continental Northern (ten recorded for the Full-glacial and fifteen from the Late-glacial, out of a total of ninety-one), Continental, Oceanic Northern and some others. The very long list of ruderals or weeds must indicate the prevalence of open conditions, bare soil surfaces and freedom from competition; and it is evident that many weed species hitherto thought to be introductions to Britain by Neolithic and later agriculturists are of much older standing. An appropriate sequel to Dr. Godwin's paper was the demonstration by D. Walker and R. West (Cambridge) of material collected from Late-glacial deposits in the Lake District, and of the

characters by which they had succeeded in distinguishing the pollen of *Betula nana* from that of *B. pubescens*. Dr. E. Dahl (Oslo) compared the sub-fossil and present distributions of some Scandinavian alpine plants and showed that these could be explained by the estimated maximum summer temperatures, since very warm periods in summer are detrimental to the species involved. Dr. Ch. H. Andreas (University of Groningen) discussed glacial relics in the Netherlands, and particularly *Carex aquatilis*, of which the existence in the country in Pleistocene times has been confirmed by the discovery of material in deposits of the Würm-glacial and Late-glacial periods. In the latter case it was accompanied by the remains of many of the species which grow with it to-day.

"Natural Factors Contributing to a Change in our Flora" were reviewed by Prof. T. G. Tutin (University College, Leicester). He stated that the three main causes of qualitative change are evolution, climatic changes and the introduction or extinction of species. The main processes of evolution are: (1) the gradual differentiation of species through mutation and selection without change of chromosome number, producing in time what Valentine has called *g*-ecospecies. *Primula vulgaris*, *P. elatior* and *P. veris* show a comparatively late stage of this process, and *Melandrium rubrum* and *M. album* a somewhat earlier stage. (2) The process of doubling, quadrupling, and so on, of chromosomes producing polyploid series and giving rise to *a*-ecospecies in Valentine's terminology. *Spartina townsendii* is a well-known example. Apomixis enables hybrids, notably triploids and pentaploids, which would otherwise be sterile, to reproduce successfully and largely accounts for the great number of 'small' species in genera such as *Hieracium* and *Rubus*. (3) The process of aneuploidy, which entails the gain or loss of one or a few pairs of chromosomes and also gives rise to *a*-ecospecies. This is rarer; but in certain genera, and in particular *Carex*, it is commoner than polyploidy.

Prof. Tutin then turned to climatic changes and suggested that these were the primary cause of *Senecio paludosus* and *Trichophorum alpinum* becoming extinct. *Alisma gramineum* and *Scutellaria hastifolia* he thought had probably been introduced by natural agencies. Quantitative changes in our flora are seldom noticed except among rare plants or plants that were formerly rare—the main causes are changes in climate (and annual fluctuations in weather), and drastic changes in habitats due directly or indirectly to man. The dramatic spread of *Chamaenerion angustifolium* and *Crepis taraxacifolia* was discussed. In conclusion, he suggested that the two most important natural factors producing changes in our flora are evolution and altering climate—both very powerful and far-reaching, but both slow-acting. There is a great need for more observations from amateurs to provide the essential basis for experiments to be made by professional botanists.

A valuable opportunity of comparing changes in our own flora with those which have taken place in a district just across the English Channel was provided by Dr. Paul Jovet (Muséum Nationale d'Histoire Naturelle, Paris), who spoke in French. Abbot Questier had left note-books recording his observations made daily during 1843-76 in Valois, and by comparing these with the records of contemporary botanists from 1924 until 1949 it was possible to

give a more complete account of the modifications than has yet been attempted for any English district. Prof. A. R. Clapham (University of Sheffield) dealt with "Human Factors contributing to a Change in our Flora" by considering the distribution and habitats of five abundant and widely distributed species which are more or less confined in Britain to secondary man-made habitats. These are *Aegopodium podagraria*, *Chærophylloides temulum*, *Anthriscus vulgaris*, *Tanacetum vulgare* and *Tussilago farfara*. He suggested that some of these at least could be regarded as ancient inhabitants of Britain which had colonized river drift-lines, etc., and been available for spreading into clearings made in the forests by Neolithic man. They would be likely to attract attention as potential foods or medicines, and when their original homes had been destroyed or modified, wayside hedges remained as suitable habitats. Dr. E. Hughes (School of Agriculture, Cambridge) described possible human historical factors which seem to explain the present distribution of *Eriophorum latifolium* and other species in the Conway valley. Areas enclosed in the sixteenth century contain this cotton-grass, which is absent from those enclosed in the medieval period.

Dr. Maurice Burton (British Museum (Natural History)) discussed "The Zoologist's Approach to a Changing Flora". He said that zoologists are all aware of the dependence of animals on plants, either directly or indirectly; but they are very diffident about considering anything beyond the limits of their own subject. There is a big gulf between the work of zoologists and botanists, and he suggested that many zoological problems might be resolved if we knew more about the detailed dependence of animals upon the flora. R. D. Meikle (Royal Botanic Gardens, Kew) discussed the post-war additions to the British flora. Excluding micro-species, rediscovers and aliens, there still remained four species of outstanding importance which added a new family and two new genera to the British list. *Diapensia lapponica* L. was noteworthy as having been discovered by an ornithologist to the astonishment of botanists, and *Kœnigia islandica* L. was one of the few non-critical British plants discovered in a herbarium: both are undoubtedly native on remote hills in Scotland. *Equisetum ramosissimum* Desf. in Lincolnshire may have arrived fairly recently by spores carried by the wind from the Continent; *Cerastium brachypetalum* Pers. on railway banks in Bedfordshire may be derived from native stocks elsewhere which have been passed over for the common *C. viscosum*.

The geographical approach to changes in our flora was considered by Dr. S. M. Walters (Botany School, Cambridge), Dr. J. Heslop-Harrison (University College, London) and Dr. A. Melderis (British Museum (Natural History)). Dr. Walters dealt with "The Continental Element in our Flora". He pointed out that the whole of our flora is of an oceanic type, as one might expect from our cool mild climate with no great extremes, and the so-called 'Continental' species are those which do not occur commonly in western Europe. For convenience three types of these 'Continental' species can be recognized: (a) the Continental Northern Element which includes species characteristic of the northern coniferous forest and also some, like *Viola rupestris* Schmidt and *Astragalus danicus* Retz., which are not woodland plants; (b) the Continental Element proper, of

species widespread in central Europe and extending into eastern Europe and Asia—such as *Veronica spicata*; and (c) the Continental Southern Element species with a patchy and discontinuous distribution in western Europe. These grade from examples like *Carex humilis* Leyss., a typical hill-steppe species, to those like *Buxus sempervirens*, which is perhaps Sub-Mediterranean rather than Continental Southern. Dr. Walters pointed out that our 'Continental' species are generally plants demanding soils of high base status (particularly lime), most of them are intolerant of shade and unable to persist in the later stages of succession, and some show considerable ecotypic differentiation. Some of them are now absent from areas from which it is difficult to believe that they are excluded by present factors of climate or competition. He suggested that present distribution could be explained by changes in climate having altered the available habitats, and by clearances of forest in different parts of the country taking place at different times.

Dr. Heslop-Harrison's paper discussed "The North American and Lusitanian Elements in our Flora" as based on the lists of constituent species accepted by Præger. He showed that the "North American" species are all aquatics or plants growing near lakes, and, after examining earlier explanations of their present distribution, suggested that they could have been brought to the British Isles from North America, via Greenland, by the migratory movements of birds such as the Greenland white-fronted goose, *Anser albifrons flavicornis*. The weight of evidence is now strongly against pre-glacial survival as an explanation of the present distribution of the Lusitanian species. It seems more likely that their present areas are the remains of former continuous ones and that the problem they present should not be considered separately from that of other southern species in the British flora. He suggested that their present marked discontinuities of range are to be attributed partly to submergence of former land surface, partly to area shrinkage in later periods of climatic deterioration, and partly to extermination through the appropriation of their habitats by harder or better adapted species. The exhibit prepared by Dr. A. Melderis on "Some Parallels between British and Scandinavian Plants" compared the mountain floras on the basis of the world distribution of the constituent species.

The contributions made by alien species to changes in the British flora were the subject of several papers. Sir Edward Salisbury (director, Royal Botanic Gardens, Kew) introduced this aspect under the title of "A Changing Flora as shown in the Study of Weeds of Arable Land and Waste Places". He pointed out that recent work had increased the probability of the views he expressed twenty years ago concerning the evolution of plants of open habitats in relation to the vast morainic deposits at the end of the glacial epoch. The wide distribution of some of these species that appear to belong to no definite geographical component may well be an ancient feature. Human activities have provided sanctuaries for plants of open habitats; and for those which are found mainly in artificially created conditions it is largely a matter of guesswork whether they are to be regarded as native or not except in the cases where we have evidence of their introduction. He reviewed changes in weeds found in arable land, introductions from Europe and America and contrasts between the rate of spread of different

introduced species, and he reminded the audience that "the British Flora is not an event but a process that is continuing both with respect to accretions and diminutions".

"The Recent Influx of Aliens into the British Flora" was considered by Mr. J. E. Lousley (general secretary, Botanical Society), who enumerated the known and suspected agencies by which plants are introduced. He stressed the changes in these sources due to variation in commerce and customs, and urged the need for closer study of the means of introduction. Opportunities for sampling the plants being brought in at docks, railway yards, canal wharves and rubbish tips, and the stages by which species became established in artificial habitats or naturalized in competition with the native flora were reviewed. *Thlaspi alliaceum*, *Ranunculus muricatus*, *Vulpia megalura*, *Rapistrum rugosum*, *Bunias orientalis*, *Tetragonolobus maritimus*, and *Acæna anserinifolia* were considered in some detail, and their history in Britain described. All fairly recent introductions, they were selected as forming a series, in the order given, showing decreasing dependence for their persistence on human activities. An exhibit of "Wool Aliens" by Dr. J. G. Dony (field secretary, Botanical Society) had special reference to those found in Bedfordshire during the past five years, with an analysis of the species found according to the countries where they are believed to be native. The spread of the North American *Epilobium adenocaulon* and the New Zealand *E. pedunculare* in Britain were illustrated respectively by Mr. G. M. Ash and Miss A. J. Davey (University College of North Wales, Bangor).

Trees and shrubs were discussed by Dr. E. F. Warburg (University of Oxford), Mr. A. D. Bradshaw (University College of North Wales, Bangor) and by Mr. C. D. Pigott and Dr. S. M. Walters (Botany School, Cambridge). Dr. Warburg pointed out that alien woody plants had been generally neglected in favour of herbaceous species, and that it was important that they should receive more attention than had been given them in the past. Trees and shrubs were introduced for forestry, for ornament, for fruits and for other purposes. Those introduced for ornament were responsible for the largest number of escaped and naturalized species; but field botanists seldom recorded them. One example he gave was *Rhododendron ponticum*, which was of considerable ecological importance, and yet the available data were insufficient to give its range or spread. Mr. Bradshaw outlined the ecological differences between *Crataegus oxyacanthoides* and *C. monogyna* and the distribution of hybrids between them. Mr. Pigott and Dr. Walters suggested that *Buxus sempervirens* had entered Britain in the boreal period, and that the dry sub-boreal period with Neolithic clearance of the woodlands had provided opportunities of secondary spread. In England place-names derived from the name of the tree followed the limestone ridges. They considered it native on steep slopes such as the one above the Mole at Box Hill and as scrub by ancient trackways; but in some places it had been planted in recent times.

An exhibit by Mr. D. E. Allen (University of Cambridge) on "The Changing Botanists of Britain" showed that the spread or decrease of many species would be likely to pass unnoticed in earlier days, when the main interest was in collecting specimens for the herbarium. The last paper read to the Conference was by Sir Arthur Tansley (chairman of the

Nature Conservancy) on "The Conservation of British Vegetation and Species". He described the work and organization of the Nature Conservancy, which is specially concerned with the scientific and practical importance of preserving as much as possible of our native flora and fauna. The central immediate object of the Conservancy is to establish a number of National Nature Reserves, of which six are now ready for 'declaration', on making which responsibility for the area is assumed. With the Peinn Eighe reserve in Wester Ross already declared, these make the Conservancy's total holdings to date 21,615 acres, and other reserves are in an advanced stage of negotiation. He outlined the plans for developing the scientific work of the Conservancy, which include the establishment of two research institutes, one in the north and the other in the south of England.

Canon Raven, in his concluding remarks, said that this had been a very memorable conference indeed and that the papers had opened up aspects of field botany which were new. Many suggestions had been made by the various speakers, and he hoped that the Society would develop some of these as projects for collective work involving country-wide studies. The papers which had been read and accounts of the exhibits would be published as a book with the same title as that of the conference.

MOUNTAINS AND GRAVITY*

By P. EVANS

Burmah Oil Company, Ltd., London

THE first laboratory measurements of the gravitational attraction between two bodies were made in 1797 by Cavendish, using the torsion balance. Much later, in a more direct method, an ordinary balance was employed, the scale pans being replaced by small equal spheres and a large mass of lead placed first under one sphere and then under the other. Both methods present experimental difficulties, but the force of attraction between two particles is now known with accuracy.

Even before the Cavendish experiments, attempts had been made to find the gravitational attraction of a large mountain mass. Measurements in the Andes seemed to be only partially successful, but an investigation near Schiehallion in Scotland in 1774 gave a value for the gravitational attraction which is reasonably near the truth. The deflexion of a plumb-line towards the mountain was measured, using as a reference point a star conveniently overhead.

Surveyors' observations made for the determination of latitude involve the same principle, and if the plumb-line is not truly vertical the latitude determination will be in error. Latitude measurements in the plains of India showed big discrepancies, and exactly a hundred years ago, in 1852, the Surveyor General of India wrote to a mathematician, Archdeacon Pratt, of Calcutta, directing his attention to the unsolved problem of reconciling these determinations of latitude. It soon appeared that the errors could be explained only if the plumb-bob was being deflected away from the Himalayas, instead of, as would be expected, towards them.

* Substance of a Friday Evening Discourse at the Royal Institution, delivered on May 9.

The possible explanation of this discovery led to much discussion, and many subsequent measurements of the deflexion of the vertical have been made. The problem can more conveniently be expressed in terms of variations in the earth's gravitational field, gravity being smaller near the mountains than would be expected. Measurements with modern instruments capable of detecting a change in the force of gravity as small as one part in a hundred million are much easier and quicker to make than are measurements of the deflexion of the plumb-bob.

In 1855 the Astronomer Royal, Sir George Airy, suggested that the visible crust of the earth is supported on a denser layer and that the extra mass of the mountains is balanced by light material extending down as roots into the denser layer: this goes far towards explaining the anomalous plumb-bob and gravity readings immediately south of the Himalayan range. In 1859 Pratt developed an alternative hypothesis. He supposed that the upper layer of the earth's crust had originally been of uniform density and thickness, without mountains or valleys or ocean deeps, and imagined that in the course of time the crust underwent vertical expansions and contractions. He considered that the material below the crust would prevent any downward expansion, so that where the crust expanded mountains were formed. It followed that beneath the mountains the crust must necessarily be composed of lighter material than is found beneath surrounding parts where there are no mountains. It is not always realized that Pratt's hypothesis was an attempt to explain mountain formation by simple vertical expansions of the earth's crust.

The Airy hypothesis of mountain roots received little attention; but his underlying notion of the mountains floating in a denser yielding material was taken up by Dutton, who, in giving more precision to the idea, coined the term isostasy. Later, Hayford and Bowie firmly welded the isostatic idea to the Pratt hypothesis; they found from a study of data, mostly referring to America, that if allowance was made for the compensating effect of the supposed lighter material beneath the mountains, computed strictly in accordance with the Pratt hypothesis, many observed values of gravity were brought very nearly into agreement with calculated values, the depth at which compensation is complete being taken at about a hundred kilometres. These and subsequent calculations utilizing numerous gravity determinations from different continents have shown that, when large surfaces of the earth are taken as a unit, there is in many cases a fairly close approach to the distribution of masses required by isostatic theory. It became generally supposed that the Indian gravity evidence, as well as the American evidence examined by Hayford and Bowie, supports the Pratt conception of isostasy: that is, the earth's crust was supposed to be made up of a set of vertical columns, each one uniform throughout, each differing in density from its neighbours, and each having its density exactly related to the present relief of the surface, regardless of what that relief might have been in past ages. Geologists have long known that this does not represent a possible condition of the earth's crust, yet the Pratt-Hayford-Bowie conception of isostatic compensation of hills and mountains remains the accepted basis of routine calculations in the computation of gravity anomalies. Although the Pratt hypothesis can be defended as a mathematical convenience which does not pretend to