E.M.B. 42.

A PRELIMINARY REPORT ON AN INVESTIGATION INTO THE BIOLOGICAL CONTROL OF WEST INDIAN INSECT PESTS

By

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JULY, 1931.

LONDON:
PRINTED AND PUBLISHED BY HIS MAJESTY'S STATIONERY OFFICE
To be purchased directly from H.M. STATIONERY OFFICE at the following addresses:
Adastral House, Kingsway, London, W.C.2; 120, George Street, Edinburgh;
York Street, Manchester; 1, St. Andrew's Crescent, Cardiff;
15, Donegall Square West, Belfast;
or through any Bookseller.

1931.

Price 1*s.* 0*d.* Net.

70-221-42.

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(4873) Wt. P3512/1055/2317 1,500 7/31 Hw G.3 A2

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PREFACE.

Although the difficulties with which the agriculturists of the Empire, like those of the rest of the world, are struggling at the present time, appear to depend upon causes which lie not so much within the field of action of the agricultural technician as within that of the statesman, the technician, if he be given the opportunity, can certainly contribute to their solution. Additional research on fundamental agricultural problems is undoubtedly desirable; but what is perhaps even more urgent at the present moment, is a thorough-going and diligent application of the great stock of useful knowledge and tested remedies already in our possession.

For example, Dr. S. A. Neave has recently estimated, after a careful study of the available data, that not less than one-tenth of the human effort in the Empire on basic industries, such as agriculture, is dissipated by our insect enemies. He concludes that since the population of the Empire may be estimated at about 450 millions, an additional population of some 45,000,000 could be supported by the same effort as is now exerted, if it were possible to eliminate insect pests.

The reduction of insect damage throughout the Empire is therefore of primary importance. A great many adequate and reliable methods by which this can be effected are known to entomologists. But not all of these methods are everywhere applicable. Such processes of mechanical and chemical control, such as spraying, fumigation, and so on, in spite of their proved usefulness in many parts of the world, are essentially unsuitable in many parts of the Colonial Empire, partly because of their excessive cost and partly because of the technical difficulties involved.

In these regions, the most helpful as well as the most economical method of attack seems therefore to be the method of biological control, or, in other words, the method of using the parasitic and predacious enemies of pests to reduce their numbers and destructiveness. However, this method is a highly technical branch of economic entomology, necessitating special knowledge, special equipment,

and special methods, which, at least in the smaller colonies, are not always available, in spite of the urgency of their entomological problems.

The Imperial Institute of Entomology is therefore endeavouring to build up at its parasite laboratory in Farnham Royal, a staff of entomologists highly trained in the methods of biological control, whose services will be available to all parts of the Empire. The following Report, prepared by Dr. J. G. Myers, and embodying the results of his preliminary survey of the possibilities of biological control of the insect pests of the West Indies and adjacent colonies, represents the initial effort of the Laboratory in this direction.

Owing to the necessity of dealing with the West Indies as a whole and, consequently, of carrying on, under unusually arduous and exacting conditions, investigations on a large number of insect pests attacking many different tropical crops, it has been impossible for Dr. Myers, during the period covered by this report, to make minute and detailed studies of particular problems in restricted areas. Nevertheless, he has succeeded in getting together, in a remarkably short space of time, an extraordinary complete and valuable account of the insect problems of the West Indies. In many cases he has been able to determine quite definitely, the lines along which future efforts should be made and in addition to a great deal of useful advisory work, has already been able to introduce into areas in which they are urgently needed, some of the natural enemies of the most important pests of the region.

One of the great advantages of surveys of this type is that they give an opportunity for the study of the incidence and intensity of damage by various pests under a great variety of topographical, climatic, and agricultural conditions, and permit the observer to evaluate the effect of environmental factors much more rapidly than would be possible by the experimental method. Many interesting and suggestive comparisons of this kind will be found in the body of the report, but two of the most important are certainly those which concern the bounty system of pest control, common everywhere in the tropics, and the difference in the incidence of pests in diversified peasant agriculture as compared with the system of large estate cultivation. The observations made by Dr. Myers, though still incomplete, appear to indicate, on the one hand, the serious inefficiency of hand collections as a means of controlling pests

and, on the other, the real value of the mixed agriculture, characteristic of small holdings, in maintaining a diversified fauna and preventing an undue increase of any one injurious species. The interest of such points to the agricultural economist is obvious, and they afford an excellent illustration of the view advanced at the beginning of this short preface—that the agricultural technician, in spite of the limitations which specialisation imposes on his work, can often draw from a careful study of the problems falling within his special field, indications which the economist will find useful and which even the statesman cannot afford to despise.

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I.—INTRODUCTION.

THE present report is designed to present as briefly as possible the preliminary results of the investigation begun in the West Indies in November, 1928, and to be continued until November, 1931. It is impossible to acknowledge in detail the very great assistance received from all quarters, both official and unofficial, in all the countries visited. The Governments and planting communities in every colony facilitated the work in all possible ways, while the Imperial College of Tropical Agriculture furnished a spacious laboratory as headquarters for the investigation. I am indebted especially to the Principal of the College (Mr. G. Evans, C.I.E.), to the Commissioner of Agriculture for the West Indies (Professor H. A. Ballou), and to the Assistant Commissioner (Mr. G. A. Jones), to the Directors of Agriculture in British Guiana (Professor J. S. Dash), Jamaica (Mr. H. H. Cousins), Trinidad (Mr. E. J. Wortley, O.B.E.), and Barbados (Mr. R. W. R. Miller) and their staffs, and to the local Agricultural officers in all the northern islands visited. The generous and enthusiastic co-operation of the local entomologists has everywhere been a very pleasing feature. In the non-British countries I am indebted for very special help in Suriname to the Director of Agriculture and his staff, and in Cuba to the Director of the Cuba Sugar Club Experiment Station.

Both for every official facility and support, and also for ever ready personal advice and encouragement I owe a great debt of gratitude to Sir Guy Marshall, Director of the Imperial Institute of Entomology, and to Dr. W. R. Thompson, Superintendent of the Farnham House Laboratory. I wish to thank also Dr. S. A. Neave, Assistant Director, and the staff of the Institute, for assistance of many kinds, including the identification of most of the insects collected.

My wife has furthered the investigation not only in the specific studies officially allotted to her, but also in every other direction, and has especially facilitated the work in foreign countries by her knowledge of languages.

The officials of the Empire Marketing Board have been kind and helpful to a degree, and the finance officer has smoothed out all the financial difficulties attendant on constant travelling.

A very brief summary has been appended to the end of the report, and another, where necessary, at the end of the account of every pest.

This report is very largely a record of field work. In a later and more comprehensive manual it may be possible to collate more adequately the work of previous investigators and to supply a bibliography. At present only the works actually referred to in the text are listed.

II.—GENERAL CONSIDERATIONS.

The main object of the mission was to study the possibility of biological control for the main pests of Agriculture in the British Colonies of tropical America. Wherever possible, actual introductions of parasites have been made. In addition, local Governments, planters' organisations and individual planters, requested and were given advice on agricultural problems connected with entomology.

Methods.

The methods used were essentially similar to those described by Dr. Thompson in his Farnham House Report (1930), with certain modifications necessary for tropical conditions and a new field. Thus the scarcity of previous fundamental work on even the most important pests (the froghopper being a notable exception) and the general lack of published data on ecological conditions, combined with the quality of the labour supply, rendered it quite impossible to employ field-agents recruited locally, save under the direct personal supervision of the investigator or his wife. All critical field work, as well as all the laboratory researches, had thus to be carried out by the two latter. By this means also was acquired the necessary knowledge of agricultural processes which in different colonies vary tremendously even for the same crop.

The procedure has been briefly as follows—firstly, to collect general ecological and agricultural data on the regions visited, with a view to collating them with the incidence of pests; secondly, to obtain a notion, expressed where possible in figures, of the status of each pest; thirdly, to discover by dissection, rearing and field observation its natural parasitic and predacious enemies, and to ascertain the average mortality caused by each; fourthly, to study the life-history and ecological requirements of the several natural enemies with a view to their possible utilisation; and fifthly, to see whether any other natural or artificial (e.g. agricultural) limiting factors are operating. In the course of the work, 28,424 dissections and examinations have been made.

The chief factor in deciding what parasites were most suitable for introduction into a given region has been personal judgment, influenced strongly by the record of the parasite's actual work under general ecological and agricultural conditions similar to those of the region of importation. These two latter criteria may not hold in every case, but they are the only quantitative ones available, and without them the procedure would be unnecessarily hit-and-miss. One would, for instance, unhesitatingly condemn an attempt to introduce a parasite, however efficient, from a temperate region into the tropics, unless and until, the possibilities of tropical parasites had been exhausted.

It has been felt also that biological control has now achieved so many well-authenticated successes under varying conditions, as to yield a considerable body of empirical data extremely valuable for the guidance of future attempts. Thus every success of any note, so far, has been won by the introduction of parasites into countries where they did not occur. It is therefore sound to explore fully the possibilities of this method before considering, for instance, the utilisation of indigenous parasites by mass production or local distribution. Any attempts in the latter direction should, in our present knowledge, be regarded simply and solely as experiments.

It was obviously necessary for the investigator to limit his attention to the more important pests, and even there to concentrate on a few main ones, rather than dissipate his energies over a wider field. An endeavour was made to investigate at least one main pest for each of the chief colonies, and where possible this was chosen in the light of requests actually made by the Government concerned. Thus banana-borer (*Cosmopolites*) was put on the list for Jamaica, coffee leafminer (*Leucoptera*) for St. Lucia, and arrowroot worm (*Calpodes*) for St. Vincent. None of these is really important elsewhere in the British West Indies.

Ecological Factors.

In a later section is given a brief account of those general ecological features which are important in the various colonies in determining the status of the chief agricultural pests. For the climatic and other basic records demanded by the ecologist the investigator was necessarily dependent on published sources. In many cases the records were not strictly comparable, and where they lacked entirely it was obviously impossible to supply them in the time available. But

Transeau, Tansley, Chipp and other workers stress the fact that the ecologist has at his command a much more reliable index of total environmental conditions than is afforded by the crude records in a meteorological screen. It is an indicator which incorporates also the effect of historical factors. This index is the plant association occupying the area in question. Its use is already familiar to planters who use single conspicuous species of plants as signs of " good " or " bad " soils. As Tansley and Chipp have pointed out, however, " the whole natural plant community . . . . is the best indicator rather than particular species." This has been used in the present study to an extent limited only by the botanical knowledge of the investigator. In many localities this involved breaking new ground, for ecological botany in the West Indies, with a few notable exceptions, has fallen between two stools. The older botanists were largely collectors and systematists only, while the newer school, discouraged by the difficulties of identifying the elements of a large tropical flora, tend to be more interested in chromosomes than in plants and to wallow in the dogmas of laboratory genetics rather than perspire in the forest. The best ecological work, at least in the British islands of the region, has been done by chemists without special botanical knowledge.

This emphasis on plant ecological considerations in biological control work is not new, for extensive studies on these lines have been made by Thompson and other workers engaged on corn-borer (*Pyrausta nubilalis*) parasite investigations in Europe. It has led, however, in the present mission to two more or less new theoretical considerations which it is believed will be of paramount importance in future practical work, at least in this area.

The first is a modification of the general view that islands, by reason largely of their limited fauna, offer more promising conditions for biological control than do continental areas. This belief has arisen largely from comparing results of attempts made on the one hand in tropical islands and on the other in temperate continental regions such as North America. The comparison is thus unfair at the base, for the relative importance of natural enemies as against climatic factors is undoubtedly much less as we increase our distance from the Equator, until at the Poles the exceeding paucity of all forms of life is due to climatic factors alone. In a tropical rain-forest, on the other hand, with its wealth of species and predominantly favourable climate, the survival of species and individuals is determined largely

by competition resulting in a biological balance. That this competition is severe is surely indicated by the infrequent occurrence of even two individuals of the same tree species together. This biological balance is broken only where edaphic factors strongly favour one or two species, as in mangrove-swamps or mora forest (*Dimorphandra* spp.), or where man makes a clean sweep of the original vegetation and plants extensive areas of single plant species, like sugar-cane. We shall revert to these questions later.

Even when applied to the South American continent and the Caribbean islands, the comparison between continents and islands from the viewpoint of biological control, is likely in practice to prove misleading; for if we are right in considering biological factors of predominant importance in the Tropics, it is biological or ecological segregates rather than geographic ones with which we ought to deal. From this point of view, the cane-lands of British Guiana, for instance, form several ecological islands—islands, moreover, covered with one dominant introduced plant, separated from other cane islands of the continent by vast stretches of radically different plant associations sheltering widely different insect faunas. That these biological barriers have been effective is shown by the fact that cane was grown in these areas for some centuries before it was attacked by several of the more important pests (e.g. *Castnia* and froghopper) which now ravage it, although these insects are undoubtedly indigenous to the immediate forest hinterland—and had thus been there all the time. It is indicated also by the occurrence in the cane-lands of British Guiana, Venezuela and Trinidad, of three entirely different species of *Diatraea*, as the most important small moth-borer in each case. The parasites of these pests are similarly restricted in their distribution. If, therefore, both the agricultural pests and their present parasites show such strong segregation even in areas so close geographically as Trinidad, the Guianas and Venezuela—all parts of the same zoogeographical subregion—we have every reason to expect that new parasites introduced into such ecological islands will prove as successful as in their geographical counterparts. The success of the Australian ladybird (*Novius*) in California against the cottony cushion scale, was one very noteworthy success of an introduction into an ecological island, albeit part of a continental area.

The second new theoretical consideration based on ecological data is one which has been more or less implied in the recognised technique of biological control work. It is well known that the greatest successes

of biological control have been achieved by the introduction of an insect's natural enemies into countries which it has reached without them. The search for parasites has therefore been prosecuted where possible in the original home of the insect concerned. But if the notion of biological islands is sound, and if we desire not only to find promising parasites but also to discover any other limiting factors, the absence of which in agricultural areas may have led to the insect's outbreak as a pest—if, in short, with a view to exploring all possibilities of biological and cultural control we wish to discover why the insect has become a pest, it seems to me that we must be ecologically more fundamental. We must examine the status of the insect in an entirely primitive environment, in a virgin plant-association, and try to evaluate its position in an older and more stable balance than that of the cultivated areas. There is a modern view, that progress in animal physiology and ecology is best served by laboratory studies of a given organism under more and more rarefied conditions of single physical environmental factors. This implies the belief that from the accumulation of such data, isolated from all contextual and historical considerations, we shall eventually be able to synthesise an intelligible explanation of the organism's activities in the field. But modern philosophic thought tends more and more to emphasise the fact that wholes show properties which cannot be deduced from those of their parts, still less from their parts under artificial isolation, and the ecologist above all—the student *par excellence* of the inter-relations of organisms and their environment—must face the problem of studying ecological wholes and their properties. He is likely to achieve the most success in those environments which have been least modified by the biological revolutions which everywhere accompany agriculture. Thus in the present investigation the primitive environment of a pest has been regarded not only as the most promising source of efficient parasites, but also as the key to its present status and eventual control. Work under these conditions has often involved slow travelling, but the balance is even, since ecological observations can be made from a canoe or a horse better than from a train or a motor-car.

The prevailing impression from a study of the West Indian agricultural pests is one of constant flux. The attacks of the giant moth-borer, the froghopper, and many other pests began in comparatively recent times. Other, at present, harmless native insects will probably learn to feed upon economic plants. Others again, like the pink

bollworm (1920) and the banana-borer (*Cosmopolites*) have been recently accidently introduced. The sudden change of huge tracts of forest to cane culture, from cane to cacao and back again (as in Trinidad), from cacao to coffee (as in Suriname) or cane to bananas (as in Jamaica), upsets whole insect faunas and weed floras. It is time these ecological transmutations were carried out less blindly, and with an eye to biological consequences.

Biological control brings nothing fundamentally new to the West Indies. The history of this region since its discovery has been one long record of the introduction of foreign organisms on the one hand and the elimination of native ones on the other. The organisms concerned have come from every division in the biological scale, from bacteria to human races. Measured by the predominance of European institutions in these islands the process, in so far as it was a deliberate one, has been highly successful, but some, both of the imported and the indigenous plants and animals, have become injurious, and it is these, so far as they affect agriculture and forestry, that we seek to control by biological means.

Itinerary.

Trinidad has been the base, and was the scene of the first four months' work. Only a few weeks at intervals were later spent in Trinidad, the rest of the time being occupied in British Guiana, Dutch Guiana, Cuba, Haiti, Santo Domingo, Jamaica and the Leeward and Windward Islands. All the British colonies have been visited save the Bahamas (from which no requests have come for advice or assistance) and British Honduras, and all the important sugar-cane islands except Porto Rico, Guadeloupe and Martinique. A visit to Porto Rico will be necessary for a proper understanding of the moth-borer situation, in respect of which this island seems to occupy an intermediate position between the Greater and the Lesser Antilles. There also it may be advisable to procure coffee leafminer parasites for St. Lucia. Santo Domingo and Haiti will also need a further visit for special study of froghopper and root-borer (*Diaprepes*) parasites, and some of the Lesser Antilles for their special pests ; but apart from this, the chief work remaining is the intensive search for new parasites on the mainland of Central and South America, especially the entomologically largely unknown territories of Venezuela and Brazil.

The regular aeroplane services, the cost of which is fortunately rapidly falling, have rendered possible certain operations in the actual introduction of parasites which would have been impossible under other conditions.

In the account of the practical work below only such data have been included as are strictly relevant to the problems of biological control. Life-history studies and incidental observations have been reserved for publication in the appropriate technical journals.

III.—ADVISORY WORK.

This has varied, as to its origin, from Government requests to questions from individual planters; and in substance from matters relating strictly to biological control to queries in agriculture pure and simple. Questions on which the investigator himself was able to take action will be mentioned in dealing with the pests concerned. There remain others in which his contribution had to be purely advisory.

Firstly, the lack of fundamental biological and agricultural data on some of the most important pests, information which could be accumulated only by full-time local research workers, concentrating on definite and limited problems for several seasons, was so apparent that action seemed necessary. This was especially the case with the small and large moth-borers of cane. The cane froghopper, also, although it had been for some years the object of most valuable and intensive ecological studies on the chemical and the physical side, had not received the attention of a full-time research entomologist since Mr. C. B. Williams concluded his report. This lack was supplied by the appointment to the staff of the Trinidad Froghopper Committee, of Mr. A. Pickles, to carry out intensive biological, and where possible quantitative, work on the froghopper with the advice of the present investigator. Mr. Pickles is now doing excellent work and has already obtained important practical results which are mentioned below.

In British Guiana the Governor and the Director of Agriculture requested a plan of local research of the small moth-borer. This was formulated on the basis of a three years' grant which has now been made available from the Colonial Development Fund.

Similar projects have been put forward for Trinidad at the request of the Principal of the Imperial College of Tropical Agriculture and the Director of Agriculture, acting for the Trinidad Sugar Committee; and for Antigua, at the instance of the Agricultural Society, which is forwarding its request through the Government of the Leeward Islands. A grant in aid of the latter has now been made from the Colonial Development Fund.

The fundamental research on the small moth-borer, it is suggested, should be concentrated in British Guiana and Antigua, since these two colonies present the greatest ecological and agricultural extremes in the British colonies of the region. It is suggested that these studies be co-ordinated under the general direction of the present investigator. They would most certainly yield results of practical value, firstly to the colonies concerned, and secondly to all those which produce sugar. In suggesting a three-year period, it was not so much long-range research which was envisaged, as quantitative studies on infestation, actual loss, and experiments on the exact effect of agricultural operations and direct control measures on the pest itself and on the parasite balance. Such experiments could be definitely expected to yield results of immediate practical value in three years. The very large sums of money now expended annually on the mere hand collection of these pests could most emphatically be better invested in research. With the small moth-borer, the most important pest of sugar-cane in tropical America, the agriculturists are working at present entirely in the dark.

Details of the British Guiana, Trinidad and Antigua schemes have been submitted to Sir Guy A. K. Marshall and Dr. W. R. Thompson. They are not suitable for inclusion here at the present stage. The Trinidad plan includes both the small and the large moth-borers.

The Government of Jamaica has asked for advice as to the biological control of the banana-borer and of the citrus black fly (*Aleurocanthus woglumi*).

With regard to the first, they have been informed that no really efficient natural enemy of the banana-borer is known, and that it is unlikely that such will be found anywhere in the American tropics, though the search will be prosecuted during the course of other investigations. There is some possibility that a parasite will be found in Brazil, where the borer has been known apparently for a much longer period than in the West Indies. Unquestionably, however, the most promising region to search is the East Indies, especially New Guinea, where Mr. Muir found the borer to be rare.

The black fly, which is probably the worst insect pest in Jamaica, has natural enemies in the East, the most promising of which are now being imported into Cuba, under the joint auspices of the Cuban Government and the United States Bureau of Entomology. It was suggested that when these are established, a supply be obtained for

Jamaica. Fortunately, the communications between Jamaica and Cuba are comparatively good. A local attempt was being made in Jamaica to control the black fly by colonising a *Crematogaster* ant, known as the " Dugald Campbell Ant," on the infested trees. This ant was found, undoubtedly, to clear away the black fly, but it assiduously fosters the green scale (*Coccus viridis*), a hitherto unrecorded pest in Jamaica which bids fair to become quite as important on coffee and citrus as the black fly itself.

Wherever and whenever possible, cultural measures have been recommended in the control of pests and too exclusive a reliance on the promise of biological control has been deprecated.

IV.—PRACTICAL WORK.

A.—Ecological Conditions in the Countries Visited.

Introduction.

In this section I propose to present briefly the main geographical, topographical, meteorological, biological and agricultural data on which I conceive that the distribution and abundance of the insect pests depend, and which I anticipate will influence the prospects of controlling those pests by biological means. Even social factors exert an influence here, for the relative density of population decides many questions of biological balance, while the pest conditions of peasant holdings differ widely from those of estates, so that the growing tendency towards peasant agriculture in nearly all the British colonies, and away from it in, for instance, Haiti, is bound to have its effect, both quantitative and qualitative, on the insect population.

The area visited divides naturally into three sections—firstly, the Guianas plus Trinidad; secondly, the Greater Antilles; and between them, influenced by both, the third, the Lesser Antilles. The most northerly point is in Cuba, near Havana, which is only just south of the Tropic of Cancer, while the most southerly visited is in Dutch Guiana at about 4° N. latitude. The latitudinal range extends from Barbados (about 59° W.) and Dutch Guiana (about 55° W.) to the western extremity of Cuba (about 85° W.).

In altitude the investigation has so far proceeded from sea-level to about 7,000 feet (in Haiti and Jamaica), above which, even in Hispaniola, agriculture is unimportant or even non-existent.

Inter-relation of Ecological Factors.

It is hardly practicable in a general review to detail separately the effect of the various kinds of ecological conditions listed above. A few examples of their inter-relations must suffice to justify their study in an investigation of this kind.

Geographical factors have been paramount in isolating and maintaining two entirely distinct faunas—mainland and Antillean, in the

area under discussion. Guiana and Trinidad, though the latter is geographically an island, are continental in character, with an exceedingly rich fauna and flora, and on the whole a considerable number of parasite species attacking the main pests, in some cases without very much effect.* The dominant vegetation formation is rain-forest, and the present pest situation cannot be properly interpreted without a study of the changes which have accompanied its partial removal. This applies in a varying degree also to the islands.

The Greater Antilles have a poorer and more specialised fauna, with the more important pests, save the recently-introduced ones, better controlled than in either of the other two regions. Porto Rico, as might be expected, would seem in this respect to be intermediate between the Greater and the Lesser Antilles. The latter are inhabited by a still more limited fauna and flora, at times almost oceanic, and many of the most injurious insects seem entirely free from parasitic attack. In these small islands the ecological conditions can usually be matched very closely in some one or other of the Greater Antilles, and the greater incidence of the chief pests, e.g. small moth-borer (*Diatraea*), root-borers (*Diaprepes*) where they are common to the two groups, may be attributed, with considerable assurance, to the absence of the parasites which attack them in the larger islands. The small islands, therefore, offer a most promising field for biological control work, second probably only to the Hawaiian Islands.

Topography influences climate, not only the rainfall directly, but also the relative humidity under conditions of equal rainfall. And the three, together with the relative density of the population, have largely determined what proportion of a given colony still remains under the forest covering, which in most cases was originally the dominant vegetation. This proportion, it may be readily seen, exercises a very considerable influence on the biological balance, in such matters as alternate plant hosts for pest-insects and subsidiary insect-hosts for useful parasites.

* It is necessary here to draw a sharp distinction between abundance of *individuals* and abundance of *species* of parasites. There is a general tendency in the mainland areas for pests to be attacked by a long list of parasites at a very low combined rate of parasitism, at least in cultivated plant-hosts. In this regard there is a striking contrast between British Guiana, where the moth-borer (*Diatraea*) is attacked by some seventeen different larval parasites, causing a mortality in cane-borers of less than 6 per cent., and Cuba and Jamaica, where the total list of parasites is very much smaller, and one of them, *Lixophaga*, destroys, on an average, 35 per cent.

The effect of meteorological factors is probably considerably less complicated than in the temperate zones. Thus Leake (1929) has pointed out that, " in the tropics, and especially in those areas lying within the rains belt, temperature and light do not exercise the same dominating influence; seasonal differences are marked by the greater or less intensity of the rainfall or even, as in a monsoon tract, by the alternation of a wet and dry season. Under these conditions, and they are the conditions which apply to a vast area of the earth's surface, rainfall becomes the dominating influence and the problem is materially simplified." But at least in the West Indies, as R. C. Marshall has pointed out, " the rainfall cannot be considered apart from humidity . . . .". An editorial in *Agricultural News* (Anon., 1916) remarks that " recent observations have made it clearer than ever that the chief climatic factor regulating the distribution and growth of crops in West Indian islands is humidity of the air. The degree of humidity does not necessarily vary with the rainfall; the atmosphere in some parts of Grenada, for instance, contains more moisture than in some parts of St. Vincent where the rainfall is higher. Humidity in any situation depends upon the degree of exposure, the amount of forest growth, cloud protection from the sun, and the water-holding capacity of the soil. Rainfall is the ultimate cause of humidity, but it is not the only regulating factor." An illuminating case in this connection is that of Dominica, St. Vincent and Antigua. Dominica is still largely heavily forested, and is the most mountainous and wettest of the Lesser Antilles, with an average annual rainfall of 127 inches. The average relative humidity at 9 a.m. at a representative station is 70·8 per cent. St. Vincent is nearly as mountainous but three times as thickly populated and now much less forested. It has a rainfall of about 100 inches, but, partly at least on account of a very light soil, the relative humidity of which we most unfortunately have no comparable records is apparently low. Antigua rises but little above 1,000 feet, has scarcely any forest left and enjoys an annual rainfall of about 44 inches. Yet the average relative humidity at 9 a.m. is 71·8 per cent. In Dominica it has long been remarked that scale-insects are very severely checked, and, in fact, usually well-controlled, by the attacks of parasitic fungi. Only after very exceptionally dry seasons (as 1902) do they ever rise to the status of important pests (Bodkin, 1912). In Antigua, according to Ballou (Rept. Antigua, 1913) " the green scale (*Lecanium viride*) appears to increase at times to a somewhat alarming extent, and it then almost entirely

disappears. A large proportion of these scales are parasitised by an entomogenous fungus, *Cephalosporium lecanii.*" I have myself in Antigua seen an infestation of purple and other scales on citrus in which every scale examined was killed by a fungus parasite. Now in St. Vincent, which in spite of its high rainfall is ecologically a dry island, conditions are far otherwise, for scale-insects are there extremely serious pests which make, for instance, commercial citrus-growing almost impossible.

It is extremely doubtful whether the orthodox records of relative humidity, usually made in a clearing, are of much ecological significance. What is needed is a series of comparable observations made in undisturbed conditions in every one of the more important or extensive plant associations, whether cultivated, induced or indigenous. Sweetman (1929) has recently shown that even in the relatively low vegetation of a lucerne field in Wyoming the relative humidity was much greater among the plants than at the height of three and a half feet above the ground, and at night often reached 100 per cent. The local records of the U.S. Weather Bureau were taken at the height mentioned and thus gave no indication of the conditions under which the plants were growing. In going from one plant association to another, or even from one type of rain forest to another, it is often possible distinctly to feel differences in the relative humidity of the atmosphere. It cannot be questioned that at the present time the vegetation gives the visiting ecologist a much more reliable indication of the relative humidity than the local records.

Biological Factors.

Turning now to purely biological factors, we may draw attention to the fact that, taking the year round, insectivorous birds are almost certainly much more important agriculturally than in the temperate regions. Not only is there an abundant avifauna throughout the year, but in the northern winter the West Indies receive countless myriads of migratory small birds which are wholly insect-eating, and a host of waders which are much more insectivorous, as Williams showed (1922), than most ornithologists imagine. And there is in addition a group of very efficient and entirely ubiquitous predators which in temperate regions are of no moment, but in the tropics probably account for more insects even than do the birds. I allude to the lizards, and especially the small plant-haunting species

of the genus *Anolis*, which are frequently present in incredible numbers and have been shown by Wolcott to feed upon a variety of pest insects. The ground-lizards, especially of the genus *Ameiva*, are also very great insect-eaters, but their numbers have been severely reduced or even wiped out wherever the mongoose has become established.

Introduction of foreign animals and plants.

We must recognise that most of the problems with which we have to deal are due solely to the introduction, intentional or accidental, of foreign organisms. It is thus singularly appropriate that we hope for a solution from an extension of the same process—" a hair of the dog that bit us." Most of the chief crop plants and a high proportion of their major pests, have been, as remarked before, imported into the islands where they now bulk so largely. A writer in *Agricultural News* (Anon., 1915), indeed, described the West Indies as a " land of exotics." The inter-relations of these foreign organisms among themselves and with the indigenous plants and animals must, then, form an integral part of every pest-problem we take up. There are, however, more general problems of this nature consequent not on the necessary acclimatisation of foreign crops, nor on the accidental entry of exotic pests, but on early deliberate attempts at biological control. Some of these introductions will be mentioned when we refer to the specific colonies concerned.

The effect of the general introduction of European cats and dogs seems to have received but little attention. It is probable that their influence on the indigenous West Indian fauna has been much less devastating than in New Zealand, where more than one endemic species has been indubitably exterminated by the domestic cat, while dogs are to-day among the worst enemies of the kiwis (*Apteryx*). On the small West Indian island known as Swan Island, cats are believed by Barbour to have exterminated a local lizard and a thrush. European dogs, trained for the purpose, are said by Las Casas to have taken a large part in the extermination of the aboriginal Indians in Hispaniola, under the Spanish. This was one of the first instances of biological control in the New World ! Feral dogs (*jibaro* or *xibaro*) of European stock are by no means uncommon in the Cuban mountains, and, at least up to 1850, in Santo Domingo. They are pests of stock, but I have not heard that they have caused much destruction to the native fauna. The domestic cat I have seen in the suburbs of

Port-of-Spain with a ground-lizard (*Ameiva atrigularis*) in its mouth. This is important for two reasons if it be a general habit—firstly, the lizards of this genus are known to be among the most useful insect-eaters; and secondly, wherever the mongoose has become established, it tends to extirpate these lizards everywhere, save in the immediate vicinity of towns. This both Dr. Barbour and myself have observed in a number of the islands.

With regard to the introduction of insectivorous birds, it is extremely doubtful whether this is ever necessary or advisable in any of the West Indies. Efforts should rather be directed towards the active protection of the indigenous species already present, albeit in some cases in depleted numbers. This protection should, above all, take the form of supplying cover, and in drier islands, drinking-places.

Two introductions have been so widespread and have modified so profoundly the biological balance almost throughout the area, that they necessitate more detailed discussion here. I allude to the artificial distribution of the giant toad (*Bufo marinus*) from the mainland, and the importation of the mongoose (*Herpestes birmanicus*) from Southern Asia.

Work of the Giant Toad.

Unlike most amateur attempts in this direction—witness the many deplorable cases in New Zealand—the introduction of the giant toad seems to have been followed by no conspicuous ill-effects. It is true that in Jamaica, at least, it was early accused of eating young ducklings, while Barbour (1930*b*) says "it feeds upon small batrachians, and may extirpate some native species, though as yet it seems a worthless but guiltless introduction." But it certainly eats many insects. In Trinidad its stomach has been found crammed with mole-crickets, while in Barbados one specimen was found to contain forty leaf-caterpillars of a destructive type (*Mocis repanda*) (Anon., 1902). According to Hill (in Gosse, 1851) it was first introduced from Cayenne into Martinique and thence to Barbados, whence Jamaica obtained a stock, all before the middle of last century. Curiously enough, it was originally brought in to destroy rats—then by far the most destructive pest of sugar-cane. "They had been considered in Barbados very important auxiliaries to the planter in this work, by their pursuit and destruction of the young rodents." It is much to be doubted whether they were ever active in this direction. Be this as

it may, they are now widespread, well adapted to agricultural conditions and exceedingly abundant in many of the islands. Both in Antigua and Barbados, and probably elsewhere, they are preyed upon by the mongoose (Anon., 1902, 1905).

Influence of the Mongoose.

This brings us to the most important attempt at biological control which has yet been made in the West Indies. I allude to the introduction of the mongoose for the suppression of rats. In order to introduce a brief discussion of the mongoose controversy in its proper setting we must dip into some obscurities of local history. The first and most serious agricultural pest ever recorded from the West Indies was the " blast," which was somehow associated with ants, but which, in the words of Wheeler (in Réaumur, 1926, pp. 232–239), to whom we must refer for an interesting summary, still remains " an unsolved riddle in the history of economic entomology." In 1518 and the two succeeding years this trouble was so serious, causing wholesale destruction of vegetation and widespread famine, that the whole island of Hispaniola was almost abandoned. The next plague was apparently that of rats—the black rat (*Epimys rattus*)—which was already a serious pest in the French islands by 1654. In 1789, Browne computed that it often destroyed a quarter or more of the Jamaican cane crop (Allen, 1911, p. 216). Large sums were expended annually on trapping and other measures of direct control. The first attempt at biological means, other than the use of dogs, was apparently the introduction of ferrets from Europe. These were alleged to have been incapacitated by the attacks of Chigoes (burrowing flea, *Tunga*). Then somewhere about 1750, Sir Charles Price hit upon the notion of importing a South American carnivore which would be adapted to the attacks of these insects. These animals appear not to have become established and their very identity is quite enigmatical, but the negroes were impressed with something rat-like in their appearance, and named them " Charley Price Rats " (Hill, in Gosse, 1851, p. 445). One Thomas Raffles, in 1762, is credited with the next attempt at an abatement of the increasing plague. He is said to have introduced from Cuba an ant, *Formica omnivora*, which Morris, 120 years later, stated was still a foe to all pests and vermin, but which, according to Wheeler (*loc. cit.*) is as much a mystery entomologically as the " blast " with which, by some writers, it was connected. Later still, as we have seen above, the giant toad was

imported. Meanwhile the rats increased, not only in Jamaica but also in the other islands. In Barbados from 1875 to 1879 the Government paid for 654,459 rats' heads at a penny a piece (Morris).

Finally, the mongoose was introduced, first apparently into Trinidad (1870) and later in the 'seventies or early 'eighties into most of the other islands. To Jamaica four pairs were imported in 1872 direct from Calcutta. They multiplied and spread so rapidly and attacked the rats so vigorously that ten years later they were credited with saving the island £45,000 per annum. The present distribution of the mongoose in the West Indies is described in detail by Barbour (1930*b*). Suffice it to note here that it occurs in British Guiana, and on all the larger islands save Dominica, Montserrat, Anegada, Virgin Gorda, St. Eustatius, Saba, Water Island, Just van Dyke and Tobago. Into some, if not all of these, its introduction is now prohibited by law.

In Dominica it failed to establish itself. According to Barbour the ten liberated " either could not withstand the excessively moist environment, for Dominica is by far the wettest spot in the West Indies, or were caught by the local boa." In Cuba, where it was imported about 1886, it has spread very slowly and does not at present occupy more than about 1,000 square miles about Havana (Barbour, *loc. cit.*). In British Guiana the mongoose is apparently confined to the settled coastal strip. Whether it will ever gain a footing in the virgin forest of the hinterland is uncertain.

In most of the islands, between ten and fifteen years after the introduction of the mongoose, public opinion of it made a complete *volte face*. Rats, though diminished, were still abundant, and the mongoose was said to be destroying many ground-nesting birds, lizards and toads, while its depredations on the poultry were wholesale. There was alleged further a great increase in insect pests due to the killing of insectivorous vertebrates by the mongoose.

In Jamaica, where the damage by rats in cane-fields seems to have been most severe, this phase of public disfavour passed very soon, and the mongoose is still considered to do more good than harm. The same opinion prevails in Martinique and in St. Lucia where the animal was imported to suppress the fer-de-lance snake (*Bothrops atrox*) once exceedingly common, but now very rare in the former

(Barbour, 1930) and uncommon in the latter*. In Trinidad, however, and in St. Kitts, Antigua, Barbados and St. Vincent, the mongoose is generally considered an unmitigated pest. Bounties for its destruction are, or have been, paid by the Governments of all the above-mentioned islands. The highest price paid is apparently in Trinidad, where for a time it was one shilling, though it is now reduced to sixpence. Until recently one of the large estates added an additional sixpence. In 1903 it was even proposed to raise the reward to five shillings. Later it became necessary to pass an ordinance making it illegal to keep mongoose in captivity, for it was feared they were being reared for the bounty. During the first eight months of 1930, 21,231 mongoose were paid for in Trinidad, the numbers for the corresponding months of 1928 and 1929 being 30,026 and 32,650 respectively†.

What then are the facts as to the influence of the mongoose upon West Indian agriculture? It occurs at once to a visitor to compare the incidence of pests in the islands with, and those without, the mongoose. Unfortunately the exceeding diversity of conditions in all the islands renders the comparison less valuable than it might be. Maxwell Lefroy in 1910(*a*) wrote that "the condition of Montserrat and Dominica at the present time, where the mungoose has not yet been introduced, is a great contrast to the condition of the preceding islands [Jamaica, Barbados, Grenada, St. Vincent, Antigua, St. Kitts] from the point of view of insect attacks, and there is good reason to believe that this is due largely, if not wholly, to the fact that the mongoose is absent from the two latter." The lesser incidence of scale-insects in Dominica than in some neighbouring islands is undoubtedly due to the favouring influence of an excessive rainfall on their fungous parasites. The same happy conditions to a slightly

* The police pay 6*d.* a head for fer-de-lance, and Professor Ballou informs me that he has recently seen as many as 15 to 20 heads accumulated at a country police station as a result of a few weeks' collecting.

† The strong insistence on the bounty system for the "control" of all kinds of pests is probably to be explained rather on psychological than on agricultural grounds. When one considers the theoretical assumptions involved, it would be impossible to imagine a less practical method. Even the froghopper is still paid for at the rate of some cents per hundred.

In the West Indies and British Guiana alone, on a modern estimate, the sum annually paid out by Governments and estate managements for the hand-collection of mongoose, borers, froghoppers and other pests would amply support a large research institution with half a dozen first-class specialists working out measures for practical, permanent, economic control. But no, the cultivator must have his scalps, while a process of posterior rationalisation leads him to believe that he is "cleaning-up" his fields.

less degree prevail in Trinidad, and Jamaica, where the mongoose is common. Montserrat differs from its neighbours in insect infestation in no marked degree. With regard to rats, it is true that these are at times a serious pest on Dominican estates (Rept. Agric. Dept., 1928–29), but they are still also highly injurious in Jamaica. " In some parts and on some crops they cause the loss of as much as one third " (*Journ. Jamaica Agric. Society*, XXIV, p. 90, 1920). Rats and petty thieves (praedial larcenists) are, in fact, the most important agricultural pests of Jamaica, for the island is remarkably free from injurious insects. There can be little doubt that the earlier phenomenal and widespread outbreaks of rats in Jamaica were materially reduced by the mongoose, and it is probable that future plagues would be similarly alleviated or even prevented. But under normal conditions and in the other islands it is doubtful whether the mongoose is very efficacious as a rat-destroyer. In Hawaii, where it was introduced from Jamaica in 1883, it " plays a certain definite part as a control factor. Being much less prolific than rodents it does not keep up with them sufficiently to be a 'cure-all' for rats, but it helps " (Pemberton, 1925). About 50 per cent. of 356 pellets examined contained nothing but remains of rats and mice. In the midst of the much richer West Indian fauna the proportion of rats to the total diet is shown by the stomach examinations of Watson, of Urich and of Williams, to be incomparably smaller. It is proven also that considerable numbers of insect-eating birds, lizards and toads are eaten, and large quantities of insects, most of which are injurious. There can be no doubt also that certain ground-nesting birds, and a number of the larger ground-lizards and snakes, have been either exterminated or more than decimated. The ground-lizards of the genus *Ameiva*, which have been shown by Wolcott and others to be valuable insect-eaters, formerly occurred as a distinct species on almost every one of the larger islands. According to a valuable survey made by Barbour in 1929, these are now extinct on St. Croix, St. Thomas, Nevis, Guadeloupe, St. Lucia and St. Vincent, and more or less confined to town limits in St. Kitts and Antigua. In St. Eustatius, Montserrat and Dominica, where the mongoose does not occur, these lizards are still in considerable numbers. Similar facts may be quoted regarding other genera of lizards and snakes. There has been an interesting development of the snake-mongoose situation in St. Lucia and Trinidad, where the common boa (*Constrictor orophias*) is now feeding upon mongoose quite extensively.

It has been suggested that the damage done by the mongoose to birds has been offset by its destruction of rats, which ordinarily would destroy many tree-nesting birds beyond the reach of the mongoose. But it has been otherwise pointed out that the latter has made the rats essentially arboreal animals, thus driving them further into the haunts of birds. It may be mentioned, however, that the black rat (*Epimys rattus*), which was introduced into New Zealand in the early days of settlement, eventually became almost wholly arboreal (and is now *the* " bush-rat ") there, following on the later importation of its arch-competitor, the brown rat (*Epimys norvegicus*) which is now the domestic rat. It seems probable to me that the same thing has happened in the West Indies, and would have happened even without the intervention of the mongoose.

To sum up, it may be stated that, agriculturally speaking, the mongoose is undesirable, since, although it has undoubtedly diminished the numbers of poisonous snakes, and has played a certain part in diminishing the more severe plagues of rats, it has exterminated or greatly reduced a number of species of ground-nesting birds and insectivorous lizards and toads, and is, in addition, an important pest of poultry. In the absence of sufficient data on the food-habits of the above birds, lizards and toads, it must, however, be admitted that the effect of the mongoose on the insect pest situation is not definitely known, but has evidently been highly exaggerated.

Conditions in the Countries Visited.

In the following section an attempt has been made to supply comparable data ; but in the present state of our knowledge and the limited time of the investigator's visits this has not been always possible, and it is to be feared that the result is rather a patchy picture.

Dutch Guiana or Suriname.

Geography and Meteorology.—A good recent general account from an agricultural point of view is that of Wardlaw (1930). Suriname lies between British Guiana (on the west) and French Guiana (on the east) with Brazil to the south. " Roughly speaking, the country consists of three large divisions, namely, the coastal alluvial belt, the sandy savannah and the rolling hilly country of the interior. From the latter several important rivers arise, which as they traverse the flat, low-lying coastal plain form large tidal estuaries.

Such are the Corantijn, Nickerie, Coppename, Saramacca, Suriname, Commewijne, and Marowijne (from W. to E.). The average rainfall is 82 inches per annum, with a minimum of 71 inches at Nickerie (in the west) and a maximum of 100 inches at Moengo (in the east); Paramaribo, the capital and the centre of the major agricultural activities, has a rainfall of 88 inches. This is distributed in two wet and two dry seasons. The mean temperature is 79·7°, the maximum 86·8° and the minimum 72·7°. The census of 1923 indicated a population of 113,000 inhabitants" (Wardlaw). The rainfall statistics apply, of course, only to the settled coastal strip. Severe droughts are sometimes experienced. It was that of 1926 which dealt the final blow to the cacao plantations. Professor Stahel, who was then in the far interior, informed me that even the underbushes of the high rain forest were wilting and the dead leaves crackled under foot!

Agricultural Conditions.—The present agricultural conditions can be understood only in relation to their history. Sugar-cane was first grown on a plantation scale in 1652. Later coffee (*C. arabica*) was grown extensively and short staple cotton and cacao plantations were established. By 1895 cacao was the most valuable product. About this time (I quote from Dr. Wardlaw's account) witch-broom disease appeared in the Saramacca district and spread by degrees through the cacao lands:—"By 1902 the effects of the disease were seriously felt in the colony while in 1904 the damage done was so great that planters were faced with ruin." The next year planters began to seek an alternative crop, and a banana industry was begun, only to be wiped out by Panama disease before the end of 1911. By 1914 many of the fields were planted with Liberian coffee, and at the present time this is the main agricultural crop. Rubber (*Hevea*), sisal and long staple cotton have also been tried. Stainer (*Dysdercus*) was responsible for the failure of the latter.

Connected with these frequent changes is the great extent of abandoned lands, a feature which at once strikes the visiting entomologist, and which must have its effect on the incidence of pests.

"At the present time the coastal alluvium alone is of use for permanent agriculture, and as this lies below the level of high tides the land to be taken into cultivation has to be enclosed within dykes and drained. This process—empoldering—consists in surrounding an area by dykes or embankments sufficiently high to keep out

surrounding water at any state of the tide. The whole system includes a sea-dam to protect from sea-water, a back dam to keep out savannah water, and side dams to complete the enclosure. The enclosed areas are then provided with drainage canals. Drainage water is run off at low tide by opening sluice gates. The work entailed in empoldering and canal digging is very considerable, and mostly dates back to the slave days when labour was cheap. With the present economic conditions, when additional land is required, the usual procedure is to clean up old abandoned estates where canals and dykes have already been laid out. Otherwise only minor extensions can be carried out.

" Originally the colonists of the Guianas settled on the river banks at some distance up-stream where plantations could be established in the usual way. The river-side alluvium, however, did not prove to be very productive, and it remained for the Dutch to recognise the superior fertility of the coastal alluvium, and to apply to it the same system used in their own inundated coastal lands in Holland.

" The coastal alluvial belt . . . consists mainly of heavy clays derived from sea-borne mud from the river Amazon. These deposits are very deep; they vary in texture from sandy loam to stiff clay, and in colour from yellow to grey except when modified by organic matter. Running through this belt and more or less parallel to the coast line are sand and shell reefs. These are generally regarded as useless for permanent agriculture.

" Further inland in localised areas the alluvial clay is overlaid by, or partially intermixed with, a deposit of spongy peat or ' pegasse,' a black vegetable deposit of the debris of marsh plants. In British Guiana these pegassey clays or pure pegasses are relatively extensive. In Dutch Guiana they are much less so and occur in limited areas only. All these soils lie below the level of high tide."

The clay soils are decidedly acid, compact and badly aerated, and while of considerable potential fertility, they need very thorough tillage and adequate drainage (Wardlaw).

Most of the agriculture is on the estate scale. " The small estates have gradually declined and been abandoned or combined to form larger plantations. Now there are but 60 or 70 active plantations all told, including four under sugar-cane and two under coconuts. The day of the small plantation is past, and larger properties formed by combining several of the original smaller holdings under one management alone can compete in the modern economic struggle."

There are, however, also a certain number of small mixed farms of a European type, established originally by Dutch emigrants who owned no slaves. Javanese indentured labourers, too, at the completion of their contract have been encouraged to settle in the colony and take up small holdings. Their cultivations showed almost every kind of tropical American food-plant and many introduced ones into the bargain.

Although the coffee plantations are now flourishing, the colony is by no means prosperous, " and a subsidy from Holland is required each year to balance the budget."

So much for agricultural conditions.

The sandy savannah lands behind the coastal alluvium consist of strongly leached granitic country, supporting scrubby bush and generally regarded as useless for agriculture. They are backed by the slightly hilly country of the interior, which extends under a practically continuous covering of high rain-forest to the Brazilian border, forms by far the greater part of the area of the colony and is practically uninhabited. Recent explorations have not here shown any large tracts of good land suitable for extensive agriculture.

Pests.—It is from the forested interior, on the Coppename River, that witch-broom disease (*Marasmius perniciosus*) is believed to have made its descent on the cocoa plantations of the coast. The main pests of cane, namely, small moth-borer (*Diatraea*) and the large moth-borer (*Castnia*), may have had a similar origin. The wild food-plant of the latter, *Heliconia Bihai*, is a very common constituent of the rain forest, while *Diatraea* has been taken in the interior of Amazonia, though its original food-plant is at present entirely unknown. Cocoa thrips (*Heliothrips rubrocinctus*) also occurs in the interior (Reyné), but on *Psidium* in open river-beds and not on wild cocoa in the rain-forest itself (see Myers, 1930*a*).

Most of the chief insect pests of Suriname are indigenous. A notable exception is the green scale (*Coccus viridis*) on coffee. The fauna and flora are very rich and continental in character, but largely unworked. There is, for instance, no collected " Flora," and no comprehensive account of any single family of insects, with one notable exception, that of the mosquitoes. The time spent in Suriname was largely taken up with a visit to the wild cocoa on the Coppename River, an account of which is given in the section on cocoa pests. A visit will, it is hoped, shortly be made to the cane-lands.

British Guiana.

Geography.—British Guiana, lying between Suriname and Venezuela, is both larger and more diversified than its Dutch neighbour. It lies between latitudes 9° and 1° N. and longitudes 57° and 61° W. The total area is over 90,000 square miles, " of which quite 99 per cent. are undeveloped. The colony has a coast-line of about 250 miles, and extends inland to a depth of nearly 600 miles . . . . the inhabited portions of the colony are the alluvial flat which extends from mid-water mark to a distance inland of about 10 miles, and the banks of the rivers for some distance from the mouths " (Aspinall). This plain of marine alluvium, much of which is at or below sea-level, is of varying width ; " as far as is known it is some 50 miles wide on the Courantyne [Corentijn] Coast, while on the Essequibo Coast at Suddie it is not more than two or three. It widens out again in the north-west district " (Sampson, 1927). This coastal region is followed by a slightly elevated broader belt of sandy and clayey—practically sedentary—soils traversed by sand-dunes, and all largely forested. Inland of this again, and forming by far the greater part of the whole area of the colony, are the densely forested higher lands which, in the extreme south-west, pass into extensive grassy savannahs rising from which are isolated mountains and mountain ranges (*Handbook of British Guiana*, 1922, p. 4).

Meteorology.—The mean annual rainfall of the coast belt, as exemplified by Georgetown, is 89 inches (Harrison, 1925), taking the average from 1880 to 1925. There are two wet and two dry seasons, the long rainy season lasting from about the middle of April until August, and the short one through December and January. Taking the coast-lands of Demerara as a whole, the average annual rainfall from 1880 to 1924 was 92·86 inches, while that of the coastal Essequibo was 102·41 and of coastal Berbice 80·06 inches (Harrison, 1925, p. 3). The average rainfall of 17 inland forest stations (Harrison and Stockdale, p. 15) was 107 inches, but Hitchcock states that the rainfall on the lower Essequibo may rise to over 150 inches, while in the savannah region of the south it may fall to 50 inches. " There is, as a rule, in the forest region in the interior no well-marked dry season. The distribution of the rainfall is generally more regular throughout the year than it is nearer the coast, where a long dry season is always experienced from August to November. Rarely at the forest stations do 10 days pass on which rain does not fall, except occasionally in the months of September and October in some

districts " (Harrison and Stockdale, *loc. cit.*, p. 14). In the savannahs of the far interior, 200 to 300 miles from the coast, the average annual rainfall is in places as low as 46·2 inches (Harrison, 1925, p. 5).

The temperature near the coast is very uniform. " During the period 1846 to 1925, the mean temperature in the shade was 80·4° F., the mean of the maximum temperature being 84·7°, and the mean of the minimum temperature 75° " (Harrison, *loc. cit.*). In the hottest part of the year, the long dry season, August to November, the temperature (shade) rarely goes higher than 88° and at night falls to about 80°. In the winter it rarely falls below 74° and usually rises only to 82° to 84°. The temperature in the sun is strikingly high in contrast (140° to 145°). The humidity is always high. " The percentage of complete atmosphere humidity varies from a maximum of about 86 per cent. at 6 a.m., to about 70 per cent. at 1 p.m., and to about 79 per cent. at 6 p.m." (Harrison). Because of this it is uncomfortable to be out of the air currents. The houses are raised on pillars and the structure is open to allow a free circulation. Clothing and leather mould quickly (Hitchcock, *loc. cit.*). At the Penal Settlement, Mazaruni, about 40 miles inland in the forest, the temperature ranges from a mean minimum shade temperature of 74·7° to a mean maximum of 84·5°, with an extreme range from about 72° to 89°. Other records from the interior show that the variation may be as great as 70° to 95°.

Agriculture.—The coastal belt has an area of about 10,000 square miles, but only the fringe is touched. On the east coast practically all the land which is or has been cultivated is within six miles of the sea or river estuary front. To the west, along the Pomeroon and the rivers of the north-west, there is probably no cultivation extending to a depth greater than a quarter of a mile. The reason why cultivation is limited to such a restricted area is that the land is below high water sea-level, and in order to render it fit for cultivation it must be empoldered (Sampson). The same system of dykes and canals is employed as in Suriname, and the method was, in fact, initiated by the Dutch, who first settled in British Guiana in 1615.

The main rivers bring down little or no silt, and the heavy impervious clays of the coastal alluvium are believed to be derived from the Amazon river. They are built up, partly through the agency of coastal and riparian vegetation, to a slightly higher level on the shores and river banks, and are interspersed, as in Suriname, with sand and shell " reefs." Behind these marginal silt soils are extensive

areas of pegasse, some covered by swamp-forest (most of north-west district) and some by swamp-grassland, known as " water savannah " (behind the front lands of the east coast). Over water savannah in the neighbourhood of Acquero, we journeyed with no difficulty dry-shod on foot for some miles during the dry season, to return by corial (canoe) in the wet season over nine feet of water.

The population, of which nearly a half is East Indian, is about 307,000, or a little over three to the square mile.

The main crop, supplying 60 per cent. of the total exports, is sugar-cane, and this is almost entirely estate-grown. Only large scale production can meet the overhead costs. Sixteen of the twenty-one factories cover nearly 90 per cent. of the production (*Sugar Commission Rep.*, 1930, p. 91). Rice is next in importance, and is grown extensively by East Indians. " The yield per acre is a good deal higher than that obtained in India " (Jones, *Sugar Commission Rep.*, Pt. IV., p. 57). The only other valuable agricultural crops are coconuts, Liberian coffee, limes and ground provisions (with plantains).

In the interior, in addition to mineral wealth, there is abundance of fine timbers which are only very gradually being utilised; but according to the latest ecological investigations the possibilities for extensive agricultural development are exceedingly remote.

Fauna and Flora.—The fauna and flora are extremely rich, with a truly remarkable contrast between the coast-lands and the interior. As in Suriname there are practically no comprehensive accounts of the flora or of the insects, and in the case of woody plants even less is known than in the neighbouring colony. By far the most important pest is the small moth-borer (*Diatraea* spp.) which attacks both cane and rice. The large moth-borer (*Castnia licoides*) attacks cane, while a still larger species (*Castnia daedalus*) is, with the coconut butterfly (*Brassolis sophorae*) injurious to coconuts. These are all almost certainly indigenous and seem to belong to the forest fauna rather than to that of the coastal savannahs. This would help to explain why some, like the cane *Castnia*, inflicted no apparent damage on crops until the latter had been established in the colonies for several centuries. An exception is probably afforded by the cocoa-beetle (*Stirastoma depressum*) which occurs plentifully on the coast lands, but was not found in the interior. Its original home was probably the long stretches of so-called " wild cacao " (*Pachira aquatica*) which line the river courses above the mangroves (*Rhizophora Mangle*).

Trinidad.

Geography.—Trinidad, as already mentioned, is biologically a part of the mainland. It is separated from it by no more than a few miles of shallow sea.

It is an oblong island of about 1,900 square miles lying some 10° north of the Equator and about 60° west of Greenwich.

The island is crossed by three ranges of mountains or hills, running west to east, and decreasing in altitude from north to south. The two highest peaks are El Tucuche and the Heights of Aripo, both in the Northern Range and both just over 3,000 feet high. The plains between the Northern and the Central Ranges are flat; those between the Central and the Southern very undulating. South of the Southern Range and north of the Northern is hilly country largely devoted to cocoa and forests.

Meteorology.—Rainfall varies from 50 to 100 inches annually. On the easterly half it is approximately 75 to 100 inches and on the western half 50 to 75. In the sugar-cane areas the average is 65 inches (Jones). " Relative humidity is high, the mean range falling between 78 and 85 per cent. There is a dry season of varying intensity from January to May and a wet season for the rest of the year, with a short ' Indian summer ' about September " (Marshall, 1930*b*, p. 8). Since the above was written, Croucher (1930) has given a valuable summary of observations made at St. Augustine.

The temperature at sea-level varies during the cool season—December to April—from a mean minimum of 67° F. to a mean maximum of 88° F. During the rest of the year the corresponding temperatures range from 71° to slightly over 90° (Marshall).

Agricultural Conditions.—There has been no general soil survey of the island and any brief generalisations would be only misleading at this stage. An excellent survey has, however, been made of the sugar estates soils (Hardy, 1929, part 1 published) and similar work is in progress on the cacao soils. With a few exceptions the soils of the cane-lands are very heavy. South of the Central Range there are two main types of cane soils, the Naparima red soil and the Naparima black marls. Both are rather heavy, but the former is markedly deficient in lime while the latter is better supplied. There is a very striking correlation between severe froghopper attack and the incidence of the red soils. The two soil types sometimes alternate in bands and in such fields the " blighted " canes are frequently confined to the red soil strips.

Cacao is, and has long been, the most important crop. It is followed fairly closely by sugar-cane and at a considerable distance by coconuts. Other crops include ground provisions, coffee (*C. arabica, robusta* and *excelsa*) and citrus fruits. Most of the agriculture is carried on in the plains but much cocoa is grown also in the low hills and upon the lower slopes of the mountains to 1,500 feet. All the latter are wooded, and there also remain extensive stretches of lowland forest, of two main types, namely the ordinary tropical mixed rain-forest and mora forest characterised by a heavy dominance of mora (*Dimorphandra Mora*). There are large swamps on both west and east coasts and connecting them a line of savannahs runs across the plain under the lee of the Northern Range. Similar savannahs occur also elsewhere in the island. These savannahs, which are determined apparently solely by edaphic factors, are areas of sterile residual highly-leached material called by Hardy (1929) " cocorite soils," and supporting a tangled growth of coarse grasses (such as *Andropogon* and *Trachypogon plumosus*), sedges and *Heliconia psittacorum*, with straggling bushes of *Byrsonima crassifolia* as the dominant woody plant, *Curatella americana, Coccoloba pubescens*, some Melastomataceae, and in places numerous cocorite palms (*Maximiliana caribaea*), and occasionally moriche palms (*Mauritia setigera*). Savannah lands of this type do not seem to be either the original home or a present source of infestation of any of the main pests. Neither froghoppers nor the borer (*Diatraea* spp.) have been found on the grasses, though some of the latter (*Andropogon*) have a borer of their own (*Chilo* sp.).

In 1928 considerably more than half the sugar-cane was grown in very large units by the factory owners, the rest being supplied by a large number of small growers known as cane farmers (Jones). Most of the other crops are produced largely on an estate scale.

The population is about 397,000 of which a third are East Indians. The density is about 213 to the square mile.

Fauna and Flora.—The fauna and flora of Trinidad are essentially mainland in character and very rich. There are excellent catalogues of the butterflies, the moths and the mosquitoes. The ants have also been fairly well studied. A flora of the island has been for a long time in preparation. As in the Guianas, most of the pests are indigenous or probably indigenous species. The cane froghopper (*Tomaspis saccharina*) is, in fact, found elsewhere only in Grenada.

The two main crops, cocoa and sugar-cane, are heavily attacked by insects, but coconuts are remarkably free from pests though frequently diseased.

The Lesser Antilles in General.

We have already had occasion to remark more than once that Trinidad faunistically and floristically belongs not to the West Indies but to the mainland. In proceeding now northward along the island chain to Grenada, we leave behind, for instance, that heavy, extremely moist type of true rain-forest of which crabwood (*Carapa guianensis*) may be regarded as an indicator. Such woods, so characteristic of Trinidad and the Guianas, recur in the northern islands only in two localities, one in extreme eastern Cuba and the other in north-eastern Santo Domingo.

Geography.—For present purposes the main British islands of the Lesser Antilles may be divided roughly into three groups : firstly, the moist, heavily forested islands (Grenada, St. Lucia and Dominica), which are on the whole the more mountainous ; secondly, the dry islands (Antigua, St. Kitts and Nevis) ; and thirdly, Barbados, St. Vincent and Montserrat are ecologically intermediate between the first and the second groups, though like the second they both grow cotton as a very important crop. North of Grenada most of the islands of the Lesser and Greater Antilles are occasionally visited by destructive hurricanes.

Climate.—Thus, in general, the passage northwards is accompanied by a decrease in rainfall and by a shifting of agricultural emphasis from cacao to sugar-cane and cotton. Again we must be impressed by the extraordinary adaptability of the sugar cane, which is the mainstay of the colony under conditions so diverse as those of British Guiana (90 inches of rain annually) and of Antigua (44 inches, or about half). As one might expect, the drier islands are very much more developed agriculturally than the moist ones, the two extremes being Barbados, which is hand-cultivated over the greater part of its area, and Dominica, only a small fraction of whose forests and mountains have been cleared.

Generalising again, we may point to a strong tendency, in the drier islands especially, for the main insect pests, even when they are not introduced but probably indigenous, to be singularly free

from parasitic or other natural enemies. In Dominica, however, it has long been remarked that scale-insects are almost completely checked by fungous parasites.

Fauna and Flora.—The distribution of plants and insects in accordance with the geographical and climatic conditions sketched above has not received the attention it deserves. Although American botanists have lately accomplished excellent floristic and vegetational work in individual islands, Grisebach's *Flora*, published in 1864, still remains the only comprehensive account of West Indian plants. The insects, however, are in even worse case, since, save in a few limited groups, no survey work at all has been done, and our knowledge is based solely on desultory collecting. Ballou's book (1912), intended as an entirely popular work, gives a mass of useful information on the natural history and control of the main agricultural pests, but says very little about their inter-island distribution. The best treatise on West Indian zoogeography is by Barbour (1914), but I am unfortunately not able to refer to it in Trinidad. It is based largely on a study of the vertebrate fauna. A number of southern forms, for instance, the boa (*Constrictor orophias*), extend their range, in the wetter islands, as far north as Dominica.

Introduction of Foreign Animals.—In the interests of biological control and for other reasons which remain obscure, a number of introductions have been made of other animals, of which the most famous is the mongoose. This mammal now occurs on practically all the islands save Dominica, Montserrat, Anegada, Virgin Gorda, St. Eustatius, Saba, Water Island, Just van Dyke and Tobago, and is absent also from many, if not most, of the smaller islets (Barbour, 1930). A discussion of the mongoose question will be found in the introduction to this section. A Trinidad opossum (*Didelphys marsupialis insularis*) has been established in the British islands, save Barbados, as far north as Dominica, and has probably played a part in the decrease or even extinction of certain birds, notably the ground dove (*Geotrygon mystacea*) (Barbour).

Small Cyprinodont fishes have been widely imported as agents for mosquito control, while the giant toad (*Bufo marinus*) of the mainland, has been carried to many islands where it is now abundant. The blackbird or grackle (*Holoquiscalus fortirostris*) was introduced from Barbados to Antigua, and to St. Kitts, where, however, it is still very scarce. There is a widespread belief in Barbados that the

common Kingbird or " Dr. Morris Bird " (*Tyrannus dominicensis*) was introduced into Barbados by the gentleman whose name it bears, but this is incorrect, for the bird is undoubtedly indigenous. " Doubts have from time to time arisen as to the economic value of this bird, and by 1927 it had been decided that instead of being beneficial, the bird was noxious and should be destroyed. This conclusion was reached because of the observed facts that the bird fed on wild honey bees, and on various native wasps which were thereby greatly reduced in numbers, and because it was suspected of preying on the beneficial parasite, *Tiphia parallela*, which was alleged to be diminishing in numbers." Accordingly, its food-habits were investigated by Tucker (1930*a*), who is quoted above, and who found one *Tiphia* in the stomachs of the hundred birds he examined, but very many adults of two serious cane-borers (*Diaprepes abbreviatus* and *Metamasius sericeus*). It is a curious commentary on popular beliefs that further south, in Trinidad and British Guiana, it has become an established practice on several of the larger estates to set up thousands of bamboo perches in the cane-fields for the encouragement of the southern representative of the same species [*Tyrannus melancholicus* (*satrapa*)].

Monkeys from West Africa were introduced at a very early date —it is believed by slave-ships—into Barbados, Grenada and St. Kitts. The Barbados and St. Kitts species (*Cercopithecus sabaeus*) has become an important agricultural pest in the latter island, where I was asked as to possibilities of biological control, by means, for instance, of a bacterial disease or virus. I pointed out the lack of success which had attended such attempts with other mammals, such as rats and fruit bats, and emphasised the great risk of trying any such measures against monkeys, since diseases to which they are liable tend also to affect man. As a matter of fact, Cameron has already found (1929) that the St. Kitts monkeys are the hosts of a dangerous African blood fluke or Bilharzia (*Schistosomum mansoni*).

The Grenada monkey, which is not common, is the West African *Cercopithecus mona*.

Maxwell-Lefroy (1902) was impressed by the fact that most of the more important pests of the Lesser Antilles were introduced. At that time he was probably correct in considering scale-insects the most important pests throughout the islands. At the present time, so great have been the changes in the pest situation, several other groups of insects are far more injurious. Fortunately, the excellent work and

records of Maxwell Lefroy, and, after him, of Ballou, under the old Imperial Department of Agriculture, enable us to follow these changes from year to year, almost from the beginning of the century. Practically the only present major pests which were important at the beginning of the period thus reviewed are the small moth-borer (*Diatraea saccharalis*) of cane and the cotton-stainers. Cacao thrips, hardbacks, root-borer (*Diaprepes*), banana-borer (*Cosmopolites*), pink bollworm, green scale, have all come into prominence much later; while several major pests of that time, for instance, black scale and leaf mite of cotton, have decreased into comparative insignificance.

Grenada.

Little will be said of this island at the present juncture. Only two brief calls have been made, and no adequate opportunity has yet presented itself to compare cacao conditions there with those prevailing in Trinidad and the Guianas.

The island, which is about 21 miles long by 12 miles broad, lies in latitude 12° 5′ N. and longitude 61° 40′ W. The area is about 120 square miles. The average annual rainfall is 80 inches, but nearly twice this falls in the interior. The annual rainfall at 21 stations scattered over the island varied in 1928 [*Report for 1926–28* (1930), p. 12] from 12·01 inches to 221·98. The former figure was evidently abnormal, since the rainfall at the same station (Pt. Salines) in 1927 was 35·55 and in 1926, 34·50. The highest rainfall recorded on any one day was 13·86 inches on 20th January at Nianganfoix. The dry season lasts from the end of January to about the middle of May. Near sea-level the mean maximum temperature is 90° F., and the mean minimum 68°. The country is hilly and well-wooded.

The population is nearly 60,000, or 493 to the square mile.

The main crop is cacao. Spices are also important.

The chief insect pests are cacao thrips and cacao beetle. Damage by the latter seems to be confined almost entirely to the leeward side. One species of cane moth-borer (*Diatraea canella*), which is otherwise confined to the mainland and Trinidad, reaches its northern limit here. There are occasional froghopper (*Tomaspis saccharina*) outbreaks. The beetle (*Araecerus fasciculatus*) is becoming a serious pest of stored mace and nutmegs.

St. Vincent.

This island, which is 18 miles long by 11 wide, also has received only two brief incidental visits. The area is 133 square miles. It lies in latitude 13° 10′ N. and longitude 60° 57′ W. The average rainfall is about 100 inches. That at the Botanic Station for 35 years was 102·53 inches. In spite of this St. Vincent strikes one as considerably drier than Grenada, Dominica and most of St. Lucia. That this impression is ecologically correct is shown by the successful and extensive growing of cotton, and by the heavy incidence of scale-insects as pests. It is correlated with a light soil, very little retentive of moisture. The relative humidity at the Experiment Station in 1928 [*Report for 1928* (1929), p. 23], varied from 61·4 per cent. in February to 78·1 in November, with an average of 72·9, but the hour of observation is unfortunately not mentioned. The rainy season lasts from August to November. The temperature varies from 60° F. to 80° (Aspinall). Like Grenada the island is mountainous (up to 4,000 feet) and well-wooded.

The population is estimated at 51,000, or 383 to the square mile.

Arrowroot is the chief crop, but an opportunity to see this when its chief and practically only pest, the leaf-roller (*Calpodes ethlius*) is abundant, has not yet occurred. Sea Island cotton is a very important product, and sugar-cane, cocoa and spices are also grown. Cotton-stainer (*Dysdercus*) has given considerable trouble.

Barbados.

Barbados is totally unlike any of the other islands we shall deal with in this report. In the first place it is flat and largely of coral formation. It is about 21 miles long by 14 broad, or rather larger (166 square miles) than the Isle of Wight (Aspinall). The latitude is 13° 4′ N. and the longitude 59° 37′ W., and thus considerably east of the main chain of the Antilles. The temperature varies from 75° F. to 83°. At Codrington the daily mean maximum temperature for the year 1928 was 85·4° F. and the daily mean minimum 72·9° F. The maximum extreme for the year was 85·4° F. and the minimum extreme 64·2° F. The annual rainfall ranges from about 50 to 70 inches, the wet season extending from early June to late October. Generally speaking the rainfall of the higher or red soil terraces is about 10 inches more than that of the lowlands, or black earth areas (Harrison and Jukes-Browne, 1890). The total mean

rainfall for the year 1928 from 141 stations was 57·21 inches, the average for 60 years being 60·53. At Codrington the mean relative humidity at 8 a.m. was 72·1 per cent and at 5 p.m., 70·2 per cent. [*Report for 1928–29*, p. 89]. The lowest was 61·9 at 5 p.m. in May and the highest 81·7 at 5 p.m. in November.

For information and references on the soils of Barbados I am largely indebted to Professor F. Hardy. Six-sevenths of the area are covered by coral limestones, which contain, however, extraneous materials derived from the volcanic ash thrown up by active volcanoes of the Caribbean area (Harrison and Jukes-Browne, 1890; Harrison, 1920). The early Tertiary rocks of the island core, which are strikingly similar to those underlying the Naparima series of Trinidad, and to others in Venezuela, all probably portions of a vast Tertiary formation which once extended over a large part of the South Caribbean region—are exposed practically only in the Scotland district of the north-east, where the highest part of the island rises by terraces to 1,105 feet. The higher terraces (above 500 feet) are covered by a red soil, an unctuous loamy clay, very deficient in lime and representing the end product of the weathered coral limestone. The lower lands, forming the bulk of the agricultural area, are of black earth, which is less weathered, partakes more of the nature of an alluvial soil and is very shallow. The extraneous volcanic constituent has proved an important factor in the great fertility of Bardados soils in general. Drainage is largely subterranean so that streams are virtually absent. The combination of these factors gives Barbadian agriculture its peculiar character. Finally, the dense population of over a thousand (1,012) to the square mile has destroyed almost the last vestige of original forest. Even in 1897 only 66 acres were registered as in forest and brushwood (Morris). There is thus no hinterland and no considerable areas of weed or other alternative host-plants for the main agricultural pests. Hand-collecting and other direct means of control are thus more likely to succeed in Barbados that in any other area I have seen.

Sugar-cane is practically the only exportable crop grown, and almost the whole working-class population is dependent upon it either directly or indirectly (Jones, 1930). The standard of local agriculture is very high. There is very little peasant cultivation, most of the cane being grown on estates.

Ground provisions and cotton are subsidiary crops.

The moth-borer (*Diatraea saccharalis*) is perhaps worse in Barbados than in any other British colony; and second only to *Diatraea* is the root-borer (*Diaprepes abbreviatus*). Sweet potato weevil (*Euscepes batatae*) is also very injurious. Whether or not these three are native insects it is impossible now to say; but the probability is that at least the first and second are indigenous.

St. Lucia.

St. Lucia lies to the north-east of St. Vincent, in latitude 13° 50′ N. and longitude 60° 58′ W., and is about 233 square miles in area, rather larger than the Isle of Man (Aspinall). It is mountainous and volcanic, reaching an elevation of 3,140 feet, and is largely clothed with dense rain-forest.

The climate is humid, the wet season extending from June to November. The average annual rainfall varies from 80 to 100 inches, and the mean temperature from 72° to 90°F. The Cul-de-Sac cane-lands receive about 95 inches and Roseau about 100 inches. In 1925 the mean relative humidity at the Union Experiment Station (observations at 7, 12 and 5 o'clock) was 72 per cent., ranging from 65·7 in March and April to 77·9 in August [*Report for 1925* (1926).] Whoever sees only the vicinity of Castries (106 inches of rain) and the western side of the island generally will gain a wrong impression of St. Lucia conditions as a whole. This slope of the island is much the wetter and reminds one of Dominica. The windward side is drier, especially as one approaches Vieux Fort in the south-east, where there are only about 50 inches of rain, and those badly distributed, the dry season being very prolonged.

Croucher (1929) states that the cultivated soils of St. Lucia may be classed in three main groups—firstly, the heavy alluvial loams of the northern valleys; secondly, the lighter sedentary soils of the south and south-west; and thirdly, sandy, detrital or hill-wash soils. The first class, of brown siliceous loams and clays, comprises most of the cane-lands save those of Vieux Fort, which belong to the second category and are shallow, light loams, with numerous quartz crystals, neutral or alkaline in reaction, deficient in humus and potash, and apt to suffer from drought.

On the west coast, about Castries and south of it, and in the mountains which one crosses to the east coast, all bears the impress of very moist rain-forest conditions. Razor-grass (*Paspalum virgatum*) is very plentiful on all the roadsides, while in the luxuriant forest,

Heliconia Bihai, various Pipers, tree-ferns and great beds of a *Gleichenia* are frequent. Northward along the leeward coast conditions are considerably drier. *Sporobolus indicus* is the dominant roadside grass and there are long stretches of logwood (*Haematoxylon campechianum*). I even saw some *Acacia arabica* at Corinth.

When the backbone range is crossed the rain-forest is left behind, and as one approaches Dennery the lower precipitation is indicated by the masses of guava shrubbage (*Psidium Guajava*) on waste lands and pastures. The dry coastal hills are covered with semi-deciduous scrub, containing much *Tecoma leucoxylon* (the dominant tree), logwood, a small-leaved *Bauhinia*, *Cordia cylindristachya* and *Coccoloba pubescens*. Further south, towards Vieux Fort, conditions become drier still; *Bursera gummifera* appears and cacti (*Cereus* sp. and *Opuntia*). In this stretch, in May, the whole scrub was grey in colour, the *Tecoma* being almost all, and the *Bursera* entirely, leafless.

The population is about 57,000, or some 245 to the square mile.

Sugar-cane remains much more than twice as important as any other crop. Lime products and cocoa come next; then coconuts, bay rum and fruit (Jones, 1930). An effort is now being made to grow coffee again (*C. arabica*). The failure of this industry many years ago is obscurely attributed to " blight."

There is very considerable peasant agriculture.

The main insect pests are small moth-borer (*Diatraea*) of cane, and leaf-miner (*Leucoptera coffeella*) of coffee. Green scale (*Coccus viridis*) has been introduced in recent years and is now abundant on coffee.

Dominica.

Dominica, nearly 300 square miles in area, is the largest of the Leeward Islands and the wettest spot in the West Indies. It lies between latitudes 15° 10′ and 15° 40′ N. and longitudes 61° 14′ and 61° 30′ W., between Guadeloupe and Martinique. It is volcanic and rugged, rising to over 5,000 feet in densely forested mountains.

According to Hardy (1922) the soils of Dominica have been derived from volcanic rocks (lavas, breccias and tuffs) consisting chiefly of hypersthene andesite and its fragmental equivalents. Rainfall and topography have given rise to three main soil types—firstly, those of the central uplands, above 1,000 feet; secondly, those of the windward coastal belt; and thirdly, those of the leeward coastal belt.

Lateritisation, due mainly to excessive leaching, has been pronounced in the wetter districts. The central upland soils are markedly acid in reaction, those of the drier leeward coast belt approximately neutral, while the rainy windward coast soils are somewhat intermediate in type (Hardy). The coastal temperature varies from 70° to 90° F., the hills, of course, being cooler. In 1928, at the Botanic Station, the highest maximum was 95° F. on 22nd May, and the lowest minimum 63° on 25th January.

In 1928 the mean rainfall of 20 stations was 127·23 inches; that of 8 leeward stations being 87·35 inches; of six windward stations, 146·23 inches; and of three inland stations, 208·45 inches. The lowest rainfall at any station was 63·27 inches at Batalie, and the highest 260·29 inches at Shawford. At most stations the wettest months are August and September, and the driest, May. The mean relative humidity at the Botanic Gardens in 1928 was 70·8 per cent. at 9 a.m., and 65·6 per cent. at 3 p.m.; the lowest being 56·7 per cent. at 3 p.m. in April, and the highest 79·6 per cent. at 9 a.m. in December and January (*Report for 1928–29*, p. 29).

The population is 37,000 or only 127 to the square mile.

The island is but little developed agriculturally. A flourishing lime industry was sadly diminished from 1922 by withertip disease (*Gloeasporium limetticolum*). "Within three years the crop was halved and it has remained at around 200,000 barrels of fruit since 1925" (Jones, *loc. cit.*, p. 46). Cacao and coconuts are also grown, and a fruit trade with Canada is being initiated. A considerable portion of the cultivation is in the hands of peasants.

These crops are all, at present, remarkably free from insect pests. The only ones which are causing much concern are leaf-eating weevils of the genus *Diaprepes* and its relatives. Scale-insects, it is believed, are kept entirely in check by fungous parasites, for which the humid climate is highly favourable. Rats are said to be a serious pest on the estates (*Report for* 1928–29, p. 34). It is to be hoped that means will be found to combat them other than that of attempting again to introduce the mongoose.

Montserrat.

Montserrat is a small, mountainous (3,002 feet) island of an area of some 32 square miles situated in latitude 16° 45′ N. and longitude 61° W.

Hardy (1922) reports that the soils of Montserrat may be divided into two main types according to their geographical origin. They are both derived from fragmentary volcanic rocks, chiefly hypersthene andesite, consolidated into agglomerates, breccias and tuffs. In the northern part of the island these consolidated rocks are exposed and denuded, constituting shoal rock. Elsewhere, and especially in the southern part, erosion has produced extensive talus slopes, consisting of masses of loose debris carved by water into deep ravines or ghauts. The *talus* soils are thus soils of transportation while the *shoal* soils are sedentary. The chief feature of the former is their great porosity. They are described by Hardy as light, fawn-coloured, highly fertile loamy sands, not very retentive of water, easily tilled, save for the local occurrence of a high proportion of stones and small boulders; and they constitute the best cotton lands of the island. In reaction they are distinctly alkaline. Shoal soils are of much less importance agriculturally. They are distinguished markedly from the talus soils by a deficiency or at least a minimum of natural under-drainage. Some of the humid upland forest soils in this category are of a heavy type, while many of the hilly land soils below 1,000 feet are infertile sands. In the valleys of the northern part of Montserrat, Hardy distinguishes still a third sub-type of shoal soils, which owing to shelter and consequent humidity conditions are of considerable fertility, and support a prolific tree-vegetation. They are sandy loams or clay loams. The mean annual temperature is about 78° F., the highest maximum at the Botanic Station in 1926 being 91° in March, June, August and September, and the lowest minimum being 66° in February and March. The average rainfall from 11 stations in 1926 was 55·73 inches, ranging from 38·79 at O'Garras to 67·57 at Paradise. The wettest month on the whole is November, and the driest, March. At the Botanic Station the mean relative humidity for the year 1926 was, at 9 a.m., 68·3 per cent. and at 3 p.m. 64·3, the lowest being 55·8 at 3 p.m. in March and the highest 75·9 in November.

The gentle slopes of the hills up to 1,500 feet are cultivated, while the upper parts are forested. The forest has been badly damaged by recent hurricanes, especially that of 1928. In those spots where the destruction was greatest, tree-ferns are now forming almost pure stands, just as in St. Lucia (and in New Zealand) they are among the first to colonise land-slides and their scars. *Tecoma leucoxylon* is as much a favourite for shade and roadside planting as it is in Antigua

and St. Kitts. It decays badly and rapidly as soon as it has reached any considerable size, and is soon useless as a windbreak—which is what Montserrat agriculture pre-eminently needs. Other common roadside trees are tamarind, *Hymenaea Courbaril*, mango, West Indian mahogany (*Swietenia Mahagoni*), and *Bursera gummifera*.

Wasteland and field edges are occupied on the leeward side by such plants as *Parthenium Hysterophorus*, *Leonotis*, *Ageratum*, *Momordica Charantia*, *Triumfetta*, Guava bushes, *Jatropha Curcas*, *Annona muricata*, *Ricinus communis*, *Pisonia aculeata*, *Tecoma stans*, *Leucaena glauca*, *Thunbergia fragrans*. At Trants, on the windward side, drier conditions were indicated by *Calotropis gigantea* as a common weed in the cotton fields.

The population of 12,120 works out at a density of about 379 per square mile.

By far the most important crop (80 per cent. of the exports in 1927) is Sea Island cotton. The lime industry is famous but has been repeatedly seriously damaged by hurricanes. A thriving fruit and vegetable trade with Canada is growing up, especially in tomatoes.

There are nearly 2,000 peasant proprietors of five acres or less (Jones).

As in the other cotton islands the pink bollworm became a very serious pest soon after its introduction, but it has lately suddenly decreased to almost negligible proportions. Several pests, of which the green bug (*Nezara viridula*) is the most important, are becoming increasingly injurious to tomatoes. I saw extensive rat injury in a tomato field, but it was said to be unusual. The mongoose does not occur here.

Antigua.

Antigua, in latitude 17° 6′ N. and longitude 61° 45′ W., is about 108 square miles in area. Following Tempany (1916) we may divide the island into three principal regions, firstly, the central plain which traverses the island diagonally from west to east; secondly, the north-eastern undulating, limestone region, slightly more elevated than the central plain; and thirdly, the south-western mountainous part, volcanic in origin, and rising in Boggy Peak to 1,360 feet. There are no rivers and but one little stream.

The limestone area covers about a third of the whole. Its soils approximate to one type, which is fairly light, pervious and rich (up to 50 per cent.) in calcium carbonate. The soils of the central plain are heavy clay soils, deficient in lime, and requiring thorough drainage and tillage for the maintenance of tilth (Tempany). In the southern or mountainous districts the soils are of a much more desirable type, non-calcareous, but moderately retentive of water, though easy to drain and to work.

The average annual rainfall for 55 years is as low as 43·61 inches [*Report for 1928–29* (1930), p. 20]. In 1928 the rainfall of 64 stations varied from 22·42 to 54·55 inches. The driest months are April, May and June (all under one inch each) and the wettest September and December. The highest maximum temperature at the Botanic Station in 1927 varied from 91° F. in September to 85° in January and February, while the lowest minimum ranged from 65° in January to 71° in September. The relative humidity at the same station showed an annual mean of 71·8 per cent. at 9 a.m. and 67·7 at 3 p.m., the lowest being 63·4 at 3 p.m. in February and the highest 76·5 at 9 a.m. in November.

The wasteland and pastures are covered with a xerophytic scrub in which *Acacia arabica* and *A. Farnesiana*, predominating, take the place which mesquite (*Prosopis juliflora*) occupies in the drier parts of Haiti and Jamaica. Associated with these plants are other dry land shrubs, like *Cordia Collococca*, *Leucaena glauca*, various cacti (*Opuntia* spp., *Cereus* spp.) and Agaves.

The predominant shade trees throughout the island are *Tecoma leucoxylon* and West Indian mahogany (*Swietenia Mahagoni*), which grows magnificently, seeds very freely and is wholly deciduous here. *Bucida Buceras* is a very common tree.

In the moister valleys among the hills (e.g. Mill Hill, rainfall about 60 inches) there are remnants of mesophytic forest. The wasteland vegetation there is also of more mesophytic type, e.g. guava (*Psidium Guajava*), logwood (*Haematoxylon campechianum*), *Solanum torvum*, *Annona muricata*, *Pisonia aculeata*. Cotton field weeds included *Parthenium Hysterophorus* and European fennel (*Foeniculum vulgare*). The population is about 30,000 or 278 per square mile.

Agricultural conditions " are probably as difficult as, if not more difficult than, those in any other West Indian Colony " (Jones). Droughts are frequently severe. The alluvial soils are in places

extremely heavy, but this is associated with a retentiveness which enables sugar-cane to be grown under a very low rainfall without irrigation.

Sugar forms 96 per cent. of the exports (Jones). Cotton, limes and sisal are grown on a small scale, and ground provisions largely for local use.

There is considerable peasant agriculture, especially in the hills, and a land settlement scheme to extend it further is being developed.

By far the most important pest is the small moth-borer (*Diatraea saccharalis*) of cane. Pink bollworm has been serious, and the sweet potato weevil (*Euscepes*) is abundant. Citrus scales seem to be largely checked by fungous parasites. There had been a severe infestation by several species on a plantation near the reservoir, but at the time of my visit it was impossible to find a live scale. This is surprising in such a dry climate, but it will be noticed that the average relative humidity in Antigua, according to the orthodox screen figures, is actually higher than that of Dominica, with its superabundant rainfall.

St. Kitts.

St. Kitts lies in latitude 17° 18′ N. and longitude 62° 48′ W., and has an area of 68 square miles. The island is volcanic, with a high mountainous central part rising in Mt. Misery to 3,711 feet.

The average rainfall from about 30 stations for 15 years is 54·45 inches. In 1928 the range was from 37·93 inches at Canada to 74·72 inches at Wingfield. September was by far the wettest month, and May the driest. The mean maximum temperature for 1928 was 84·0° F. and the mean minimum 74·0° The maximum extreme—89°—was registered on 6th and 14th August, and 18th September, and the minimum extreme—68°—occurred on 13th February and 23rd March. The mean relative humidity was at 9 a.m. 69 per cent., and at 3 p.m. 68·8 per cent., the lowest being 64 per cent. at 3 p.m. in May, and the highest 75 per cent. at 9 a.m. in September and October (*Report for 1928–29*).

The soils are of volcanic origin and form a dark grey loam, easily worked but light enough to suffer considerably from drought under a higher rainfall than Antigua. The higher slopes of the mountains are covered to the summit with dense mesophyte forest, the haunt of the monkeys which descend to ravage the higher cultivations. The

lower slopes are given over to labourers' patches of ground provisions, while estate cultivation is confined to the modicum of flat or gently-sloping land which surrounds most of the island, between the sea and the mountains. There is practically no waste land in this region and no room even for pastures, the stock being hand-fed throughout the year. The predominant shade tree, planted along most of the roads, is *Tecoma leucoxylon*, so-called " white cedar." Huge old gnarled cedars, *Cedrela*, occur. On banks, ravine sides and lower hill slopes of the coastal areas the scrub consists largely of *Acacia Farnesiana*, *Tecoma stans*, *Opuntia* spp., *Cereus* sp., *Annona* sp., *Leucaena glauca*, *Ricinus communis*, and such herbs as *Bryophyllum calycinum* and *Rhynchelytrum roseum* (*Tricholaena rosea*).

The only estate crops are sugar-cane and cotton. In 1927 the former supplied 81 per cent. of the total exports and the latter 10 per cent. Sea Island cotton is grown as a catch-crop on the cane-lands, thus decreasing overhead cost. There is practically no peasant agriculture. The population is estimated at 18,300 or 269 to the square mile.

With the decrease of the pink bollworm, the only really serious insect pest is the small moth-borer (*Diatraea saccharalis*) of cane.

Nevis.

Nevis, with an area of 50 square miles, is separated from St. Kitts by only two miles of sea. It is practically one large volcanic cone rising to 3,596 feet, the higher slopes and summit of which are densely forested. There are practically no streams.

The average rainfall at the Experimental Station for the past 23 years was 45·43 inches. August and September are usually the wettest months, and February, March and April the driest.

The minimum temperature during 1927–28, from readings taken at 9 a.m. and 3 p.m., was 66° F. in February (1928), and the maximum 91° in August (1927).

The soil is a heavy clay. On the lower slopes there is much abandoned land and rough pastures, largely covered with *Acacia* scrub and *Calotropis gigantea*. The chief cotton-field and roadside weeds are *Argemone mexicana*, *Parthenium Hysterophorus* and *Valota insularis*.

The population is about 12,500, or 250 to the square mile.

Sea Island cotton is by far the most important crop and is grown chiefly by peasants, either on their own holdings or on the share system with the estate owners. Ground provisions are grown extensively for the St. Kitts market. Coconuts, sugar-cane and sisal are practically the only other crops, and these are at present quite unimportant.

The chief insect pests are the pink bollworm, which has, however, here as elsewhere in the West Indies, now greatly decreased, green bug (*Nezara viridula*), cotton leaf-worm (*Alabama argillacea*), cotton-stainer (*Dysdercus*) and sweet potato weevil (*Euscepes*).

The Greater Antilles in General.

It is not easy to generalise regarding these large and highly diversified islands. Parts of them were the seat of the earliest European settlements in the New World, a fact which may help to explain why none of those insect pests which can with any degree of certainty be regarded as indigenous to them is so injurious as in most of the Lesser Antilles, Trinidad and the Guianas.

There can be no doubt that insect pests are on the whole far less serious in the Greater Antilles. Only in the case of sugar-cane can this estimate be substantiated by a quantitative comparison of infestation ; but there is abundant other evidence. In the first place many important pests are entirely absent, at least as pests—for instance, large moth-borer (*Castnia*) and froghopper ; in the second place I know of no case in which Jamaican, Cuban, Haitian or Dominican planters have organised large scale hand-collecting of injurious insects—and when they are at all impressed with the extent of insect damage this is invariably what planters the world over tend to do. Recently-introduced pests, however, like the green scale (*Coccus viridis*), the black fly (*Aleurocanthus woglumi*) and the banana-borer (*Cosmopolites sordidus*) are becoming serious.

For the plants, Grisebach's *Flora* is still essential, and Urban's work (in *Symbolae Antillanae*) is very useful. Valuable catalogues of the insects of Porto Rico and of Jamaica have been published by Wolcott (1923) and Gowdey (1926–28) respectively.

Porto Rico.

Porto Rico has not been visited, save for a stay of two non-consecutive nights to break an aeroplane journey.

It lies in latitude 18° 15′ N. and longitude 60° 30′ W. Its area of 3,350 square miles is slightly less than that of Jamaica. The lowlands are divided by a longitudinal mountain range (highest peak, El Yunque, about 3,500 feet) into a wetter northern portion and a drier southern, subject to droughts. This variation is governed by the prevailing north-east trade winds. The annual average rainfall for the whole island is 77·3 inches (Wetmore). On the north-east of El Yunque and about its base the annual average is 135 inches (maximum 169). The south coast is almost universally dry, the annual mean being 40 inches or less. February is the driest month, while the wettest are from May to October, according to locality. The population, of which two-thirds are classed as white, is about 1,300,000 or some 388 to the square mile. Sugar-cane is the chief crop, with tobacco a good second, and coffee (*C. arabica*), now much less important than in Spanish days.

The chief cane pests are small moth-borer (*Diatraea saccharalis*), which is much worse in the southern areas than elsewhere in the island, and white grubs (*Lachnosterna* spp.) (Wolcott, 1924*b*). Coffee leafminer (*Leucoptera coffeella*) and banana-borer (*Cosmopolites sordidus*) are important. In the drier areas the hornfly (*Lyperosia irritans*) is a serious pest.

The turkey buzzard (*Cathartes aura*) has been successfully established in one section, but is apparently not extending its range. Wetmore believes that its only enemy is the mongoose, and that other conditions are favourable. Five other species of birds have been introduced, but only one, the hooded weaver finch (*Spermestes cucullata*) from Africa, is spread over a large area. Another African species, *Amandava melpoda*, is locally abundant. Both these small finches feed almost exclusively on grass seeds and may be considered neutral from the agricultural point of view.

Santo Domingo.

Santo Domingo, with an area of 20,596 square miles, occupies the eastern two-thirds of the large island of Hispaniola. It lies entirely, but only just within the Tropics, between latitudes 17° 36′ and 19° 57′ N. and longitudes 68° 18′ and 74° 40′ W. Greenwich. There are three chief mountain ranges, one reaching to an altitude of over 10,000 feet, extending east and west and covered with dense forest. Between these various ranges are rich and fertile plains of great extent.

Only a brief reconnaissance journey has been made to Santo Domingo from Haiti. On the southern and most direct overland route from Port-au-Prince to Santo Domingo City there is much dryish savannah country devoted to ranching, and interspersed with long stretches of a dry, open type of forest, with trees such as *Bursera gummifera* and occasional cacti (*Cereus*), and *Bromelia Pinguin*, which may pass into still more xerophytic scrub with *Agave* and *Opuntia*. Some of the lower hills are clothed with a curious type of forest which, at the time of our visit in December, presented an extraordinary dead grey appearance from the fact that the trees were entirely leafless and covered almost continuously with a dull-grey tufted erect Bromeliad. Both these types may be classified as monsoon forest. The road is occasionally lined with mesquite (*Prosopis juliflora*) which is spreading rapidly in Santo Domingo, where it was introduced by the Haitian invaders in 1840 (Ekman).

On the northern route to La Cumbre more mesophytic conditions were observed, with such plants as *Haematoxylon campechianum*, *Coccoloba pubescens*, *Oreodoxa regia* among the roadside vegetation, and more typical savannahs with *Andropogon* and *Curatella americana*. Thus in the lowlands; but when the road entered the mountains conditions became rapidly moister and at the highest point, where it crossed the saddle (about 667 feet) the extreme humidity rendered possible the growth of a rain forest of the moistest tropical type. This will be described in more detail in the account of the mahogany-borer (*Hypsipyla*), which was here investigated.

The rainfall in 1928 varied from 12·63 inches near Azua (south-west coast) to 178·28 inches at San Francisco de Macoris (north central), the average of 16 stations being 63·4 inches—a figure which, in a country so diversified, is of little ecological value. It is curious that the central mountain range divides the country into two regions with regard to season. While the dry season prevails in the south, the wet season is in full swing in the north, and *vice versa*. Thus the wettest month by far in Puerto Plata (north), in 1928, was November, and the driest, July; the wettest at Ingenio San Isidro, near Santo Domingo City, in the south was May, and the driest, February (Pulliam, 1929). The thermometer rarely rises above 90° F. (Aspinall).

The population according to the last census was nearly 1,000,000, or rather fewer than 48 to the square mile.

Sugar-cane is the most important crop, supplying exports (raw sugar) of a value of about seventeen million dollars in 1928. Cacao comes next with exports worth seven and a half million dollars in 1927, but owing to storms at flowering time in 1928 only four and a quarter in that year. Coffee (*C. arabica*) is third on the list, followed very closely by tobacco. Hides and maize are of increasing importance.

The chief pests of cane are *Diatraea* and white grubs, neither of which is so serious as in Porto Rico. Of coffee and cocoa pests little seems to be recorded.

Haiti.

Geography.—Haiti is in many respects the most interesting country of the West Indies. With an area of about 9,000 square miles it occupies approximately the western third of the island of Hispaniola. Since, however, the frontier between Haiti and Santo Domingo has not yet been finally fixed, the exact extent is unknown.

The Haitian countryside is exceedingly mountainous. Of these great rounded Mornes, the highest is Morne La Selle, which reaches an altitude of about 8,900 feet. Short rapid streams are plentiful, but although all those which contain water in some part of their course for most of the year are called rivers, there is really only one considerable river, the Artibonite, which is about 165 miles long.

Climate.—In all lowland parts of the republic the temperature is hot and remarkably uniform. There is no frost, ice or snow even at the highest levels (Woodring *et al.*, 1924, p. 39). An important element is the very small difference, ordinarily about 9° F., in the mean monthly temperature between the hottest and the coolest months. At Furcy (elevation 5,133 feet), the only mountain station at which records have been kept, this difference is even more striking, being only 3·6°. The annual mean temperature of seven lowland stations varies from 76·3° to 80·8° F., while that of Furcy is 65·1°. Above 3,000 feet the nights are extremely chilly, and at 5,000 feet and above even the permanent inhabitants suffer considerably from cold (Woodring *et al.*).

There are two distinct rainy seasons, one in spring and the other in autumn. Owing to the high relief of the surface, the rainfall varies tremendously even in short distances. The windward slopes of the mountains are generally very wet and the leeward sides very dry. The annual mean rainfall of 33 almost entirely lowland stations

varies from 20·6 inches at Gonaives to 105·1 inches at Mirebalais. The average annual rainfall recorded for eight years by the Haytian American Sugar Company on the Cul-de-Sac Plains was 36·9 inches and on the Leogane Plains, 47·4. A feature of the drier areas is the long period—up to three months—which elapse with no rain at all, and the frequency with which the rain, when it does come, falls in sudden tempests, accompanied by hail (Woodring *et al.*). There is a strong local belief that the rainfall has decreased considerably since French colonial days, but a comparison of recent figures with those published by Moreau de Saint-Mery in 1797–1798 lends no support to this notion.

Like the rainfall the relative humidity seems subject to enormous variation—daily, seasonal and local. Monthly means at Port-au-Prince show that the relative humidity is lowest in February (63 per cent.) and highest in October (75 per cent.). This is lower than in many other tropical countries. At Furcy, 5,133 feet, the relative humidity is consistently higher (about 90 per cent.) than at Port-au-Prince on the plains below.

Vegetation.—The vegetation has been profoundly modified by a rather dense population. Virgin forest is confined to almost inaccessible regions. Forest of any kind is practically confined to the windward slopes of the mountains. There, in places, a wealth of tree-ferns, begonias, lianes, and epiphytes gives an aspect of real luxuriance. Among the important trees are mahogany (*Swietenia Mahagoni*), sablier (*Hura crepitans*), royal palm (*Oreodoxa regia*), mapou or silk cotton (*Ceiba pentandra*). A drier kind of hill forest (monsoon type) is marked by the abundance of lignum vitae (*Guaiacum officinale*), *Bursera gummifera*, and *Agave*, the undergrowth at about 2,000 feet matted together with a climbing bamboo (*Arthrostylidium haitense*).

Above a certain elevation, which varies greatly in different parts of the republic, the broadleaf forest is replaced by open woods of pine (*Pinus occidentalis*).

The vegetation of the plains is in general highly xerophytic (true thorn forest), with a multiplicity of spiny bushes and various cacti and agaves. Bayahonde or mesquite (*Prosopis juliflora*) covers large areas, replaced towards the hills by campêche or logwood (*Haematoxylon campechianum*). On the less arid plains and on the mountains is considerable savannah country with *Andropogons* and

other indigenous grasses, and introduced Guinea grass (*Panicum maximum*). Many miles of high country, especially near the Dominican border, are densely covered, to the exclusion of nearly all else, by the injurious East Indian weed-grass, Madame Michel (*Themeda quadrivalvis*), which is spreading also into Santo Domingo. Much of the present mountain savannah is the result of deforestation, especially of pine woods.

In French colonial days Haiti was the most cultivated and prosperous country of the New World. Relics of this departed glory, ruins of extensive aqueducts and sugar factories are scattered among the cacti of the plains, but to a biologist its most striking monument is the European flora which flourishes in the mountains about Kenscoff and Furcy. There one may walk for miles over rolling downs the turf of which is composed almost entirely of European grasses, clovers, and weeds. (I may mention the genera, *Poa, Festuca, Silene, Sisymbrium, Trifolium, Pastinaca, Daucus, Myosotis, Leontodon, Taraxacum, Plantago, Prunella, Rumex, Fumaria, Foeniculum, Euphorbia, Sonchus, Lapsana, Hypericum, Geranium, Senecio, Hypochaeris.*) There are swarms of European dungflies (*Scatophaga stercoraria*), and in the gardens, apple-trees infested with woolly aphis (*Eriosoma lanigerum*), strawberry plants with European snails (*Helix aspersa*), peach and plum trees. One may pick European blackberries (*Rubus fruticosus*) in profusion, but in seeking them, may stumble over a rocky outcrop covered with showy Begonias and a magnificent red *Fuchsia*—and the European illusion is lost.

Agriculture and Population.—There has been no recent census of Haiti. The latest estimates vary from one-and-a-half to two-and-a-half millions, the former figure being probably more accurate. The population is very unevenly distributed, but the more fertile regions support about 250 persons to the square mile.

Agriculture, which is mainly of the peasant type, is carried on in some of the ranges, notably of the La Selle massif, almost to the summits of the peaks. A very large proportion of it is devoted to producing for sale in the innumerable local markets such provision crops as millet, maize and sweet potatoes.

By far the most important export crop—six to seven times as valuable as any other at least up to 1922—is coffee. Cotton comes next and then cocoa, campêche (logwood) and sugar.

Pest Situation.—It will be shown in later sections that the insect pest situation in Haiti is highly peculiar, but a few general points are worth mention here. Cane-fields in Haiti, whether peasant or estate-cultivated, are probably freer from insect pests than those of any other country. Coffee is but little attacked, the most important pests being not such widespread ones as the leafminer (*Leucoptera coffeella*) which, though present, does little damage; but obscure indigenous species such as the cricket, *Cremon repentinus*. Cotton leafworm (*Alabama argillacea*) is periodically severe, but pink bollworm on the chief cotton varieties now grown, is entirely negligible. Another introduced pest, the banana-borer (*Cosmopolites sordidus*), however, causes very great damage. With the possible exception of the latter, and of *Alabama*, which is migratory, there are no insect pests in the republic to compare with any single major pest in the British colonies. There is a general tendency towards this happy state of affairs throughout the Greater Antilles (save perhaps Porto Rico) and its intensification in Haiti, the geographical and biological centre of the group, is perhaps to be expected; but an additional explanation undoubtedly lies in the Haitian system of extremely diversified peasant agriculture.

The most important physiognomic bird of the Cuban landscape, the turkey buzzard (*Cathartes aura*), does not occur in Hispaniola, though an unsuccessful attempt was made by the Haitian Consul in Jamaica to introduce it from that island (Cousins). It has been successfully established in Porto Rico by Government importations from Cuba some time since 1873 (Wetmore, 1916, p. 30).

Cuba.

Geography.—To sum up Cuba in a few short paragraphs is not easy. It is a long, narrow island, the largest in the West Indies, of 44,164 square miles (including the Isle of Pines), extending from longitude 74° to 85° W. (Greenwich) and from latitude 19° 40′ to 23° 30′ N. The north coast is in general high and steep, and the south low and swampy. The surface is on the whole hilly or at least undulating, with extensive grassy plains in the central region and high mountains in the east, culminating in the Pico Turquino, which reaches 6,630 feet above sea-level, but was long believed to be higher. Even in the central provinces " there are ranges of rounded hills composed of metamorphosed igneous rocks as well as scattered remnants of limestone either in the form of isolated hillocks or *mogotes*, as they are called locally, or more extensive chains called

sierras in contradistinction to *lomas*, the term sometimes used for hills other than those of limestone" (Barbour and Ramsden, 1919, p. 78). Cuba is well watered.

Soils.—The soils of Cuba are among the most fertile in the world (see Bennett and Allison, 1928). They have been produced largely by the erosion of the limestone rocks. "The Trinidad Valley includes areas which have been under cane probably almost continuously for well over a hundred years. Near Guanajay I saw the beginnings of borings for oil. The top soil was nearly 70 feet deep, and earth from this level put into a seed-bed supported a growth just as luxuriant as soil taken from near the surface" (Barbour, 1923, p. 15). Among the most extensive groups of soils and the most important agriculturally are the extraordinary permeable red clays of the Matanzas and Nipe families, lying on and derived from limestone and serpentine respectively. These red soils are markedly deficient in lime. "In the Matanzas family part of the low average of ·82 per cent. of calcium oxide comes from particles of limestone occurring just above the underlying limestone, where decomposition has not proceeded to the advanced stage obtaining in the representative soil material above. Leaving out the sample thus affected, the lime oxide average drops to ·54 per cent. This probably is present entirely in mineral particles not yet disintegrated or in combination with constituents other than carbonates, since no carbon dioxide from carbonates was found in any of the samples analysed . . . . The group of red soils represented by the Nipe series has lost practically all its lime . . . ." (Bennett and Allison, 1928, p. 76). As we shall see later, this is of great importance from the ecological point of view.

Climate.—According to the excellent tables supplied by Fassig (1925) the mean annual temperature at 10 lowland stations varies from 73·3° to 78·8° F., with an average of 76·4°. The normal annual rainfall at 19 lowland stations varies from 43·60 inches at Havana to 70·68 inches at Santa Barbara, with an average of 54·97 inches. "Rainfall is evenly distributed geographically, but is heavier over the western provinces and lighter over the eastern provinces . . . . In all provinces there is a minimum rainfall in January or February with a steady increase to a maximum in May or June, followed by a decrease in July, with a secondary maximum in September or October. . . . . A conspicuous feature of Cuban rainfall is the high degree of dependability during the usual crop growing months—from May to November" (Fassig). Cuba lies within the hurricane belt.

Vegetation.—The vegetation has on the whole a sub-tropical rather than a tropical facies. Dr. Ekman denies that any true tropical rain-forest exists in Cuba save perhaps in the Baracoa region, where occurs one tree (*Carapa guianensis*), highly characteristic of the moistest Guiana and Trinidad rain-forest.

Most of the cane-lands were originally lowland forest country. This forest, which is of a predominantly broadleaved hardwood type, not wholly evergreen, was still being extensively cleared, by extremely wasteful methods, up to within the last ten years. According to Bennett and Allison, royal palms (*Oreodoxa regia*), which are still the most noteworthy physiognomic plants of the cane lands and almácigo (*Bursera gummifera*), and to a less extent, mahogany (*Swietenia Mahagoni*), cedar (*Cedrela*), majagua (*Hibiscus elatus*) and guasima (*Guazuma tomentosa*), are indicators of good sugar-cane land. Júcaro (*Bucida Buceras*) grows on soil of inferior quality.

Some observations on mahogany forest will be found in the section devoted to the tip-borer (*Hypsipyla*). The lowland forest is everywhere greatly diminished in area. In the cane areas it is usually represented by no more than scattered islands on uncultivable limestone outcrops. Such remnants are often dominated by gigantic ceibas (*Ceiba pentandra*).

In the piedmont foothills of Pinar del Rio and at higher elevations elsewhere, there are considerable areas of open pine (*Pinus cubensis*), woodland or park country with a ground cover of wire grass (*Sporobolus indicus*).

The mountains and higher hills are in general covered with evergreen hardwood forest, differing considerably from that of the lowlands, and marked by an abundance of ferns, including arborescent and climbing (*Lygodium*) species, and lianes, and a dense shrubby undergrowth. A species of Juniper occurs. Over large areas, the undergrowth and the small trees of the lower strata have been cleared, and coffee planted with no other preparation and without disturbing the original canopy. Seen from neighbouring peaks or from an aeroplane, these coffee plantations are almost impossible to distinguish from untouched forest.

We have yet to mention the extensive savannahs and swamps. The former occur in many parts of the island and are used largely for pasturage. Though found on widely different soil types, they

agree in their essentially edaphic origin. The prevailing grass is espartillo (*Sporobolus indicus*), but *Andropogon virginicus* also occurs. The dominant palm is palma caña (*Sabal maritima*), but corojo palm (*Acrocomia crispa*) is occasionally frequent on the edges and in wetter patches. The small and more or less scattered shrubs include star apple (*Chrysophyllum oliviforme*), *Curatella americana*, and peralejo (*Byrsonima crassifolia*).

Swamps are often extensive, especially on the south coast, culminating in the great Cienaga de Zapata, which has an area of about 1,800 square miles. This consists of peat, marl and mangrove areas, with a certain proportion of coralline limestone, almost bare of soil save in pockets and holes (Bennett and Allison).

Pasture areas and even cane-lands are often invaded and covered by dense, impenetrable thickets of aroma (chiefly *Dichrostachys nutans* and *Acacia Farnesiana*—the former introduced from Africa).

Population and Agriculture.—The population of Cuba is about 3,600,000 or some 81 to the square mile. Two-thirds or more are classed as white. Most of the agriculture is on an estate scale, some of the larger sugar estates representing colossal undertakings.

By far the most important crop is sugar-cane, in the production of which Cuba leads the world. Bennett and Allison doubt whether "any other country of comparable area can excel its record, at this time, in agricultural specialisation upon a single crop." Next in value is tobacco, of which the most famous for quality is grown in a comparatively restricted area of sandy and gravelly soil in the western or Vuelta Abajo district. Pineapples are largely grown, and to a less extent citrus fruits, bananas, coconuts and coffee (*C. arabica*). The coffee industry is located in the mountains of Oriente, southern Santa Clara and certain districts of Pinar del Rio. It does not, however, now supply more than three-quarters of the local consumption, which is 65 million pounds a year. Cacao cultivation, once extensive, has declined even further than that of coffee. Potatoes are grown for export very successfully on the Matanzas clays. Henequen is the only commercial fibre crop. Cattle-raising for draught and slaughter (one is convinced that most Cuban beef has served in both capacities) is a highly important industry. Lumber, chiefly hardwoods and cedar (*Cedrela*), is still exported in considerable quantity.

Pests.—The cane-fields of Cuba have long been known for their comparatively light infestation by insect pests. In this respect they must, however, now yield to Haitian estates. The coffee leaf-miner (*Leucoptera coffeella*) is relatively unimportant, but this crop is now menaced by the introduced green scale (*Coccus viridis*) which is causing considerable concern.

Jamaica.

Geography.—In the Caribbean Sea, south of all the other Greater Antilles, the island of Jamaica, with an area of 4,450 square miles, lies between 78° 20′ and 76° 10′ W. and 18° 30′ and 17° 40′ N.

The country is extremely mountainous, with a main ridge running east and west, and spurs extending to north-west and south-east, the latter culminating in the Blue Mountains, with Blue Mountain Peak 7,360 feet high. It is calculated that only 646 square miles are flat. Rivers and streams, usually rapid, are plentiful—in fact the Arawak name, Xaymaca, which it still retains is said (Cundall) to imply an abundance of rivers.

Geology and Soils.—For geological purposes three principal physical regions may be distinguished (Reed, 1921, p. 172, modified). These are, firstly, the interior mountain range forming the nucleus; secondly, the elevated limestone plateau surrounding the nucleus; and thirdly, the low, flat coastal plains round the margin of the island.

The mountain nucleus is made up of much-folded Cretaceous rocks—shales, conglomerates, tuffs and a few marine limestones.

The plateau region, which occupies fully four-fifths of the island, consists of soluble white Tertiary limestones weathered into cock-pits, swallow-holes, basins and deep gorges.

The coastal plains deposits are of late Tertiary or Quaternary age. They include a variety of limestones, clays, gravels and alluvium. The soils have been very little studied.

Climate.—The mean annual temperature at Kingston is 78·7° F., ranging from 75·7° in February to 81·4° in July. The highest maximum recorded was 97·8° F. (August 11th, 1923), and the lowest minimum, 56·7° (December 4th, 1887). According to Maxwell Hall the mean annual temperature varies with altitude from 78·8° at sea-level to 75·3° at 1,000 feet, 72·0° at 2,000, 68·7° at 3,000,

65·5° at 4,000, and so to 55·1° at about 7,500, with a minimum of 47·3° at the latter station, but at Cinchona (5,017 feet) on the night of January 29th we found that the thermometer descended to 42° F.

The average rainfall for 50 years was 104·60 inches in the N.E. division, 57·79 in the North, 87·28 in the W. Central division, and 54·13 in the South, with an island average of 76·46 inches. The driest area on the coast is around Kingston and further west, where the annual rainfall is between 30 and 35 inches only. In all divisions by far the wettest month is October, save in the N.E. division, when it comes in November. There is another peak in May and, in the very moist N.E. district, January also is wet. December is easily the driest month in the South and W.C. divisions and is dry also in the other two, where, however, March is drier still.

At Kingston in 1927 (*Jamaica Report, 1928*, p. 21) the mean relative humidity was 83 per cent. at 7 a.m. and 66 per cent. at 3 p.m. This represents about 2 per cent. below normal.

Vegetation.—Few islands of similar size are so diversified as Jamaica. The great variations in rainfall and altitude are naturally reflected strongly in the vegetation, which, save in the high mountains, has been further profoundly modified by a very dense population. The most xerophytic vegetation occurs about Kingston and on the Liguanea plain—where the dominant shrubs and small trees are, among others, mesquite (*Prosopis juliflora*) here called, " cashaw," logwood, *Tecoma stans*, *Croton linearis*, with a few *Cereus* and *Opuntia*, many huge Agaves and clumps of *Bromelia Pinguin*, and carpets of thin wiry grass. The beautiful small tree *Spathelia simplex* is abundant. Cacti were much fewer than in the still more xerophilous vegetation of the Cul-de-Sac Plain of Haiti. Further west the mesquite grows in extensive pastures of Guinea grass (*Panicum maximum*), and cacti are much less plentiful than east of Kingston. Spreading saman trees (*Pithecellobium Saman*) are a feature in many of these pastures.

The other extreme, so far as lowland vegetation is concerned, is seen in the north-east district, where several species of *Philodendron* hanging from the trees, and a wealth of other climbers and epiphytes testify to the moistness of the climate. *Flemingia strobilifera* grows extensively, as in Trinidad. There are pastures of sour grass (*Paspalum conjugatum*) and Pará grass (*Panicum barbinode*) and banks of " maiden-hair " ferns (*Adiantum*).

The northern coasts tend to be bordered by sea-grape (*Coccoloba uvifera*) and the southern by more frequent mangrove swamps bordered inland by *Acrostichum aureum* or by areas of coarse sedges, and of Pará grass and *Typha* matted together with a species of *Mikania*. In the lower courses of some of the rivers are huge, almost pure, stands of *Phragmites occidentalis*. The much larger *Gynerium saccharoides* occurs in smaller clumps, while *Arundo Donax* grows usually higher up the river courses. The dry hills are covered with an open type of forest with *Bursera gummifera* dominant, its shedding leaves giving at certain times a golden aspect to the landscape.

The extensive well-settled plateau country of the central parts is like nothing else in the West Indies. Numerous pastures of Guinea grass are enclosed by stone walls like those of Derbyshire and dotted, park-like, with large trees of silk cotton, *Spondias*, mangos, *Hibiscus elatus* and cedar (*Cedrela*), and smaller ones of pimento (*Pimenta officinalis*) and cedar.

The Cock-pit Country is a jumble of rounded, steep-sided limestone hills, which would be called *mogotes* in Cuba, all densely forested and separated by deep ravines.

Almost all the lowland forest and much of the mountain woods up to 2,500 feet, and even, in cases, above 5,000 feet, have been destroyed, largely in the interest of peasant cultivation.

The forest of the Blue mountains reaches the summit of the highest peaks. Cedar (*Cedrela*) ascends on the southern slopes to 3,717 feet. The first *Juniperus* appeared at 2,217 feet. There is much peasant cultivation up to 5,000 feet and higher, and there is less forest than scrub, with such shrubs as *Baccharis scoparia, Dodonaea viscosa, Bocconia frutescens*, very abundant. A moister type of vegetation, with begonias, appears as one ascends, and this eventually passes near the ridges (about 5,600 to 7,000 feet), and especially on the northern slopes, into moderately high, exceedingly wet moss-forest, with huge moss-cushions on the floor, and moss-streamers from every twig of the dominant *Podocarpus coriaceus* and other trees. The undergrowth, rich in Melastomataceae and Rubiaceae, is matted together by a small climbing bamboo (*Chusquea abietifolia*), and interspersed with dense, practically impenetrable masses of *Gleichenia* ferns and *Weinmannia* scrub. Prickly tree ferns are plentiful.

An interesting feature of the mountain vegetation is the number of species of European plants which have long been established. They do not, however, form an important part of the plant-covering as they do in some of the Haitain mountains. At Newcastle (3,974 feet), on the southern slope of the Blue mountains, we saw dandelions (*Taraxacum officinale*), gorse (*Ulex europaeus*), white clover (*Trifolium repens*), rib-grass (*Plantago lanceolata*), and on passing through Hardwar Gap to the wet southern slope, *Lapsana communis*, *Geranium dissectum*, *Fragaria vesca* and a *Hypochaeris*, to name a few. These were, however, only roadside weeds. Above Cinchona, gorse forms more extensive thickets. Strawberries occur at the side of the track right to the top of Blue Mountain Peak, but the indigenous plant associations are not invaded.

Population and Agriculture.—The population of Jamaica was estimated in 1928 to be about 974,742. This gives a density of 219 to the square mile. There is considerable peasant agriculture.

In spite of the widespread incidence of Panama disease, bananas are the chief export crop, with sugar-cane products second in value, followed by coffee, dyewoods and coconuts. Stock-raising is important. Some of the Guinea grass pastures are magnificent.

Pests.—Jamaica is unusually free from serious insect pests. The chief damage to cane seems formerly to have been inflicted by rats, and these, in spite of the mongoose, are still important pests. Apparently now, however, the cane-field rat is chiefly the later-introduced brown species (*Epimys norvegicus*) and not the black rat (*Epimys rattus*), which, although responsible for the earlier outbreaks has now, as in New Zealand, largely taken to the trees. The small moth-borer is on most estates quite negligible. The banana-borer can be controlled by good estate cultivation but is still serious on peasant holdings. Coffee, pimento, cocoa and coconuts are not troubled by any insects worth mentioning, save perhaps the recently-introduced green scale (*Coccus viridis*) on the first.

B.—Observations on Particular Insect Pests.

(a) *Sugar-cane Pests.*

Sugar-cane is, of course, the most important crop of the British West Indies and British Guiana. In the present investigation its pests have, therefore, received the most attention. Sugar-cane was

introduced into the New World without, apparently, bringing any of its Old World pests with it, just before the close of the fifteenth century. Only gradually have the indigenous American insects learned to attack it, or rather to adapt themselves to the extraordinarily specialised conditions of the cane-fields. These conditions though always peculiar, vary greatly in different regions, for sugar-cane is surely the most adaptable of all tropical crops. In some cases practically no natural enemies have followed the cane-pests into the agricultural areas, and in nearly every case which has been adequately investigated, the parasites attack them more plentifully on other hosts than sugar-cane. The closest approach to a balance, where economic damage is comparatively small, has been achieved in parts of the Greater Antilles, where cane has been grown longer than elsewhere. That this balance, such as it is, is not due merely to the effect of long ratooning, as in Cuba, where cane has been grown in certain fields without replanting for a century, is shown by its presence even more markedly in Haiti, where such long ratooning at least on the estates is not practised. That it cannot be attributed to climatic factors such as rainfall, is evident from its occurrence through the Greater Antilles under the full range of climates in Jamaica, Cuba, Haiti and Santo Domingo. The true factors of this balance will be suggested in describing the moth-borer situation below.

A curious and intriguing feature of the sugar-cane pests is their tendency to be restricted to single colonies or regions. The pests of cacao, of cotton, and of banana, for instance, are much the same throughout, but several of the most important insects attacking cane are confined, at least so far as economic importance is concerned, to single colonies. A striking example is the cane froghopper. This tendency is doubtless to be correlated with the very great adaptability of cane as a crop. Thus the ecological conditions in a cacao field must necessarily be essentially similar everywhere, or the crop does not thrive, but in a cane-field their variation is exceedingly great.

To avoid undue repetition when dealing with the several pests of sugar-cane, a few notes on ecological and agricultural conditions in the different cane areas may be offered here.

British Guiana.

In Dutch Guiana there has, as yet, been no opportunity to study sugar-cane insects. In British Guiana, which is probably essentially the same, cane-field conditions are extraordinarily specialised. The

system of empoldering and draining, by which every field comes to be surrounded by deep trenches, and even divided into beds by narrower drains, has been already described. The cane is planted in rows, *across* these long beds, and weeds as they appear are cutlassed and thrown on to one side of the drill. This side is henceforth known as the " trash bank," the other side being cultivated with forks to a depth of eight or nine inches. The canes are cut at about 15 months old, the fields having first been set on fire to burn off the dead leaves and facilitate handling of the canes. The field is next cut when the new canes—the first ratoon crop—are about a year old. The number of ratoon crops taken off before replanting varies with the estate and with the individual field. There are rarely more than five. Fields are sometimes, however, abandoned for several years. When a field is allowed to ratoon, some of the stools fail. The process of replacing these dead plants is called " supplying " ; and it may be done either with " tops " or " stumps," the latter being old stools dug out bodily, from abandoned fields or old fields being replanted (Crabtree, in Cleare, 1923). From an entomological viewpoint supplying with stumps is pernicious. Tops for planting may be " drawn down " from abandoned fields,—another highly unsound measure of false economy.

Cultivation is generally good, and is materially helped by a process now in vogue of flooding the fields for some weeks or months after the last ratoons are cut, before re-planting. This was originally introduced as a measure against the large moth-borer (*Castnia*), which it has now almost completely controlled. It is continued, however, for its agronomic value. Its immediate effect is the replacement of the ordinary weed-flora by a crop of aquatic plants, which serve later as green manure. The flooded fields attract immense numbers of wading-birds (Charadriidae, etc.) which have been shown by Williams in Trinidad to consume large numbers of insects.

Almost the only cane variety now grown on a commercial scale is a local product, D 625, which is admirably adapted to the peculiar conditions prevailing in British Guiana, but has a relatively low sucrose content.

The weed flora of Guiana cane-fields—of great interest here as a source of alternate hosts for both pests and parasites—is highly peculiar. Dams and roadsides are often covered with continuous areas of razor-grass (*Paspalum virgatum* and *P. millegrana*). These important grass hosts of the borer (*Diatraea* spp.) are much more

plentiful in Guiana than in any other cane country visited. The first was originally described from Jamaica and the second from Brazil. Both are probably indigenous in Guiana, but undoubtedly occupy a much greater area than they ever did in any virgin association. They occur, according to Hitchcock (1922) in the less moist portions of the coastal savannahs; where, however, conditions are now considerably modified by grazing and other effects of settlement. In the upland savannahs of the interior, by the witness of the same agrostologist, they are not found.

Another common weed on some of the dams, and still more so in pastures and waste-lands generally—even in abandoned cane-fields—is the black sage, *Cordia interrupta,* which is an important food-plant of certain adult parasites of the borer. Almost as abundant is *Cassia alata.*

Sour-grass (*Paspalum conjugatum*) is a common weed in the fields themselves.

The navigation and drainage canals and trenches frequently support a luxuriant floating mat-like growth of aquatic grasses, of which the most important is *Paspalum repens* (*gracile*)*. As we shall see later, this grass has a very important bearing on the borer situation. That it also affects the mosquito problem, with which however, we are not concerned here, is shown by the observation of Chamberlain and Curry in Panama that it renders conditions peculiarly favourable for the breeding of the mosquito, *Taeniorhynchus titillans.* Since it was originally described in 1762 from Dutch Guiana, it is probably indigenous, though unquestionably far more numerous under estate than under virgin conditions. It represents the first stage in the colonisation of open water by a grass species, and would probably rarely form a climax association save under the influence of periodic clearance. Hitchcock lists it as a species of the wet coastal savannah. In the cane-lands, the aggregate area under water-grasses and razor-grasses must be very considerable.

Birds are relatively plentiful about British Guiana cane-fields. This is probably to be attributed to the cover afforded by the weed vegetation of the dams themselves, and scrubby pastures, waste-land and sand-reefs and the adjacency of the extensive mangrove swamps of the coast on the one hand, and the savannahs with forest patches at the back of every estate on the other.

* I am indebted to the Royal Botanic Gardens, Kew for great and prompt assistance in naming these and other grasses, and in checking other identifications.

A word will be appropriate here on the general position of birds in sugar-cane fields. An expanse of waving cane is apparently of little use as cover for the smaller insectivorous birds, while the fly-catchers of the family Tyrannidae—among the most important insect-eaters of the American tropics—find no suitable perch from which to look out for prey in accordance with their invariable method of hunting. These birds find it almost impossible to settle on the cane-leaves themselves. I have watched attempts on the part of the grey-headed kiskadee [*Tyrannus melancholicus* (*satrapa*)]. This bird and its cousin, the common kiskadee (*Pitangus sulphuratus*), feed extensively on the adults of the large moth-borer (*Castnia licoides*), which are diurnal in habit. To encourage their activities against this and other pests it has become the practice on certain estates to supply every field, at planting time, with numerous, much-branched perches about 15 feet high, made of simply-cut stems of the common bamboo (*Bambusa vulgaris*). So far as attracting the birds is concerned, this has been an extraordinarily successful measure. In one field in Berbice I have seen four kiskadees on one perch, and several other perches with three. The small kiskadee (*Pitangus lictor*), the fork-tailed fly-catcher (*Muscivora tyrannus*) and the ani (*Crotophaga ani*) are other very useful insectivorous birds which largely patronise these perches.

On the same estates, steps are being taken to supply additional nesting cover for birds, by planting patches of trees and shrubbery. This practice has been carried much further, however, in Trinidad. An experiment to compare the relative pest infestation in fields without bird-perches and adjacent coverts would be eminently desirable. But whatever the statistical purist may say to the absence of such data, there can be no doubt that these active measures of bird-protection, considered as an effort towards restoring that ecological balance which we know is so badly upset by the planting of continuous areas of one plant, are theoretically eminently sound.

Lizards, both ground forms and leaf-lizards (*Anolis*) are very much more plentiful in British Guiana cane-fields than in those of Trinidad.

An account of ecological conditions in British Guiana cane-lands would not be complete without a reference to the occurrence of extensive rice-fields. Rice, which is the second most valuable crop, and one which is growing in importance, is heavily attacked by

Diatraea saccharalis, the most serious of the small cane moth-borers. Maize, another host of *Diatraea*, is practically absent, save in inconsiderable garden patches.

Trinidad.

Cane estates in Trinidad are all situated in the western half of the island, between the Northern Range and the Central Range, and between that and the Southern. No estate cane is more than 13 miles from the west coast. There is in many respects a strong contrast between the northern and the southern areas (the Naparimas), and this is reflected in striking differences in the pest situation. The northern lands are wholly flat, while the southern are undulating. The soil in the Naparimas is extremely heavy, but so also are certain of the northern sections. The rainfall does not differ greatly—in 1929, according to Hardy and Urich (1930) it was 66·18 and 65·60 inches at two northern estates and 67·11 inches at a large Naparima one. Other differences will be considered later in an attempt to explain why the small moth-borer (*Diatraea*) is a major pest in the Naparimas, while on the northern estates it is positively rare.

Cultivation is very difficult. In contrast to British Guiana, " the cultivation of the ratoons is somewhat neglected on the majority of the estates. This is due to the shortage of labour during the crop season (which is also the correct time to cultivate) and the need of more tractors . . . . " (Jones, 1930, p. 61). Two ratoon crops are usually taken. It is a regular practice on one large estate in the Naparimas to plant rows of horse beans (*Canavalia*) between the cane-rows, and afterwards to plough them in.

The chief cane now grown in Trinidad is B.H. 10 (12), but Uba is grown on a large scale, while P.O.J. 2878 is receiving extensive trial.

It is not the admitted practice to burn the ordinary cane-fields before cutting, as in British Guiana, but nevertheless many fields are burned—deliberately, accidently or maliciously—while Uba is invariably burned. Where the canes themselves are not set alight, the trash after cutting is commonly fired before ploughing, at least in the Naparimas.

The deficient cultivation of the ratoon crops leads to a varied flora of weed grasses such as *Panicum barbinode* (Pará grass) and even suffruticose herbs. The former are in many cases alternate hosts of the froghopper, but it is uncertain what effect this has on the infestation. The drains, 20 to 25 feet apart, also support a certain

amount of grasses and froghoppers. The intervals between fields are known as *traces*, and these, as well as roadsides, are heavily grassed, occasionally cleared by cutlassing. The dominant trace grass on the northern estates and on the lower slopes in the Naparimas is *Paspalum fasciculatum*, which rarely flowers but forms extensive pure stands of hairy shoots. In the more trodden, central parts of the traces, *Eleusine indica*, locally called " Dutch grass," is common ; in wetter traces, *Panicum barbinode*, and on the higher slopes in the Naparimas, *Cynodon dactylon*, *Sporobolus indicus* and *Paspalum conjugatum*. Clumps of *Paspalum virgatum* are frequent, but never cover such extensive areas as in British Guiana, so that it is likely that their borer population is economically negligible. In the Cedros district this grass is exceedingly plentiful under coconuts and supports a considerable borer population. Rice and maize fields are on the whole not extensive, and the latter are attacked apparently only by a borer (*Diatraea lineolata*) which does not feed on cane.

Adjacent waste land and scrubby pastures are frequently more or less covered with black sage (*Cordia cylindristachya*), probably not botanically distinct from *C. interrupta* of British Guiana. There are extensive areas of cocoa and of woods, swamp and savannah at no great distance from most of the cane-lands. To this may be attributed the comparative abundance of birds. Active bird protection in the Naparimas has taken the form of supplying bamboo bird-perches for the common and the grey-headed kiskadee, and for the scissor-tailed fly-catcher (*Muscivora tyrannus*), which catches considerable numbers of froghoppers. On the same estate, where extension of cane cultivation during the last six years has brought in considerable areas of bush land which had been rested, it has become the practice to plant, for bird cover, patches of trees and shrubbery from 1 to 5 acres in extent. Jones and Potter (1929), who describe the procedure adopted, state that the ideal would be a small plantation for every 200 or 300 acres of cane. The area to be afforested is prepared for sugar-cane and planted in the usual way, the cane being regarded as a catch crop while the trees are young.

Ground lizards (*Ameiva*) have practically disappeared from Trinidad cane-fields, almost certainly owing to the mongoose. They are still common in the towns. Leaf lizards (*Anolis* spp.) are rare. Small green frogs are, however, surprisingly plentiful in the central shoots of cane, while large toads (*Bufo marinus*) are in some localities exceedingly common.

Grenada.

Sugar-cane is not important in Grenada. From my own brief visits and the observations of C. B. Williams (1918) it would appear that cane-field conditions differ widely from those of Trinidad. The cane-fields tend to be hilly, with a disproportionately large area of interspersed waste-land and pasture in scrub and roughage, sending tongues between the fields. Birds seem plentiful. A specially destructive moth-borer (*Diatraea canella*) reaches here its northern limit of distribution.

St. Vincent.

Sugar-cane is third in importance among St. Vincent crops. Only one very brief visit to St. Vincent cane-fields has yet been possible. The cane on the estate seen was chiefly B.H. 10 (12). Cane-field conditions seem rather similar to those of Grenada, but the infestation by borer (*Diatraea*) is considerably less.

Barbados.

Cane cultivation in Barbados reaches an exceedingly high standard. Owing to the shallowness of much of the soil, especially in the black earth areas, and to the necessity for conserving the low rainfall, the " holes " in which the canes are grown are maintained from year to year, and the position of the banks remains the same. This is apt to create conditions favourable for the root-borer (*Diaprepes abbreviatus*). On the other hand, the intensive hand cultivation, close settlement and absence of a forested hinterland has brought the weed flora, including alternate hosts of the moth-borer (*Diatraea*) to a probably irreducible minimum. Almost every inch of ground not under some crop is closely grazed by sheep, even on the craggier hills of the Scotland district. Roadside grasses are chiefly Barbados sour-grass (*Andropogon pertusus*), introduced from India, and *Sporobolus indicus*, neither of which is known to be a host of *Diatraea*. The only alternate host of the latter would appear to be maize, which is grown fairly extensively. Whether the *Diatraea* which infests this crop is the one (*Diatraea saccharalis*) which attacks cane is uncertain, and rather improbable. Throughout the West Indies the species in maize, wherever it has been authoritatively determined, is *Diatraea lineolata*, which is not known to attack cane.

In no circumstances are the cane-fields burned before cutting. Partly owing to infestation by the root-borer (*Diaprepes*) and partly

to deficient rainfall, ratooning is apparently impossible on the black soils. There the chief variety is Ba. 11569. On the red soil of the higher terraces, B.H. 10 (12) is largely grown, and is commonly ratooned, even to a third ratoon crop (Skeete).

In spite of the abundance of the mongoose and the absence of forests, small birds are unusually plentiful in Barbados. Of these the most important agriculturally are the blackbird (*Holoquiscalus fortirostris*), which is ubiquitous, and the so-called " Dr. Morris Bird " (*Tyrannus dominicensis*). Considerable bird-cover is afforded by the rather numerous tiny plantations of mahogany and other trees, and by the shade trees and hedges about dwellings.

The introduced toad (*Bufo marinus*) is common, but the ground-lizard (*Mabuya lanceolata*) is extinct (Barbour). It was apparently last seen in 1903 (Anon., 1903).

St. Lucia.

In the wet valleys of Cul de Sac and Roseau, cane is grown under favourable but very specialised conditions. Owing to the heavy rainfall, very wide, deep and numerous drains are necessary, or believed to be so. They are placed 12 feet apart, and, besides taking up a considerable area, also effectually prevent mechanical cultivation. Ratooning is extensively practised, ten or more crops being taken without replanting. A curious habit, seen nowhere else, and undoubtedly exerting an influence on borer infestation, is that of cutting at crop time only the fully mature canes and leaving the others " to keep the stool alive " or it would otherwise rot in this moist climate with no pronounced dry season. This practice is rendered possible only by the fact that the drains prevent the use of carts in the fields, and the cut canes are all tied up in bundles and " headed " out to the railway.

Several varieties of cane are grown, including B.H. 10 (12) and a local variety which is said to be a mutation from the old Bourbon, of which it retains several of the characteristics.

Of alternate hosts for borer, large razor-grass (*Paspalum virgatum*) is more plentiful than anywhere else visited save Guiana. It occurs in numerous huge clumps on roadsides and between and at the edges of fields. Sour grass (*Paspalum conjugatum*) and Pará grass (*P. barbinode*) are equally common.

On the east coast, in the valley estate of Dennery, this grass is still frequent.

At Vieux Fort, on the south-east, conditions are very different—the cane-fields exceedingly dry and occasionally irrigated, and no wild-grass hosts of the borer were observed save on the very banks of the river.

Small birds are plentiful in St. Lucia, blackbirds (*Holoquiscalus inflexirostris*) being especially abundant. The mongoose is nevertheless common, and the ground-lizards (*Ameiva* sp. and *Mabuya luciae*) are both extinct (Barbour). Attempts to introduce the Montserrat *Ameiva* were given up on account of the mongoose (Walters, 1926).

Montserrat.

Sugar-cane is of minor importance. The cane-field conditions are essentially those of a wet island, but this is due solely to the fact that the only considerable ones are planted in the mountains at an elevation of 1,100 feet, in a region of frequent mists. B.H. 10 (12) is the chief cane variety.

Although the mongoose is not present, small birds are decidedly scarce, at least in all the settled areas. Leaf-lizards (*Anolis lividus*) are very plentiful. I saw only a few ground-lizards (*Ameiva pluvianotata*), and these were about the Botanic Station. Mr. C. A. Gomez, the Curator, states, however, that they are abundant everywhere.

Antigua.

Cane is grown here under considerable disadvantages. According to Jones (1930) the standard of cultivation is lower than in Barbados and St. Kitts. Ecologically the cane-fields here and in St. Kitts resemble those of the Greater Antilles, especially Cuba and Haiti, far more than those of the other Lesser Antilles. This resemblance is especially marked in the weed-flora.

Partly in accordance with the variety of soil types a considerable number of cane varieties is grown, including not only the well-known B.H. 10 (12) and S.C. 12·4, but also some, such as B. 4507 and B. 6308, which are rarely seen elsewhere.

Short term ratooning is practised.

Burning the fields before cutting is not a regular procedure, and the central factory pays less for burnt cane. Every season, however, the labourers burn some fields, especially those which contain large quantities of cow-itch (*Mucuna pruriens*), a vine thickly beset with painfully urticating hairs.

Cane-field weeds in Antigua are negligible as alternate hosts for the borer (*Diatraea*). Owing to the relatively xerophytic conditions, razor-grass (*Paspalum virgatum*) occurs practically nowhere save in the moister Mill Hill district, and is not plentiful even there. In the other areas, *Valota insularis* grows commonly in cane-fields, but not luxuriantly. It has been recorded as a *Diatraea* host in Cuba (Plank, 1929*a*), but was not seen infested in Antigua. No other grass-hosts of the borer were observed, either in cane-fields or elsewhere. Much maize is grown, but the species of borer attacking it, if any, is not known.

Small birds are more plentiful than in St. Kitts, but in spite of the excellent and abundant cover afforded by the "cossie" (*Acacia Farnesiana* and *A. arabica*) of the scrubby pastures and low hills, they are much less abundant than they might be. From the numbers which occur in the vicinity of concrete lily-ponds, etc., I am inclined to attribute this shortage to the very great scarcity of standing water—either streams or ponds. The Botanic Garden, otherwise an excellent oasis, is not the sanctuary it might be had it even a small water-trough in the open.

In spite of this difficulty, Antigua has two ornithological features of great agricultural importance. The first is the unusual abundance of the grey kingbird (*Tyrannus dominicensis*), a very useful insect-eater. I have seen a dozen at one time in a small pasture, some keeping a look-out from the ground itself, as the kiskadee (*Pitangus sulphuratus*) often does on savannahs in Trinidad.

The second peculiarity is the widespread occurrence, seen nowhere else, of the small heron or blue gaulding (*Florida caerulea*) as a cane-field bird. Sometimes as many as ten were seen stalking about close behind two or three cutters, and snapping up the insects disturbed. At other seasons, I am informed, they follow the plough. In the neighbouring island of St. Kitts, where I saw no herons in the cane-fields, both young cane and cotton are periodically so severely attacked by a large local grasshopper (*Schistocerca pallens*) and even at times by cockroaches (*Periplaneta australasiae*), as to need

replanting (Ballou, 1917, and my own observations). These outbreaks usually occur in a very dry part of the island, where conditions are very similar to those of Antigua. The fact that these insects, though present, are never agricultural pests in the latter island, can I believe be attributed largely, if not wholly, to the activities of the herons.

Leaf-lizards (*Anolis antiquae*) simply swarm in Antigua, but the ground-lizard (*Ameiva griswoldi*), much reduced by the mongoose, is now practically confined to the town.

St. Kitts.

The standard of cane cultivation, facilitated by light and easily-worked soil, is uniformly high. Cotton is grown as a catch-crop.

Usually not more than one ratoon crop is taken, though one estate grows fourth ratoons, and a few estates, second ratoons. There is no burning of fields as a regular practice before cutting, and I am informed by Mr. R. E. Kelsick, Agricultural Superintendent, that accidental fires are extremely rare. I saw two trucks of burnt cane in April.

The standard cane varieties are B.H. 10 (12) and S.C. 12·4, the former being much more abundant.

If the weed-flora and general conditions of Antiguan cane-fields reminded one of Haiti, those of St. Kitts, being less xerophytic, are reminiscent of Cuba. *Valota insularis* is the only common field weed-grass which can be a host for the borer (*Diatraea*) and this was not found infested in St. Kitts. Another grass, *Rhynchelytrum roseum*, which is not uncommon in St. Kitts, has also been recorded (in Cuba) as a borer food-plant. I believe, however, that it is only exceptionally attacked. The plants of the higher mountain slopes were not examined.

Birds are scarcer in and about St. Kitts cane-fields than in any others I have seen. Whether they are rare also in the abundant forest, which clothes the higher mountain slopes, I unfortunately had no opportunity of judging. The sugar estates are, however, remarkably bare of bird-cover, and there are no adjacent pastures as in Antigua, the stock being hand-fed or pastured on Nevis. The grey kingbird (*Tyrannus dominicensis*), locally called "loggerhead," is fairly frequent along the roads, where telegraph wires afford it a perch; but it is not seen in the fields. Over thirty years ago (Anon., 1901) a plague of grasshoppers stimulated inquiry into this deficiency,

which it was hoped to meet by importing foreign insectivorous birds. The Indian myna (*Acridotheres tristis*) was first suggested, but wisely advised against by the Imperial Department of Agriculture for the West Indies. Finally, Barbados blackbirds (*Holoquiscalus fortirostris*) were imported, but they seem hardly to have increased and are still confined to one very limited locality. Decidedly the better way to tackle the problem would be to supply cover for birds about the cane-fields.

Leaf-lizards (*Anolis bimaculata*) are very plentiful, though rather more on trees and walls than in the cane-fields. The ground-lizard (*Ameiva erythrocephala*), more than decimated by the mongoose, was seen only in and about the chief town, where it is still plentiful (Barbour, 1920 ; the writer).

Nevis.

Sugar-cane is now of very little importance in Nevis. Cane-field weeds are much the same as in St. Kitts, but other biological factors are altered by the circumstance that there is much abandoned land and rough pasturage interspersed with the cultivations. The mongoose is, however, plentiful, and the ground-lizard (*Ameiva griswoldi*), according to Barbour, is extinct.

Porto Rico.

Wolcott (1915, 1929) describes cane-field conditions in Porto Rico as differing very widely from place to place. On some estates it is the custom to burn the trash and on others scrupulously to refrain from doing so. There has not yet been an opportunity to visit Porto Rican fields personally.

Santo Domingo.

Since only the south-eastern cane area in this Republic has been visited, and that hurriedly, very few general observations can yet be offered. Cristalina is the chief variety grown, as in Cuba ; but Santa Cruz (S.C. 12.4) and P.O.J. 2725 are being extended. Both these two varieties, growing in adjacent patches with Cristalina in the same field, were very much more heavily attacked by borer (*Diatraea saccharalis*) than the latter variety.

With regard to alternate host-plants for the borer (*Diatraea*), it may be mentioned that maize is grown extensively.

Although, according to Barbour, the mongoose is present, a ground-lizard (*Leiocephalus* sp.) was plentiful in the cane-fields visited.

Haiti.

There is only one large estate (about 25,000 acres), and this grows cane under the rather specialised, very dry conditions of the Cul-de-Sac and Leogane Plains. Cable ploughs and other implements of mechanical tillage are widely used. Certain " black alkali " (sodium carbonate) lands have received special treatment, including subsoil cutting by curved knives to a depth of 23 inches. Practically the whole area is irrigated, largely from wells, the river supply being intermittent.

There is no burning of fields at all, save for very occasional accidental fires. Even Uba cane is regularly cut without firing.

Planting was first begun about 1917, when the nondescript and degenerate " native " cane—a medley of older varieties—was used. This failed badly on account of mosaic disease and was rapidly replaced by Uba, which in 1928 formed 98 per cent. of the acreage under cane.* In 1929 this was reduced to 55 or 60 per cent., and it is hoped soon to have no more than 10 per cent. Meanwhile, Javan canes, Santa Cruz (S.C. 12.4) and B.H. 10 (12) have been very extensively planted. Of these the greatest area is in P.O.J. 2725.

The cane-field weeds are of a xerophytic type, like *Tribulus cistoides*, but occasional clumps of the stouter *Paspalum* grasses occur in moister spots. No borer was found in these, but the cane itself is so almost entirely free from attack that this is not surprising. At Leogane, Guatemala grass (*Tripsacum laxum*) and elephant grass (*Pennisetum purpureum*) was extensively planted between and on the edges of cane blocks, and Johnson grass [*Sorghum* (*Holcus*) *halepense*] was abundant. The latter has been recorded as a borer host in Louisiana and Cuba.

Under varying climatic conditions elsewhere in Haiti, cane is grown chiefly as a peasant crop, the " Creole " variety being used. It is still less infested with borer (*Diatraea*) than the introduced varieties of Cul-de-Sac and Leogane.

The most widespread gramineous crop in Haiti is undoubtedly " petit-mil," a tall non-saccharine *Sorghum* grown only for local consumption—but grown everywhere. I was never able to find it infested with borer. Maize is likewise very extensively cultivated,

* For much information and kind assistance of every kind, I am deeply indebted to Messrs. C. Elliott and V. Odoni, of the Haytian American Sugar Co.

but was not found bored, even after repeated examination. Rice-culture is necessarily more limited. A field near the sea in the vicinity of Port-au-Prince was moderately infested by sugar-cane-borer (*Diatraea saccharalis*), from which an adjacent field of cane was apparently entirely free.

In and about the cultivations, birds are moderately plentiful. In spite of the close settlement there is abundance of cover. Both the ani (*Crotophaga ani*), here called "Bourse tabac," and the grey kingbird* (*Tyrannus dominicensis*) are less common than in Cuba. Todies (*Todus subulatus*), on the other hand, are more plentiful than in Cuba; but the physiognomic bird of the cultivated areas is undoubtedly the crow (*Corvus palmarum*), in striking contrast to the very rare Cuban and Jamaican species.

Leaf-lizards (*Anolis*), of which specimens were kindly determined for me by Dr. Barbour as *A. semilineatus*, are more plentiful in Haitian cane-fields than in any others I have seen. They are equally abundant among young canes and tall mature ones, and seem very much at home on the swaying leaves themselves. Nevertheless, although lizards of this genus are well-known (Wolcott, 1924*a*) to eat caterpillars as well as other insects, the larva of a skipper butterfly (*Hesperiidae*) was not uncommon feeding on the cane leaves. According to Barbour, the related lizard, *Anolis cybotes*, is also very abundant.†

Ground-lizards are rare, and I have no record of any in cane-fields.

Cuba.

One of the most striking features of Cuban cane-fields is the very general long ratooning. It is often impossible to ascertain when a given field was planted; though sometimes it may be remembered by association with an important historical event. Eight and ten to twenty ratoons are common, thirty not infrequent, while some fields have not been replanted for a century. The fact that this is economically possible indicates that Cuba is eminently adapted for the growing of sugar-cane. And we should draw the same conclusion from the dominance of this crop in Cuba. As Allison and Bennet remark, there is probably no other country of similar area which specialises so completely in one crop.

* The common Cuban species is the closely-related *T. curvirostris*.

† It may be noted here that the lizard cuckoo (*Saurothera longirostris*), which, as its name indicates, feeds very largely on lizards, is very plentiful both in the cultivations and in the scrubby hills.

Sugar-cane was first brought to Cuba probably about the beginning of the sixteenth century. It has, therefore, been grown under these favourable conditions in at least some parts of Cuba for well over 400 years. In these circumstances, and in view of the wide-spread naturalisation of eastern tropical weeds and useful plants (e.g. mango, orange),* and, further, from the occurrence of several species of *Saccharum* as weeds in India, it might be expected that in Cuba, if nowhere else in the New World, cane would have " run wild." But as Grey (1927, p. 7) has remarked, " the cultivated varieties have never become naturalised from asexual plantings and do not grow spontaneously from self-sown seed in the fields; . . . . in fact, the agronomic conditions are not strictly congruous to normal growth development. The commercial varieties, when planted and left to their natural resources, deteriorate in physical energy and eventually die. . . . . And even under the best cultivation occasional re-plantings become necessary." Spontaneous cane would be an object of the greatest interest in the present investigation, but in its total absence from the New World, the long ratooned cane of Cuba offers the nearest approach to it.

There seems to be considerable difference in the pest situation between the old-established cane-lands of Cuba (e.g. in southern Santa Clara), and the areas which were rapidly cleared of forest and put into cane during the boom—" the dance of the millions " somewhat over a decade ago. So far as my observations go, borer (*Diatraea*), although everywhere in Cuba much less numerous than in Guiana and the Lesser Antilles, is much more plentiful in the latter (e.g. Northern Camaguëy) than in the former.†

The dominant cane variety throughout Cuba is Cristalina. In fact, the two terms are practically synonymous. Some Uba is grown, while Santa Cruz (S.C. 12.4) and some of the later Javan canes are being tried fairly extensively; but the area is so far negligible.

* The orange is so well naturalised in Cuba and occurs as a wild tree so far from settlement that even the great Humboldt was deceived, and wrote (*Personal Narr.*, Vol. III, p. 170). " It would seem as if the whole island had been originally a forest of palm, lemon and wild orange trees. The latter, which bear a small fruit, are probably anterior to the arrival of Europeans, who transported hither the *agrumi* of the gardens; . . . ."

† I take this opportunity of acknowledging the great courtesy and assistance rendered us by the administrators and their staffs at Centrals Soledad and Jaronū, the estates where most of my Cuban cane studies were carried out. On the former we enjoyed also the facilities of the Harvard Atkins Biological Laboratory.

It is not customary to burn the fields (except Uba) before cutting in Cuba. It is surprising, however, what a considerable number of fields are burned, maliciously or accidentally, during every cutting season. Uba cane is regularly fired before cutting.

The intervals between cane-fields, known as " traces " in Trinidad, are called " guarda rayas " in Cuba. In the damper places these may be covered with a pure stand of Pará grass (*Panicum barbinode*), here called Paraná. Drier guarda rayas support a growth of the following grasses :—*Cenchrus echinatus, C. viridis, Chaetochloa geniculata, Echinochloa colona, Valota insularis, Cynodon dactylon, Manisuris exaltata,* and some *Paspalum distichum.** *Manisuris* and *Panicum fasciculatum* are often weeds in the fields themselves. *Paspalum virgatum* I have never seen in guarda rayas, but it occurs occasionally as roadside clumps and covers considerable areas in the wetter pastures, in and along the beds of streams. *Hymenachne amplexicaulis,* a very thick-stemmed grass which has been recorded as a *Diatraea* host in Porto Rico, but not in Cuba in spite of thorough searching, occurs commonly in ponds on some estates. A large undetermined *Paspalum* (near *millegrana*) and an *Andropogon* growing practically in water, were examined on the border between cane-field and *Conocarpus* marsh in Northern Camaguëy. Both were slightly infested by *Diatraea saccharalis. Paspalum millegrana*—a few isolated clumps only—was searched with negative results at the Ensenada de Cochinos and in Southern Camaguëy—very far from any cane. Finally, Plank has found the introduced *Eleusine indica* fairly heavily infested with borer about yards and railway sidings.

One may pass by train in Cuba mile after mile of cane-fields with scarcely a tree to break the monotony. Bird-cover in such areas is practically absent and birds rare. The bulk of the numerous draught-oxen employed is usually pastured at a distance from the main cane estate, and fed on cane-tops when working in the cane-lands during " crop." In the less level country of Southern Santa Clara, however, and probably elsewhere, pastures of Guinea grass and *Paspalum distichum* are interspersed among the cane-fields and are usually dotted with trees (especially guásima, *Guazuma tomentosa*) or even invaded by scrub—*Acacia Farnesiana* and *Dichrostachys nutans*—all affording considerable bird-cover. Live hedges of almácigo (*Bursera*

* This applies largely to Southern Santa Clara. In other districts, Johnson grass, *Sorghum (Holcus) halepense,* is a common cane-field species, and is an occasional host of the borer (Plank).

gummifera) and bien vestida (*Gliricidia maculata*) are also frequent. The cane-fields themselves are often very thickly dotted with royal palms (*Oreodoxa regia*), which at least afford perches for the kingbird (*Tyrannus curvirostris*). On the whole, however, birds are scarce in the actual fields.

With lizards and toads it is far otherwise. One leaf-lizard (*Anolis sagrei*) is exceedingly abundant in cane-fields, and is apparently thoroughly adapted to conditions of settlement. Barbour and Ramsden (1919, p. 143) state that it is " one of the commonest lizards in the world where it occurs." Plentiful also is the ground-lizard (*Leiocephalus cubensis*), and the toad (*Bufo peltacephalus*). Cuban cane-fields are thus probably better policed by these three types of efficient insect-eaters than any others visited. The Haitian *Anolis* (*A. semilineatus*) is, I think, even more plentiful on cane-plants than its Cuban relative, but Cuba has the advantage in ground-lizards and toads.

Jamaica.

In keeping with the varied topography, cane-fields in Jamaica show striking local differences. They all agree, however, with Cuba and Hispaniola in their relative freedom from serious insect pests, and with Cuba in the frequent practice of long ratooning. Mr. Cousins, Director of Agriculture, informed me of at least one field which had not been replanted for 100 years.

Cultivation varies exceedingly in the different districts. Thus in St. Thomas, on rich alluvial soils, there is little cultivation and no manuring. In Trelawney, on a thin dry soil, indefinite ratooning is secured by alternately pen-manuring and applying fertilisers. In Vere, on heavy soil estates unsuited to bananas, the fields are irrigated and thorough mechanical tillage is the rule (Jones, 1930, pp. 70–71). It is significant that almost the only considerable infestation of borer (*Diatraea*) was seen in these Vere fields.

Up to ten years ago (Jones) the cane practically exclusively grown was White Transparent, which is the same as Cristalina. About one-sixth of the cane-lands are still under this variety, and a similar area in B.H. 10 (12), which is the most popular of its supplanters. Uba was extensively planted in the fight against mosaic disease. Cane-field grasses are in general similar to those of Cuba. On one estate I saw some razor-grass (*Paspalum virgatum*) in a cane-field

interval, but this is much rarer than in Trinidad, and infinitely less than in Guiana. *Paspalum millegrana* was found once in a similar situation, but the same remarks apply to it.

Burning of cane-fields before cutting is unheard of in Jamaica. Even Uba is regularly cut without firing. Accidentally burned cane is much less frequent than in Cuba.

Maize is fairly extensively grown in small patches, but I found no borer (*Diatraea*) in it.

Considering the broken nature of the country and the abundance of cover, not only on the estates which enjoy a heavy rainfall, but also throughout the drier areas, insectivorous birds are by no means plentiful. One sees an occasional petchary (*Tolmarchus jamaicensis*) on the telegraph wires, and now and then a few anis (*Crotophaga ani*) in the fields themselves, but the useful tinkling grackle or blackbird (*Holoquiscalus jamaicensis*) has decreased very greatly in numbers. We were in Jamaica for twenty days, in nearly all parts of the country, before I saw my first flock of the latter. Previously only one or two isolated examples had been observed. It has been suggested that this decrease is due (*a*) to eating poisoned cattle-ticks from sprayed stock and (or) (*b*) to that arch-villain in the West Indian biological drama—the mongoose. Neither theory seems adequate.

Gosse early observed (1851) that " one feature with which a stranger cannot fail to be struck on his arrival in the island, ... is the abundance of the lizards that everywhere meet his eye." So far as the plant-haunting species are concerned, and more especially the leaf-lizards of the genus *Anolis*, this is still a true picture, even in the cane-fields. The ground-lizard (*Ameiva dorsalis*), however, has been more than decimated by the mongoose, and is, as Barbour (1922) has remarked, now found principally in towns and thickly settled districts where the mongoose is less abundant than in the wilder and more uncultivated areas. The giant toad (*Bufo marinus*) has been introduced and is common in cultivations.

1. *Sugar-cane Moth-borers* (*Diatraea* spp.).

In no other case was the lack of fundamental biological data marked as in that of the small moth-borers, unquestionably the most serious pests of sugar-cane throughout tropical America.

Various attempts have been made to evaluate the final losses due to the attacks of this rather insidious pest; but none has proved really satisfactory. The problem is an exceedingly complex one. There are losses due, firstly, to the actual killing of shoots, some of which, but not all, are later replaced; secondly, to the leaving in the field of the very badly bored stems, which have dried up and died; thirdly, to the actual loss in weight through boring; and, fourthly, to the decline in the quality and purity of the juice. A conservative estimate for the British colonies, excluding Jamaica and the northern part of Trinidad, where borer damage is almost negligible, would be a final loss in sugar production of from 15 to 20 per cent.

Species of Diatraea and their Hosts.

There are at least four economically important species of small moth-borers (*Diatraea*) in the West Indies and British Guiana. There are others in the non-British cane-growing countries, and an additional number at present confining their attacks to weeds or wild grasses, but all potential pests of sugar-cane and all playing their parts as hosts of parasites or predators which may or may not attack the pest species. Some occur in the interior of Brazil and all the species of the genus *Diatraea* in the strict sense are confined to the New World. There they are indigenous and there they became the first recorded pests of cane after its importation. In no single case has *Diatraea* been found in a virgin plant association. We are as yet largely uncertain as to its original grass-hosts. There is, however, definite evidence that *Diatraea saccharalis* and *D. canella*, the two chief species attacking cane, colonised the cane-fields from two entirely different plant associations, the former much wetter than the latter.*

* Correlated with this choice of habitat, there is a striking difference between *D. saccharalis* and *D. canella* in behaviour and resistance—a difference discovered by accident. When the borers are cut out of the dead hearts for dissection it is my practice to throw them into a tall vessel of water, where they will keep in good condition for at least a day. The *canella* larvae tend to sink almost immediately and to lie quietly on the bottom, where they soon drown. The *saccharalis* larvae, on the other hand, are thrust below the surface only with great difficulty; they rise again almost at once, either floating to the surface or crawling up the sides; and they swarm right out of the vessel time after time, so that it is always necessary to keep the *saccharalis* vessel covered. *Saccharalis* larvae are, in addition, much more active, and squirm much more violently after decapitation for dissection than *canella*. Moore (1919) records that flooding is much more effective against *canella* than against *saccharalis*.

D. canella has been found in razor-grasses (*Paspalum* spp.) in Trinidad as much as 24 miles as a crow flies from the nearest cane estate and in circumstances which make it highly improbable that the infestation was derived from cane. It is probable that some of the stout grasses of the *virgata* section in the genus *Paspalum*, were the original hosts of *Diatraea canella*. *Diatraea saccharalis* is a greater puzzle. In British Guiana it practically does not occur in the razor-grasses (*Paspalum virgatum et al.*) but is frequent in the water-grass (*P. repens*). In Cuba, however, it attacks *Paspalum* (*P. millegrana* and *Paspalum* sp.) of the razor-grass type, but only in close vicinity to cane, while in similar grasses distant from cane it was never found. There is thus a strong probability in British Guiana, amounting almost to certainty in the northern islands, that the grasses are infested from the sugar-cane and not *vice versa*. It is hoped to check this theory in Cuba. *Diatraea impersonatella* has probably its original host in *Paspalum fasciculatum*, which is quite heavily attacked in northern and central Trinidad, while the adjacent sugar-cane is free from this species.

As we have seen in the ecological introduction, the predominant forest covering of the West Indies was primitively interrupted by areas of savannah land, rich in grasses and sedges. To my great surprise I have not been able to find any species of *Diatraea* in savannah grasses, and it seems quite evident that the original home of these borers was not in this plant formation.

Of the economic species, *D. lineolata* is apparently confined to maize. *D. saccharalis* also attacks maize, but is too, save only in Trinidad, the most important cane species, from Louisiana to the Argentine. The second most important *Diatraea* infesting cane is *D. canella*, which, so far as the British colonies are concerned, apparently reaches its northern limit in Grenada. A hitherto almost unknown species, *D. impersonatella*, is by far the most injurious one in Trinidad, but practically never bores cane in British Guiana.

Direct Control Measures.—More has been done in direct control measures for *Diatraea* than for any other West Indian cane-pest. On some estates in Guiana and Trinidad gangs of fifty or more men, boys or girls, are employed permanently to cut out " dead hearts " (shoots killed by borers), from which the larvae are extracted for counting and payment at so much a hundred. The economic value

of this practice is extremely uncertain. Among the few exact experiments to determine its efficacy is that of Plank, in Cuba. This author found that two cuttings-out of dead hearts reduced the infestation by 49·3 per cent. of that in the control fields and at the same time decreased the percentage of parasitism by 20. It is doubtful, however, whether this experiment was carried out on a large enough scale or over a sufficiently long period to give really final results. It is surely significant that (*a*) there is no practical difference in infestation in British Guiana between estates where assiduous cutting-out is practised and on those where it is neglected ; and (*b*) both British Guiana and Barbados are extremely heavily infested—yet the former country has cut out dead hearts to the extent of many millions per year (Moore) for nearly 20 years, while the latter has done practically nothing in the matter of direct control.

Egg-clusters may also be collected. In British Guiana, under the supervision of either a consulting or a resident local entomologist, it is a common practice to breed out either the egg-parasites (*Trichogramma minutum* and *Prophanurus alecto*) or the larval parasites (*Stomatodexia, Microdus* and *Ipobracon*) or both, and liberate them in the fields. On at least three large estates in British Guiana, mass-production of the two species of egg-parasites is carried out, but it would seem that the resulting parasites have been liberated over too large an area to achieve any critical economic result. In the case of Plantation Blairmont, it was suggested that the entire liberations be concentrated on one field of a pair, the other to be kept as a control. The result of this experiment will be watched with interest. A very much larger one is now proceeding in Barbados, under exceptionally favourable conditions, under the direction of Mr. Tucker, Government Entomologist. He has erected a very large and extremely effective plant for rearing many millions of the egg-parasite, *Trichogramma*, using as host-eggs those of the corn moth, *Sitotroga cerealella*. For plantation practice and on estates where a borer gang is permanently employed in any case, it would seem more economical, efficient and convenient to rear *Trichogramma* on actual *Diatraea* material. A comparison of Mr. Tucker's and Mr. Cleare's cost figures shows that a greater liberation per acre has been achieved already using *Diatraea* in British Guiana, at a smaller cost per acre. Whether this difference would continue to hold at the much greater production almost certainly necessary for control, is not known. It must be emphasised that the economic value either of hand-collecting borers or of rearing

local parasites, is still uncertain. To decide this, exact and large scale experiments are urgently necessary. They have been planned under the local research schemes outlined above.*

One point should be stressed before the question of egg-parasites is dismissed. Over 90 per cent. of the young larvae of *Diatraea* perish before they enter the stalk, and thus before they have committed any damage. Similar figures have been published for the European Corn Borer (*Pyrausta nubilalis*). Thus over 90 per cent. of the young larvae which are killed in the egg by the egg-parasites would have died in any case. This very considerably reduces their rate of effective parasitism, and, coupled with the fact that the two egg-parasites, *Trichogramma minutum* and *Prophanurus alecto* are very generally distributed throughout the area visited, has led the writer to concentrate more especially on the larval and pupal parasites, as more promising agents of biological control. Egg-parasites tend also to be very general in their host relationships, and it is specific parasites and specific predators which have won all the greatest successes of biological control.

The Question of Burning Trash.—Before discussing the status and parasitism of *Diatraea* in the various countries visited, it will be necessary to mention the question of burning cane-fields before cutting. This practice is regular in British Guiana, frequent in Trinidad (or else the trash is often burned before ploughing in), unknown in Barbados and Jamaica, rare and accidental in St. Kitts, Antigua, Cuba and Haiti. It has been claimed by almost all agricultural and entomological authorities that such burning kills many more parasites than hosts and thus adversely affects the balance. It is alleged that it is especially the egg-parasites that are destroyed, since they are all on the leaves, whether as adults or within host eggs, while the host larvae are safe within the cane-stalk. But it is forgotten that a far more wholesale discriminate destruction awaits the host larvae when the canes are crushed at the mill, and for the

* More recently, Tucker (1930) has published a paper on the results of the first season's work with *Trichogramma*, in which he claims to have raised the average rate of egg-parasitism during September, October and November, by 11·1 per cent. above the rate for the corresponding months in 1928. Taking the young larval mortality as 90 per cent., which is an under-estimate, this means that, owing to the liberations of laboratory-bred parasites, 1·1 per cent. more of the borer population was killed. It is claimed that economic results have already been obtained.

rest, the importance of the egg-parasites has, as we have seen above, been greatly over-rated. No critical evidence is forthcoming that the burning of fields adversely affects the parasites, and it is significant that although British Guiana, which burns regularly, has a very high borer infestation, Barbados, where it is unknown has, according to Mr. Tucker's latest figures, a still higher one—the highest, in fact, recorded in British cane-growing countries. In the light of this, Wolcott's dictum (1929, p. 63) that " the non-burning of trash seems to offer the most hopeful, albeit partial, solution of the borer problem," does not seem very convincing.

In connection with the question of burning, chance has arranged a very beautiful experiment at Central Soledad, in Cuba. Salt, in May, 1925 (1926, p. 36), observed a field of Uba, about a year old, " so seriously attacked by *Diatraea* that it had a brown appearance due to the dead tops of the majority of the canes." In two patches of considerable extent the stalk infestation was nearly 100 per cent. For the rest of the field it was on an average 61·79 per cent. This field was allowed to stand over, and was not cut until 1926. There was thus a heavy accumulation of trash, which, on the usual burning of Uba, entailed a very severe fire. It was again cut in April, 1929, and again, owing to the dense mass of trash, the fire was unduly fierce. I examined this field, then well-grown, on two occasions in September, 1929. Here was a field, if any, which should show the deleterious effects of burning. But no, on the first visit I was unable to find a borer; on the second, in company with Mr. Plank, we managed with great difficulty, to find five borers and one fly-parasite puparium (*Lixophaga*). The earlier workers recommended burning as a means of borer control. It would appear at present that they were quite as right as their successors who take the opposite view.

Infestation.—Exact figures of infestation by *Diatraea* are usually available as the result of local work—either Government or plantation. Several estates in British Guiana have most admirably for a number of years recorded the average infestation, at time of cutting, in every field. Where such records were not available, as in Jamaica and Haiti, it was necessary to make counts personally. There are two regular methods of recording the infestation—one by the percentage of stalks attacked and the other by the percentage of joints. The latter is obviously the more reliable as an index of economic damage, provided—and this is important—every infested joint is split up and

the burrows followed into the adjacent joints. This detailed examination is the rule in the Cuban surveys, but not in Barbados or British Guiana, and the figures obtained thus are so far not comparable. A uniform method is greatly to be desired. The stalk infestation, especially when coupled with an estimate of joint infestation, affords a convenient standard for comparison when time is not available for the exact determination of joint infestation. In dealing with peasant cultivations, too, in Jamaica and Haiti, a stalk infestation count could be completed while the explanation of our activities was still under way; whereas a joint investigation, involving partial destruction of the canes, would raise other issues, probably monetary.

In the countries visited, the highest average infestation by *Diatraea* in sugar-cane occurred in Barbados (Mr. Tucker's survey, with a joint infestation of 38·5 per cent.). The other important cane areas may be arranged in descending order as follows, the figures given being based on actual counts (of estate, not peasant canes), but necessarily only approximate when applied to the whole country: British Guiana (90 per cent. stalks, 20 per cent. joints), Antigua, (80 per cent. stalks), St. Kitts (60 per cent. stalks), St. Lucia (60 per cent.), Santo Domingo, Cuba (20 per cent.), Jamaica, Haiti (very rare). On many large estates in Cuba, and on all the country estates and patches examined in Haiti it is almost or quite impossible to find any borer at all. Porto Rico has not been studied personally, but from the published records it would appear to vary greatly in infestation in different areas, as also does Trinidad, which is thus hard to place. In Cuba and Jamaica the cane-lands are so widespread and the climatic conditions so variable, that it would be misleading to treat these two large islands as single areas.

A striking character of *Diatraea* infestation is its very much greater severity on estates as compared with peasants' plots. Counts of stalk infestation made in Jamaica, Haiti, St. Lucia and Antigua, have shown estate cane infested from twice to four times as much as peasant cane from the same district and often ground at the same mill. The chief cause probably lies in the greater diversification of peasant agriculture, but critical experiments are necessary to explore the possibility of limiting factors which may be brought into estate practice.

Figures have been accumulated on cane varietal differences in infestation and on individual estate differences (which are often

surprisingly great). It is proposed to omit these from the present preliminary report. The data on the percentage of parasitism by various natural enemies are based on the examination of 15,739 specimens of borers.

We may now consider the chief cane areas separately.

British Guiana.

Diatraea saccharalis is the most important moth-borer, with *Diatraea canella* a close second, and doing more damage in young canes than the former. Since the borer-gang collects material only from young shoots (dead hearts), the only extensive figures of comparative abundance of the two species are drawn from these. Thus, of 5,485 *Diatraea* larvae examined by me from cane in British Guiana, 3,563, or nearly 65 per cent., were " yellow heads " (*Diatraea canella*). In mature cane—where, of course, the attack lasts longer—the greater proportion of abandoned burrows makes specific assignment difficult, but there is good evidence that *D. saccharalis* is the more important. Of 95 larvae collected from mature cane, in one instance, 69, or nearly 73 per cent. were " black heads " (*D. saccharalis*). A third species, *Diatraea impersonatella* (*moorella*),* known locally but incorrectly as *D. lineolata*, occurs in razor-grass (*Paspalum virgatum* and *P. millegrana*), but only very rarely in cane. The second most important crop in British Guiana, and one of ever-increasing value, is rice. This is also attacked by *Diatraea* ; almost solely *D. saccharalis*, which is, in fact, by far its most important pest.

In spite of the fact that the cane-lands of British Guiana are more uniform ecologically than those of any other cane-growing country visited, the *Diatraea*-parasite situation differs so fundamentally in Demerara and in Berbice that it seems advisable to consider these provinces separately. The *Diatraea* population is, however, essentially the same, and so also is the prevalence of weed-grasses. These, which are of two main types, are of first-rate importance in the *Diatraea* complex. We have already described them and their distribution in the ecological introduction. They are, firstly, the " razor-grasses " (*Paspalum virgatum* and *P. millegrana*), and, secondly, the

* Mr. H. E. Box has recently undertaken at Farnham Royal, and with the help of the British Museum, a systematic revision of the various species of *Diatraea*. I am indebted to him for the latest determinations.

water-grasses, of which *Paspalum repens* is by far the most important. The former grow in dense clumps along roadsides and on dams. The latter sometimes form continuous floating carpets on the surface of the navigation canals and drainage trenches. Both together occupy a very considerable area and maintain a tremendous population of *Diatraea*. But the differences in the specific composition of this population go further to show what an ideal all-round host sugar-cane is for the various *Diatraea* species. The razor-grasses are infested chiefly by " yellow heads " (*Diatraea canella*). Of 580 borer larvae (I cannot yet distinguish the pupae) from these grasses in Berbice, I found 401, or 69 per cent., were *D. canella*, 176 D. *impersonatella* and only 3 *D. saccharalis*. The water-grasses, up to the present, have yielded, on the other hand, solely *D. saccharalis*.* Estate managers have been so impressed by the borer population harboured by razor-grass that in many cases energetic and expensive steps have been taken to eradicate it. The water-grasses are, of course, a hindrance to navigation and to drainage, and are, therefore, periodically cleared for this reason. The following figures will, however, show that there is another side to the question.

There are in Demerara ten different parasites of *Diatraea* larvae :—

Diptera.—Paratheresia claripalpis ; Stomatodexia diadema.
Hymenoptera.—Ipobracon grenadensis ; Ipobracon puberuloides ; Ipobracon dolens ; Ipobracon saccharalis ; Microdus stigmaterus ; Microdus parvifasciatus.
Nematoda.—Mermis sp.
Fungi.—Cordyceps sp.

Of these, all save *Ipobracon saccharalis*, which is known only from the unique type-specimen in the British Museum, were studied in the present investigation. *Microdus parvifasciatus* was not, however, met with in Demerara.

The combined parasitism of the eight remaining parasites is 6·9 per cent. of the borers in cane. The borers in rice, razor-grass and water-grass show a consistently higher mortality from the attacks of the same parasites, namely 8·6 per cent. The discrepancy is even more marked in the case of the pupal parasite, *Spilochalcis* (*Heptasmicra*) *dux*, which kills 1·1 per cent. of the borers when they are in cane,

* This lends support to the statements of Salt and of Wolcott that *D. saccharalis* infestation is worst in low-lying, wet lands. Yet it is exceedingly abundant under very dry conditions in Barbados and Antigua.

but 16·7 per cent. in rice. It should be noticed that Cleare, and more recently myself, have reared a second unnamed species of *Spilochalcis* from *Diatraea saccharalis* in rice, so that the higher rate of parasitism in rice may be due to greater efficiency in the second species.

Of the larval parasites, when cane is the host, the *Microdus* is the most important, with a toll of 3·2 per cent., while it is the only one found in the rice and wild grasses. The *Paratheresia* and *Stomatodexia* are together responsible for a mortality of 3·2 per cent. of borers in cane, but they apparently do not extend activities to the small grasses. *Paratheresia* is the rarer of the two, in the proportion of about 6 to 7. *Ipobracon grenadensis* in cane kills ·2 per cent. of the larvae, *Ipobracon* sp. ·06 per cent., *Mermis* ·07 per cent., and *Cordyceps* ·2 per cent.

The *Stomatodexia* is said by Cleare (1925) to be very rarely attacked by a hyperparasite. This has not been found in the present investigation.

The *Paratheresia* is not only rare, but is restricted to a limited area near Georgetown. In Berbice it apparently does not occur at all. I strongly suspected that it has only recently reached the British Guiana cane-lands, but whether overland from Venezuela, or oversea from the adjacent island of Trinidad, where it is very common, I do not know.

In Berbice the following parasites of the larvae occur :—

*Diptera.—Stomatodexia diadema ; *Tachinid* (not reared) ; *Sarcophaga* sp.

*Hymenoptera.—Ipobracon grenadensis ; Ipobracon dolens ; I. puberuloides ; *I. pennipes ; *I. aquaticus ; Microdus stigmaterus ; *M. sacchari ; *Spilocryptus diatraeae ; *Perisierola bogotensis.*

Fungi.—Cordyceps sp.

The six species starred represent new records, and the first five of these and *I. puberuloides* are new species, the description of which is in the press.

In addition, earwigs (*Euborellia* sp.) are credited with killing ·3 per cent., which is almost certainly an underestimate based on the finding of earwigs in recent burrows with definite remains. *Perisierola* and *Ipobracon aquaticus* attack *Diatraea* only when in water-grasses. The

others are responsible for a mortality of 4·1 per cent. of borers in cane. The most important are the *Microdus* species (2·5 per cent.), the larvae of which have not yet been distinguished from each other. *Ipobracon* kills 1·1 per cent. in cane; while the other parasites are insignificant (fungi ·2 per cent., *Sarcophaga* sp. ·02 per cent.). *Stomatodexia* was not found during the present investigation, but has been recorded by Box and Cleare as occurring in Berbice very rarely.

In the broad-leaved razor-grass (*Paspalum virgatum*) the average parasitism is 9·5 per cent. (*Microdus* 7·2 per cent. *Ipobracon*, chiefly *grenadensis*, 2·0 per cent.; fungi, ·25 per cent.); in narrow-leaved razor-grass (*P. millegrana*), the parasitism seems to be lower (7·5 per cent.) on account of the defection of the *Ipobracon* spp., which were not found. Three hundred and sixty-two larvae of the allied moth, *Chilo calamistis*, from the same lots of the same two grasses, were parasitised only ·6 per cent. in equal proportions by *Microdus* and *Ipobracon*, thus showing how closely these parasites are attached to *Diatraea*. They do not, however, display any very great preference for one species of *Diatraea* over another, save *Microdus*, which parasitised 2·1 per cent. of the yellow-headed borers (*D. canella*) and 4·5 per cent. of the black-headed (*D. saccharalis*) out of a total of 5,485 borers examined from cane. In grasses the same parasite showed a slight preference for *canella* over *impersonatella*. Water grass (*P. repens*) in Berbice seemed more heavily infested with borer (*D. saccharalis*) than in Demerara, but this population was parasitised at the rate of 43·9 per cent., chiefly by *Microdus* (24·4 per cent.) and *Ipobracon* spp. (18·6 per cent.). *Perisierola* and *I. aquaticus* occurred nowhere else. In one lot the parasitism rose as high as 68·4 per cent.

The case of *Paspalum repens* is a curious one, since this grass is quite slender and it is thus an unexpected host for cane borers. The *D. saccharalis* larvae which infest it are uniformly small, though otherwise indistinguishable from those in cane. But no pupae have been found. This raises the question whether water-grass is able to carry through *Diatraea* to maturity, for if the borers do not pupate in it, they can do so nowhere else without swimming. If this be the case, then from an economic point of view the water-grass is to be regarded not only as a harbour for *Diatraea* parasites to almost as great an extent as for their hosts, but also as a regular trap for *Diatraea*.

A very important point in connection with the weed-grass hosts of *Diatraea* is the intense attraction the flowers of the two razor-grasses exert on the adults of *Ipobracon*. Immense numbers may be collected from these grass heads. Hardly less attractive are the flowers and extra-floral nectaries of the shrubby waste-land weed, *Cordia interrupta*, which is indistinguishable from the "Black sage" (*Cordia cylindristachya*) of Trinidad and the northern islands. Great trouble has recently been taken to introduce *Ipobracon grenadensis* and *Microdus stigmaterus* into Barbados and Antigua and to plant extensive stretches of *Cordia interrupta* for their delectation. Both as regards the parasites and as regards the plant this seems to have been largely a work of supererogation. The more efficient of the two parasites, *Microdus stigmaterus*, occurs already as an indigenous insect in St. Kitts, Montserrat, and in all of the Northern islands which offer the necessary moist conditions up to and including Cuba. The plant we have the authority of Kew for considering as practically identical with the already ubiquitous "black sage." It was introduced into Mauritius, where it has later been widely planted for the food of the white-grub parasite, *Tiphia parallela*, and has become a serious weed. It should therefore not be encouraged further in the West Indies.

Turning now to the pupal parasites in Berbice we find that the Chalcid, *Spilochalcis dux*, accounts for only ·5 per cent. of those occurring in cane, while *Ipobracon grenadensis*, which normally attacks the larvae, kills about ·2 per cent., making a pupal mortality of only ·7 per cent. In razor-grasses conditions are vastly different, for in these *Spilochalcis* regularly destroys no fewer than 11 per cent. of the pupae.

Thus the total mortality of *Diatraea* larvae and pupae in British Guiana canes, through the agency of parasites, is considerably less than 7 per cent. In other words there is an almost clear field for the introduction of a really efficient parasite, capable of killing borers under cane-field conditions. At present, leaving out of account *Lixophaga diatraeae*, the famous Cuba fly, which is quite unsuitable for British Guiana conditions, and which has, moreover, already been introduced on a small scale, but apparently not established, the only such parasite we know is *Paratheresia claripalpis*. This is very rare in Demerara and does not occur in Berbice. I have suggested that it has only recently entered the country. If this be true it would be worth while to introduce it into Berbice and thus form a southern

focus. A plentiful supply could easily be obtained in Trinidad, where Mr. Cleare is at present studying its life-history.

Trinidad.

In Trinidad, although, as we have seen, the fauna and flora are closely allied to those of the mainland, the cane-field conditions are very strikingly different from those prevailing in the low-lying, moist coast-lands of British Guiana. These differences are reflected in the *Diatraea*-parasite situation. There are, however, features in the Trinidad position which are peculiar to the island, and it is quite apparent that insufficient intensive work has been done to evaluate all the operative factors. It is, for instance, a mystery why *Diatraea* is so rare in the northern cane-lands as to be economically negligible, and hardly less scarce in the central areas, while in the southern estates it is an exceedingly important pest. There is no significant difference in rainfall, but, as we have seen in the ecological introduction, soil and topography differ widely. More Uba is grown in the southern district, and as this is invariably burned, there is possibly more firing of cane-fields before cutting than in the north* ; but the difference in this respect cannot be great, as we have elsewhere given evidence to show that the influence of this practice has been much over-rated.

In young shoots, in the southern cane-lands, the most important borer is *Diatraea impersonatella.* Of a sample of 103 borers from dead hearts in April, 59 or about 57 per cent. were of this species, 42 *canella,* and 2 *saccharalis.* The latter species is, however, more important in the grown cane. A detailed quantitative survey of the species in tall cane has not yet been made. *Diatraea canella* appears to be the most widely-distributed species, and is probably indigenous to the island, in razor-grasses (*Paspalum virgatum* and *Paspalum* sp.) in which it has been found on the sea-shore and on the edge of virgin forest, in the south-east, north-west and north-east of Trinidad, up to 24 miles in a bee-line from the nearest large cane-fields.

In the new borer (*D. impersonatella*) which was not recognised as a cane-pest until the present investigation, lies the uniqueness of the Trinidad borer-situation and probably the key to the extremely uneven distribution of economic damage. The only borer so far seen

* At least one northern estate, however, grew 16 per cent. of Uba in 1929, and this is regularly burned, as are other fields which happen to be poor or weedy at crop time.

in the northern and central canes is the black-headed species (*D. saccharalis*), which is rare. As we have seen, however, the traces, especially in the north and central estates are frequently filled with a heavy growth of coarse grass (*Paspalum fasciculatum*). Now this is sometimes heavily infested with the new borer (*D. impersonatella*), while the adjacent or even contiguous canes are either free from attack or very lightly infested with the black-head (*D. saccharalis*). The new borer, then, for some unknown reason, attacks cane only in the south. A somewhat similar situation exists with the yellow-headed borer (*D. canella*), for this is sometimes quite frequent in the razor-grass (*Paspalum virgatum*) of the northern traces, while the cane is clean. Can it be that in Trinidad these two species are only just beginning to adapt themselves to cane, and have only done so to any extent in the south? The mystery is deepened by the common occurrence of *D. impersonatella* in razor-grasses but not in cane, in British Guiana. It is just possible that more intensive taxonomic work will show that three different species with similar larvae are involved.

In cane in Trinidad by far the most important borer parasite is the fly, *Paratheresia claripalpis*, which had been previously recorded as *Sarcophaga* sp. This is extraordinary in view of the fact that its activities are almost insignificant in Demerara, while in Berbice it does not occur. It is known as an efficient *Diatraea* parasite on the mainland from the Argentine to Central America, including Venezuela. In Trinidad, in company with *Stomatodexia diadema*, it kills about 17·8 per cent. of the borers in cane. The proportions of *Paratheresia* and *Stomatodexia* are about four to one. The total mortality in Trinidad due to parasites is 20·6 per cent., the remainder being attributed to the attacks of *Microdus stigmaterus*, *M. parvifasciatus*, and *M. sacchari* (·8 per cent.), *Ipobracon grenadensis* with *I. dolens* (·9 per cent.), fungi (1·1 per cent.), and *Apanteles diatraeae* (·1 per cent.).

In maize in Trinidad the borer *Diatraea lineolata* is plentiful. Its sole parasite, so far discovered, is *Apanteles diatraeae*, which kills 11·7 per cent., or over 100 times as many as it attacks in cane.

In razor-grass (*Paspalum virgatum*) the only important *Diatraea* parasite so far found is *Microdus stigmaterus*, causing a mortality of 20 per cent., but in this case the collections were insufficient to yield significant figures.

On one occasion a small *Ipobracon* was found in some numbers parasitising *Diatraea impersonatella* in *Paspalum fasciculatum*, while on another, two specimens of a *Paratheresia* apparently differing specifically from *P. claripalpis*, were reared from *D. canella* in razor-grass (*Paspalum virgatum*).

Grass hosts are less important in Trinidad than in British Guiana, the only significant ones being the razor-grass (*P. virgatum*) and the hairy grass (*P. fasciculatum*) of the traces, roadsides and coconut estates. As in Guiana, the flowers of the former are exceedingly attractive to the adult parasites of the genus *Ipobracon*, both those parasitising *Diatraea* and those of which the habits remain unknown.

The Lesser Antilles.

In studying the *Diatraea* problem in the smaller northern islands, the shortage of time made it necessary to concentrate on those colonies in which sugar-cane is the principal crop. Other islands were examined merely in passing and only inadequate collections could be made.

Ipobracon grenadensis and *Microdus stigmaterus* were introduced into Barbados and Antigua by Mr. Box, in collaboration in one case with the local Department of Agriculture and in the other with Professor Ballou (Box, 1928*a*). At the same time the weed-shrub, *Cordia interrupta*, was imported and fairly widely planted. There is no indication that these insects became established. The only indigenous larval insect parasite of *Diatraea* in the whole of the Lesser Antilles, apart from Grenada, is *Microdus stigmaterus*, which occurs in small numbers in the moister islands, or rather, probably in all but the very driest. It has been found to kill 3·3 per cent. of the borers in cane in St. Kitts, 4·7 per cent. in St. Lucia, and 1·5 per cent. in Montserrat. In addition, fungous parasites, chiefly of the genus *Cordyceps*, attack ·6 per cent. of the larvae in St. Kitts, and 1·3 per cent. in Antigua.

The egg-parasites, *Trichogramma minutum* and *Prophanurus alecto* are widespread, as in British Guiana and Trinidad. The former is recorded from Grenada, St. Vincent, Barbados, Antigua and St. Kitts, while the latter is known from St. Vincent, St. Lucia (new record) and Barbados (Box, 1928*b* ; Van Dine, 1929).

Grenada, which is the northerly limit of distribution of the yellow-head borer (*Diatraea canella*), is likewise the only one of the Lesser Antilles with an external parasite of the borer larvae, namely *Ipobracon grenadensis.*

Save in St. Lucia, which presents, on its western side, cane-field conditions as wet as those of British Guiana, and a luxuriant and extensive growth of razor-grass (chiefly *Paspalum virgatum*), the problem of weed-grasses is economically negligible in the Lesser Antilles. One of the most frequent cane-field grasses which serves as a host for *Diatraea,* is *Valota insularis,* which occurs also in the Greater Antilles. It is rarely attacked and has never yielded sufficient collections for adequate study. In short the *Diatraea* problem in the Lesser and Greater Antilles is to this extent simplified in that biologically it comprises, on the whole, only the interrelations of *Diatraea,* cane, and parasites.

The Greater Antilles.

We now come to the Greater Antilles, and it may be emphasized that the following remarks apply solely to Cuba, Haiti, Santo Domingo, and Jamaica. No personal observations have yet been made in Porto Rico. In these large islands, with a variety of ecological conditions, which may yet, save for elevations above 4,000 feet, be matched point for point in the Lesser Antilles, an entirely new factor enters the *Diatraea* situation. This is the fly, *Lixophaga diatraeae,* by far the most efficient of all known parasites of *Diatraea.* It has no other recorded hosts, and has not been known to attack *Diatraea* in any other plant than sugar-cane, save on one occasion in rice. To cane and to cane-field conditions it seems extraordinarily well adapted, and the threefold association between it and its host and the cane bears all the marks of antiquity. It is an association which was probably developed very soon after the introduction of sugar-cane into the New World, and it was probably helped in Cuba, in French colonial Haiti, and in Jamaica, by the long ratooning methods, though these no longer prevail on the larger Haitian and Santo Domingo estates. Extensive studies on *Diatraea* and its parasites have been made in Cuba by Mr. Van Dine and the entomologists under his direction at the Cuban Sugar Club Experiment Station at Baraguá. To Mr. Van Dine and through him to Mr. Loftin, Mr. Plank, and Mr. Scaramuzza, this investigation owes a very deep debt of gratitude for assistance of every kind. The

following figures of parasitism in Cuba and the other Greater Antilles have not, however, been taken from Mr. Plank's records, but from personal examination of some 5,000 borers, thus ensuring a just comparison with results from the smaller islands and Guiana. The average mortality due to parasites was found to be 38·4 per cent., of which *Lixophaga* is responsible for 34·5 per cent., *Cordyceps* and other fungi for 3·1 per cent., *Apanteles diatraeae* for ·7 per cent., *Microdus stigmaterus* for ·1 per cent., and *Sarcophaga* spp. for ·02 per cent. In the fields where some 800 *Lixophaga* were collected for introduction into Barbados and Antigua the average parasitism was 45 per cent., by this fly alone.

Two hyperparasites were reared from *Lixophaga* puparia in Cuba by Loftin, and were determined as *Aphaereta* sp. and *Trichopria* sp. Neither was found again during the five years' intensive work of the Cuba Sugar Club Experiment Station workers, but the latter occurred in small numbers during the present investigation, parasitising 1·1 per cent. of the puparia collected in Cuba in April, and 2·0 per cent. of those obtained during the previous September to November. It has been determined by Dr. Gahan as *Trichopria cubensis*. Neither is known from the other islands.

A small collection of *Diatraea* larvae from rice in Haiti showed a parasitism of 25 per cent., half due to *Lixophaga* and half to *Microdus*. The latter also parasitised borers in razor-grass (*Paspalum virgatum*) to a much greater extent (20 per cent.) than in cane, but the collections made were scarcely adequate for comparison.

These razor-grasses (*Paspalum virgatum, P. millegrana,* and a large undetermined sp.) are plentiful in Cuba, but in damp pastures or swamps. They do not flourish in or near cane-fields to anything like the extent they do in British Guiana, and a significant point is that these distant razor-grasses are practically uninfested by *Diatraea*. In other words, the cane is the chief host, and the razor-grass is infested from cane and not *vice versa*. In the same way may be explained a fairly heavy infestation found by Mr. Plank in the introduced grass *Eleusine indica,* in the factory yard where the trucks waited with their loads of cane. If the black-headed borer (*Diatraea saccharalis*) is indigenous to the Antilles, then we must look elsewhere than in the razor-grasses for its original host. *Paspalum repens,* its favourite grass host in Guiana, is recorded in the northern islands only from western Jamaica, where I did not, however, see it.

An actual Introduction.—A thorough investigation of *Lixophaga* under all kinds of biological and agricultural conditions, followed by a study of Lesser Antillean cane-fields and their fauna, left no doubt whatever that the suggestion, originally made by Box, that *Lixophaga* should be introduced into the Lesser Antilles, was an extremely sound one. The comparative low infestation by *Diatraea* in Cuba, Haiti, Santo Domingo, and Jamaica seems very clearly due to the wide prevalence and effective parasitism of *Lixophaga.* This project was accordingly carried out in the spring of 1929. The parasites were brought down by aeroplane from Cuba to Antigua, which is a regular airport, and a supply sent on in cold storage by steamer to Barbados, where they were reared and liberated with very great care by Mr. Tucker, Government Entomologist of that island. The Antigua share was handled personally, and it is hoped that both islands will have received sufficient for speedy establishment. If so, it will be a simple matter later to make further introductions from Antigua to St. Kitts and the south-eastern cane-lands of St. Lucia. These are the only other two British areas where conditions suitable for *Lixophaga* prevail. It must be remembered that this fly has already been introduced into Louisiana and Mexico on the one hand and into British Guiana on the other, without any marked success. All these areas present conditions to which it was hardly to be expected that *Lixophaga* would adapt itself.

To sum up the question of *Diatraea* parasites, it may be definitely stated that in the countries so far visited, there are only two effective parasites of any stage (egg, larvae, or pupa) of *Diatraea* in cane. These are the two flies, *Lixophaga diatraeae* and *Paratheresia claripalpis.* The latter is a widely-ranging but essentially tropical species, occurring in the islands only as far north as Trinidad, while the latter is confined to the rather specialised conditions of the Greater Antilles. *Lixophaga* is exceedingly promising for utilisation in certain of the Lesser Antilles, while *Paratheresia* already occurs in all the cane-lands where it is likely to thrive, save only Berbice, and the western side of St. Lucia. To these two districts it may be advisable to introduce it.

Further work will be concentrated on the search for entirely new parasites on the mainland—parasites which will be adaptable to cane-field conditions, and likely to thrive in Trinidad and British Guiana. In the latter colony, as we have seen, the rate of parasitism

is at present exceedingly low, and the crying need is for a new and more effective species. This the vast fauna of Tropical America will almost surely yield.

2. *Large moth-borer* (*Castnia licoides*). *History and Status.*—The first reference I have found to the occurrence of this gigantic borer as a pest is a note published in 1892 that Mr. T. I. Potter had exhibited to the Trinidad Field Naturalists' Club " a specimen of the *Castnia licus*—local name: Cane sucker—a moth, bred by him from the larva which he said lives in the trunk of the banana plant and completely destroys it." This was followed by a short article in the same journal early the next year (1893), with the additional information that, according to local belief, the banana suckers are attacked only when planted at a " bad moon."*

A curious feature of these early references is that, although the insect is reported only as a banana pest, the local name is given as " cane sucker," which would apparently argue a Creole experience of its boring in sugar-cane. Be this as it may, *Castnia* was not reported from cane in Trinidad until 1908 (Urich, 1909).

Before that, however, it had appeared as a very serious cane pest on Plantation Enmore in Demerara, British Guiana, in late 1904, where it had been noticed in small numbers in cane for the previous three years. (Ballou, 1906*a*; Quelch, 1910). Very many thousands were destroyed by hand-collecting. In Trinidad, from November, 1908 to February, 1909, in one district 25,000 moths were caught.

I have given this history in some detail since it forms one of the most remarkable records of an indigenous insect which did not learn to attack an economic plant until this had been grown in its vicinity for several centuries.

Castnia has now been almost entirely controlled in British Guiana by flooding for at least 72 hours. This process, which on some estates is carried out regularly every fourth year, is rendered easy by the superfluity of water and the ubiquity of canals, and it serves also as a very effective and valuable method of fallowing the fields.

* This is not the place to dilate on the importance attached to the moon in peasant agriculture—and not only in peasant practice. All crops must be planted, and timber, bamboos and palm-leaves for thatching must be cut only in certain phases of the moon or they will be devoured by pests. In poisoning termites with arsenic, the application must be made at a certain lunar period or it will be useless (Hesketh Bell).

The only other British colony in which *Castnia* occurs as a pest is Trinidad, where it is now widespread and increasing in destructive activity. It is possible to find carts of "farmers'" canes 90 per cent. of which have been bored by this insect. And one boring by such a large larva is more destructive than many by *Diatraea*. In Trinidad cane-fields, save an infinitesimal minority near the Caroni River, flooding is quite impracticable, and the only method of direct control is hand-collecting of the larvae from young canes and from cut stools, coupled with the capture of the adult moths.

In this way, on one estate (Skinner, 1929), 356,000 moths were destroyed between July, 1927 and January, 1928. This was followed by a campaign against the larvae, of which 1,667,357 were paid for between January and November, 1928. As usual in such campaigns, any drop in the curve of total monthly catches is attributed to a decrease in population brought about by the catching.

One Trinidad manager estimates the loss due to *Castnia* in badly infested fields as five tons of cane per acre. In such fields I have found as many as twelve bored stalks per stool.

There is a significant difference between the giant-borer and the small borers (*Diatraea*), for whereas the latter, when the canes are cut, are carried, in the vast majority, into the mill and destroyed when the canes are crushed, the former are left in the stool, where they may easily continue their development and emerge as moths.

Host-plants.—The original wild host-plant, and even the plant-formation from which *Castnia* colonised the cane-fields, although suspected, was unknown until the present investigation. Orchids and Bromeliads were suggested as hosts in the earlier literature, but this was probably only a surmise based on Philippi's record (see Salt, 1929) of *Castnia eudesmia* reared from these plants. In the present investigation an extensive search in such plants in the Trinidad and Guiana forests failed to produce it; although another worker (Darlington) found a second species (near *C. amicus*, testé Mr. Urich) in a large, undetermined Bromeliad in the Trinidad mountains. The giant-grasses, *Gynerium saccharoides*, *Arundo Donax*, and *Phragmites occidentalis* were given especial attention. The plentiful forest Musaceous plant, *Heliconia Bihai*, was also examined in Trinidad and on the mainland, but entirely without success until Mrs. Myers discovered the larvae plentifully in this plant in the North-west of British Guiana in June, 1930. This has

since been confirmed in Trinidad. *Heliconia Bihai*, known in British Guiana as " wild plantain " and in Trinidad where it is often used for shading young cacao, as " balisier," is a typical constituent of both lowland and montane (up to about 2,000 feet) rain-forest. Another much smaller species, *Heliconia psittacorum*, is a savannah plant, but this has not been found bored by *Castnia*, nor have the adult moths been observed flying about the frequent large beds in which it occurs. We must, then, add *Castnia* to the list of purely forest insects which have become adapted to cane-fields.

It is curious that *Castnia*, coming from a Musaceous host, should not have become primarily a pest of bananas and plantains, but in Trinidad its attacks on these plants are entirely negligible. According to Quelch, however, the damage to plantains in British Guiana was at one period, very severe.*

Urich (1909) gives records by Ottier and by Collens of *Castnia licoides* (*licus*) boring in young coconut palms and in palmiste (*Oreodoxa oleracea*) in Trinidad, while Mr. Cleare informs me of a case of coconut attack which occurred in British Guiana. Bodkin reports a similar occurrence. The usual coconut species in the Guianas is, of course, the much larger *Castnia daedalus*, which also, according to Reyne (1920, 1923) infests bananas.

I have one record of *Castnia* larvae in razor-grass (*Paspalum virgatum*) in a cane-trace in Trinidad, when four examples were taken from 68 dead hearts. Considering the many thousands of shoots which have been examined for *Diatraea*, without finding *Castnia*, it is apparent that this was an unusual occurrence, the grass probably being infested from the adjacent sugar-cane.

Natural enemies of Castnia.—Undoubtedly, as early recognised by Quelch, the most efficient predators of *Castnia* are birds. Of these the most important are the kiskadees [*Pitangus sulphuratus*, *P. lictor*, *Tyrannus satrapa* (*melancholicus*], and the old witch or ani (*Crotophaga ani*). To encourage such birds in the cane-fields it has become a regular practice, as we have seen, on certain Trinidad and Guiana estates to supply every field with a number of bamboo bird-perches, and to plant coverts. I have myself seen *Castnia* chased and captured by the grey-headed kiskadee (*T. satrapa*). Young (1929, p. 33)

* It is remarkable that still another Lepidopterous pest of sugar-cane—the larvae of the owl butterfly (*Caligo illioneus*)—according to Guppy in Trinidad, and Cleare in British Guiana, attacks only sugar-cane and bananas.

records a *Castnia* larva eaten by the ivory-billed woodpecker (*Campephilus melanoleucus*) in British Guiana, but this may have been *Castnia daedalus* from a coconut palm. Quelch mentions also several hawks and muff-birds as predatory on *Castnia*. He likewise ascribes considerable importance to rats, which, he says, bite out the borers from infested canes. On at least one estate the rats were considered so useful on this account that a vigorous campaign was directed against the mongoose. Quelch, however, found no difference in *Castnia* infestation on an estate where mongoose did not occur.

Of insect predators, Quelch believed ants destroyed a considerable number of the eggs. In Trinidad a large but rather infrequent beetle larva (*Pyrophorus* sp.), not yet reared successfully to maturity, destroys some of the larvae in their burrows. Its incidence may be gauged from the fact that among 270 *Castnia* larvae collected for dissection in one day in the southern part of Trinidad, there were only two of these predators—or a percentage of little more than ·3 per cent. We do not, however, know how many larvae the predator is likely to destroy in the course of its life. A similar beetle larva was found in some numbers in the bores of *Castnia* in *Heliconia* by Mrs. Myers in British Guiana.

I have had one case in which a *Castnia* pupa was destroyed by a wandering *Diatraea* larva, in a roomy cage half-full of cane shoots. This may happen accidentally in the field.

No parasites of *Castnia licoides* at any stage of its life-cycle are known with certainty, nor have any yet been discovered by dissection during the present investigation. Quelch (1910, p. 13) mentions "four egg parasites.....obtained from among a considerable number of eggs brought in." Nothing more seems to have been heard of these, and the record was perhaps erroneous.*

Now that the wild host-plant of *Castnia licoides* is known, the search for parasites on the mainland will be renewed with great hopes of success.

3. *The Sugar-cane Froghopper* (*Tomaspis* (*Monecphora*) *saccharina*).

History and Status.—This, the most important sugar-cane pest in Trinidad, produces a condition in the cane known as "blight". This trouble seems first to have been reported by Cruger in 1863 and was

* Since this report was prepared a very promising Tachnid parasite has been obtained from *Castnia* larvae infesting *Heliconia* in British Guiana. An attempt will be made to introduce this species into Trinidad.

again studied by Francis in 1878 (see Williams, 1921, p.14), but it was not until 1889 that Hart definitely ascribed it to the attack of the froghopper. There were severe outbreaks in 1906, 1907 and 1908, and in 1909 the recently-formed Board of Agriculture appointed a mycologist and an entomologist (Mr. F. W. Urich) " to investigate plant diseases in general and the froghopper blight in particular." In 1910 Mr. P. L. Guppy was appointed Assistant Entomologist, and in the same year Dr. L. W. Gough was brought to the Colony to study the problem for one season. Again in 1912 the blight was so severe, that another entomologist was engaged—Mr. J. C. Kershaw—and he also investigated the trouble for a year. In 1916 Mr. C. B. Williams arrived, as special froghopper entomologist, and his report, published in 1921, forms the basis of our knowledge of the froghopper on the entomological side. More recently, the continued occurrence of outbreaks stimulated the appointment of a committee to continue the investigation. This committee, whose activities have been financed partly by Government and partly by the planters themselves, held its first meeting in November, 1925. Its scientific work has been accomplished chiefly under the very able direction of Professor F. Hardy, and has been published regularly up to the present date, in the *Proceedings of the Froghopper Committee.*

The froghopper thus differs widely from all the other insects considered in this report, in that it has been the subject of capable research by a succession of able entomologists and ecologists. The admirable researches of Professor Hardy and his colleagues (including the late Dr. Withycombe), besides throwing a flood of light on the threefold relationship of soil-plant-froghopper, have yielded two main practical results. The first is that the froghopper damage (or " blight ") is serious only in very acid soils, and may, in fact, be prevented altogether by liming. Unfortunately we are at present largely in the dark as to the mode in which these factors operate, but the indications now are that the limed soil is physically less suitable for the froghoppers' egg-laying, and not that it merely enables the plant better to withstand the insects' attacks. The amount of lime required per acre to obviate blighting is in most cases prohibitively great, and this method of control consequently remains largely impracticable. The second result of the ecological work was to demonstrate that under certain conditions effective treatment of each young brood of froghoppers in their spittle-masses, with calcium cyanide dust, is an effective means of control.

This is an extremely inadequate summary of a mass of data which places our knowledge of the physical and chemical ecology of the froghopper on a higher basis than that of any other tropical insect.

In spite of the fact that froghoppers of the same genus occur in practically every country of America, it is only in Trinidad that one species has become a regularly serious pest. This was credited in 1917 with causing a reduction in the island sugar-crop to the extent of £300,000. The same species is responsible for occasional outbreaks in Grenada (Williams, 1918). Elsewhere sporadic damage by froghoppers (*Tomaspis*) has been reported on sugar-cane in Northern Argentina (Box, 1929), Brazil (Monte, 1929; Moreira, 1925), Dutch Guiana (Williams, 1917), British Guiana (Williams, 1918*b*), Peru (Wolcott, 1929*b*), British Honduras (Sampson, 1929) and Mexico (Urich, 1913). Occasional injury to pastures is recorded from Colombia (Vargas Vergara, 1913) and Cuba (Cardin, 1917).

Original Host-plants.—The Trinidad froghopper seems to be now perfectly adapted to the rather specialised conditions which prevail in a cane-field. The way this has been brought about is very curious. One would have expected that the greatest menace to sugar-cane would have come from froghoppers already attached to grasslands. But the writer has shown in a series of papers (*e.g.*, 1926) that the Homoptera, the sub-order to which the froghoppers belong, are more closely attached to plant-associations than to special kinds of plants. Whether the microclimate at the base of tall canes has more in common with that of a forest-floor than that of open grass-land, there are at present insufficient data to decide. The fact remains, however, that the Trinidad froghopper is primitively a purely forest species. In typical savannahs and swamp-lands of Trinidad *Tomaspis saccharina* apparently does not occur, but where such tracts are bordered by forest or cacao-fields froghoppers tend to appear as soon as one enters the shade of the trees. Even in entirely virgin forest, however, it occurs plentifully. This was tested on a recent traverse of thirteen miles in southern Trinidad, from the Guayaguayare oil-field to Moruga. An oil-pipe has been put through here, with the minimum of clearing, so that for the greater part of the way the canopy is scarcely broken, and practically no second-growth occurs. At least twelve miles are through virgin rain-forest. Here, wherever a tree had fallen or the placing of the pipe-line had caused a little more disturbance than usual, whether in mora (*Dimorphandra Mora*) or in mixed forest, tiny

patches of the grass, *Paspalum conjugatum* occurred, and on it numerous specimens of the cane froghopper. It is found also in similar situations in mountain forest.

Natural Enemies in Trinidad.—Under the regime of the Froghopper Investigation Committee attention was concentrated, even by entomologists like Withycombe, on the physico-chemical side of the relationship between blighting plant and soil. Biological factors were rather neglected and the study of the froghopper as an insect largely lapsed. The balance has now been restored by the appointment of an entomologist, Mr. A. Pickles, to the research staff of the Froghopper Committee. The froghopper was early found to have three main groups of natural enemies. In order of efficiency these are, firstly green Muscardine fungus (*Metarrhizium anisopliae*), secondly, Syrphid fly larvae (*Salpingogaster nigra*), and thirdly, two egg-parasites (*Oligosita giraulti* and *Paraphelinus tomaspidis*). The first annually kills large numbers of adult froghoppers but, as with all other fungous parasites so far investigated, it is effective only under certain meteorological (especially humidity) conditions which we cannot control. If those conditions are operating, then the fungus will be in abundant evidence; if the conditions are not favourable no amount of spore dispersal or culture work will be of the slightest value. All attempts to augment the usefulness of this fungus by artificial means have accordingly been very rightly given up.

To comprehend the present ineffectiveness of the insect predators and parasites it will be necessary to review rather more fully the conditions under which the froghopper is a pest.

We have seen that the froghopper was originally a forest insect, and presumably the same may be said of its natural enemies. In forest habitats at the present time, as Mr. Pickles and others have pointed out, froghoppers may be found in any stage of their cycle all the year round. Parasites and predators are able to breed uninterruptedly. In cane-fields in Trinidad, whatever be the state of affairs in the wet season, during the dry season conditions are exceedingly dry, and there is practically no breeding of froghoppers. An extensive population is carried over till the rains almost solely by numbers of exceedingly resistant "carry over" eggs, which have been investigated by Mr. Urich and Mr. Pickles, and have been shown to endure the greatest extremes of dryness. We know of

no way in which the Syrphid fly and the egg-parasites can maintain themselves in the actual fields during this season, and it would seem that this must constitute an exceedingly serious check on their activities. Most froghoppers deposit their eggs in plant tissue, and *T. saccharina* oviposits to a certain extent in cane-leaf bases, but the majority of the dry season eggs are laid in the soil, where they are extraordinarily resistant. This is the most invulnerable stage in the life-cycle.

The Syrphid fly at times accounts for about 6 per cent. of the froghoppers*. Efforts were early made to rear it in large numbers, but practically no success was achieved. The theoretical difficulties are such as to render inadvisable any repetition of these attempts.

The egg-parasites remain somewhat a mystery. The recorded case of the second species (*Paraphelinus*) may be at once dismissed as entirely casual. Its regular hosts are almost certainly the eggs of other insects (largely Orthoptera). The vermilion egg-parasite (*Oligosita*) is generally stated to be abundant in the over-moist mountain valleys of the Northern Range, but to be unable to survive in any numbers in the cane-fields. Unfortunately the method of rearing this parasite in the past, from collections of grasses, replete with a varied fauna, has failed to yield a single exact count of the rate of parasitism of froghopper eggs under any conditions. During the present investigation the collection from cane and from mountain grasses of actual froghopper eggs for rearing, has not produced a single specimen of the famous vermilion egg-parasite, and it remains extremely doubtful whether this is a regular parasite of froghopper eggs in the mountain valleys†. It is, in any case, quite negligible economically, and the previous attempts to rear it in numbers from mountain grasses and liberate it in cane-fields need not be repeated. More recently Mr. Pickles has discovered in Trinidad two egg-parasites, one producing a mortality up to 10 per cent. The more abundant of these is a Mymarid of the genus *Anagrus*, perhaps the

* Mr. Pickles has counted even higher percentages. It may be remarked here that the Syrphid fly larva offers a splendid subject for much-needed quantitative studies on the effect of predacious insects. It may travel a short distance from one spittle-mass to another, but almost certainly not to another stool of cane. Mr. Pickles has elaborated a counting system by which, with a very fair degree of accuracy, the population of host and predator, in these circumstances, can be estimated.

† More recently, Mr. Pickles has examined some thousands of eggs from the most varied localities, without finding a single specimen of this semi-mythical insect.

same species as that taken by Williams on a related froghopper in Panama. The other is a Trichogrammatid of the curious genus *Lathromeris*. Since these are already in the cane-fields it is doubtful whether anything can be done to augment their activities.

A considerable number of the adult froghoppers are destroyed by the forktailed flycatcher (*Muscivora tyrannus*) which migrates to Trinidad from the mainland every year, and is encouraged in the cane-fields, at least on some estates, by the erection of bamboos as perches. Williams has recorded other bird-predators.

A Lampyrid beetle larva was found once by Williams and once by myself, to feed upon froghopper nymphs within their spittle-masses. I kept my specimen for nearly a month feeding it upon nymphs. It would eat as many as two full-grown nymphs a day.

Small jumping-spiders of the family Attidae have been found by Urich, Williams and Pickles to destroy adult froghoppers to some extent.

Finally, a bug (*Castolus plagiaticollis*), predacious on froghoppers, was found in Mexico in 1911 by Mr. Urich, and introduced into Trinidad, but it appears not to have established itself.

The Search for New Parasites.—It follows from what we have said of the original habitat of the froghopper that, although apparently indigenous to Trinidad, in the cane-fields it is, to all intents and purposes, an introduced insect. Its natural enemies have not been able, to any great extent, to adapt themselves to the cane-field environment. There is thus every justification for treating the problem in the classical manner and asserting that the greatest hope for the control of the froghopper lies in the discovery of an entirely new foreign parasite which can be introduced. This parasite should come from a habitat as similar as possible to the Trinidad cane-field environment. Such a habitat will be found in the mainland probably either in cane-fields themselves or in a drier type of forest (*e.g.* monsoon forest) than that which predominates in Trinidad.

During the present investigation, froghopper conditions have been studied and a search made for new natural enemies in the Guianas and the Caribbean Islands. Williams had previously sought a parasite in the course of a few months' stay in British

Guiana and in Panama, and flying visits to Suriname, Tobago, Grenada and Venezuela, after which he decided that the possibilities of biological control were remote. Urich investigated conditions in Mexico.

I believe that the most hopeful region in which to continue the search lies in Brazil, but Venezuela is also promising. Our own researches were directed first to Cuba because it was thought that an effective parasite had been discovered by the writer in Cuba in 1925, when the Chalcid, *Carabunia myersi*, was found parasitising the nymphs of an indigenous froghopper (*Clastoptera undulata*) and often causing a mortality of over 90 per cent. A special study of its biology, however, in August and September, 1929, showed that its host-relations were extremely restricted and that it would not parasitise froghoppers of the genus to which the Trinidad pest belongs. There is, however, every chance of finding on the mainland a similar parasite for these froghoppers.

Notes on the froghopper position in the countries thus far visited are summarised below.

Several thousand nymphs and adults were dissected. Mrs. Myers made a special search in froghopper eggs and published the results in the *Proceedings* of the Froghopper Committee (1930). This work, so far as Trinidad is concerned, has now been taken over by Mr. Pickles.

Dutch Guiana.

Tomaspis rubra was found on a white-flowered *Costus* sp. in rain-forest, and on a species of *Commelina* in a Bosch-Neger clearing, both up the Coppename River, but no parasites were discovered.

British Guiana.

In the virgin rain-forest of the north-west district three species related to the cane froghopper were found.

The first (*Tomaspis* sp.), which has not yet been specifically determined, occurred in large-celled spittle-masses on exposed roots on the bare, muddy floor of mora (*Dimorphandra*) forest high up the Barima River. An adult came to light at our camp. This species was once seen also in mixed forest at Mabaruma.

The second species (*Tomaspis lineola*) was collected, one adult in truli (*Manicaria saccifera*) swamp-forest and one nymph in adjacent mixed forest.

No parasites were obtained.

On the coast in Demerara on 18 May, 1929, I was fortunate enough to see an isolated infestation of a fourth species (*Tomaspis flavilatera*) in a cane-field. There were few on the canes themselves, but literally thousands of spittle-masses on Bahama grass (*Cynodon dactylon*) on the edges of the drainage trenches, filled by recent heavy rains. It looked as though they had been forced up by the rising water from more moisture-loving host-grasses in the bed of the ditch. I shall not be surprised to find that this is a savannah species.

Dissection of a long series of nymphs failed to reveal any parasites, nor were there any Syrphid larvae among them.

The Lesser Antilles.

Only a passing visit has so far been paid to Grenada, where froghopper (*Tomaspis saccharina*) is occasionally injurious. In the other islands none was found.

The Greater Antilles.

In a short visit to Santo Domingo, chiefly devoted to other pests, no froghoppers were seen, though they probably occur. In Haiti a close search was made for five weeks in a great variety of plant-associations, ranging from sea-level to 7,000 feet, but not a single froghopper of the genus *Tomaspis* was found. A little more success was obtained in Cuba and Jamaica.

Cuba.

The froghopper (*Tomaspis bicincta* var. *fraterna*), which Cardin reported as a serious pest of Pará grass (*Panicum barbinode*) pastures during one season, was only found in Southern Santa Clara after very prolonged search. There it occurred only in one or two very isolated patches in hilly pasture consisting largely of *Paspalum distichum.* In pure guinea grass (*Panicum maximum*) potreros repeated search failed to produce it. It sometimes, however, frequented clumps of this grass growing among *Paspalum distichum* and even more or less pure stands in the moister conditions of the Trinidad Mountains above San Blas.

In Camagüey a few were collected in a guinea grass pasture at Baraguá (6 nymphs and 18 adults to 80 grass-clumps), while an adjoining wet Pará-grass field, under several inches of water, with scattered júcaro bushes (*Bucida Buceras*) and corojò palms (*Acrocomia crispa*) yielded none whatever.

Two adults were seen on sugar-cane at Baraguá.

At Jaronū, in Northern Camagüey, in a wet button mangrove marsh (*Conocarpus erecta*) on the edge of the cane-lands, it occurred quite plentifully on four species of grass, the spittle-masses being two to nine inches up the stems, probably in response to bog conditions.

The only natural enemies found were a few hunting spiders, one Nematode worm parasitising a nymph (rate, about ·3 per cent.) and a Syrphid (*Salpingogaster*) closely related to the Trinidad species. The rarity of the latter during August and early September may be gauged from the fact that only one larva was found among the 427 nymphs collected at Soledad. It may be more plentiful later in the season. Three adult flies were seen at an elevation of 2,700 feet in the Trinidad Mountains, above San Blas, in a guinea grass pasture which yielded no froghoppers.

Jamaica.

During January and part of February, 1930, an intensive search was made for froghoppers throughout Jamaica. This was especially in the hands of Mr. Pickles who joined us there, and has since published a useful account of the Jamaica froghopper position (1930*a*). It will suffice here to report that many differing plant-associations, ranging from sea-level to over 7,000 feet, were searched for froghoppers of the genus *Tomaspis*—almost without success. The only examples (*Tomaspis basalis*) were all eventually collected from one short stretch of khus-khus grass (*Andropogon muricatus*) discovered by Mr. Pickles near Annotto Bay, on the north coast.

The only natural enemy discovered was a Syrphid predator (*Salpingogaster*), not yet determined, but closely related to the Trinidad species, and showing a relative abundance of less than 8 per cent.

Why froghoppers of this type do not usually become pests in Cuba or Jamaica is an intriguing problem. In view of the findings of the Trinidad Froghopper Committee that attack on cane is

serious only on acid soils, it has been suggested that the widespread predominance of limestone formations in these two large islands is the chief cause. That this theory is quite untenable is indicated by the fact, already mentioned in the ecological introduction, that the widespread red soils, for instance, which are the product of the weathering of this limestone, are markedly deficient in lime. And these are among the chief sugar-cane soils of Cuba. Furthermore, it is noteworthy that the soil on the only spot in Jamaica where we found *Tomaspis* was decidedly alkaline*.

Future Work and Summary.—As mentioned earlier in this report, Mr. Pickles was appointed by the Froghopper Committee to make a fundamental study of froghopper biology with special attention to the data necessary in biological work. When a suitable parasite is found he will be able to take over entirely the work of establishing it in Trinidad.

To sum up the froghopper position, it may be stated that there is already a vast amount of fundamental data on its ecology, studies on which are proceeding apace. The most promising line of control is by biological means and the greatest need is for an entirely new parasite, the search for which on the mainland has already begun.

4. *Cane root-borer* (*Diaprepes abbreviatus*).

History and Status.—This weevil, which now rivals *Diatraea* as the most serious pest of sugar-cane in Barbados, offers another striking example of an apparently indigenous insect leaving a staple crop-plant unmolested for several centuries. Its attacks on sugar-cane and sweet potatoes, according to Watson (1904) were not observed prior to 1901. By 1904 it had become fairly abundant, but not serious until 1909 (Ballou, 1911*a*) and since that date it has increased in virulence every year. In 1922 Bovell and D'Albuquerque estimated a loss of $3\frac{1}{2}$ tons of cane per acre on their experimental plots.

For long it was more or less confined, as a serious pest, to the lower terraces, where it has helped to render ratooning impossible. It is now invading the higher terraces, where, in July, 1929, I saw a

* Professor Hardy was so good as to have some samples partially analysed. I quote from Mr. Pickles's report: "The soil was red-brown in colour, and contained appreciable content of calcium carbonate (0·4 per cent.), sufficient to impart a marked alkaline reaction (pH 7·5). The parent material is probably limestone. The soils are residual clays."

severe infestation on first ratoons, marked by large bare patches where stools had been killed outright. In that year five million adults were collected.

Distribution and Host-plants.—Elsewhere in the West Indies closely related weevils of the genera *Diaprepes, Exophthalmodes* and *Prepodes** are widespread and not uncommon on a variety of plants. Hutson (1917) records *Diaprepes abbreviatus* itself or its varieties, from Santo Domingo, Porto Rico, St. Croix, Virgin Islands, Guadeloupe, Dominica, Martinique, St. Lucia, St. Vincent, Barbados and Grenada; and the other important pest species (*D. famelicus* and its races) from St. Kitts, Antigua, Nevis, Guadeloupe, Dominica and Barbados. Van Dine (1927, p. 19, Fig. 10) lists *Diaprepes abbreviatus* from Cuba, as a cane root-borer, on the authority of Cardin (1915) but says that the identification has not been confirmed. We made a special search for it in Cuba, unsuccessfully. Ballou (1922*b*) notes the occurrence of *Diaprepes abbreviatus* in St. Kitts and Nevis. It is not a very serious cane pest outside Barbados, but both it and *D. famelicus* occur on a great variety of plants, the roots of which the larvae attack, while on the leaves the adults themselves feed and lay their eggs. *D. abbreviatus* has been recorded upon cane, sweet potatoes, millet, ground-nuts, Guinea corn, citrus, tobacco, and other plants, while *D. famelicus* attacks citrus, cane, and a variety of other plants. In St. Kitts, where an effort is now being made to grow English potatoes for the export market, I found this year some of the crop very heavily infested with a *Diaprepes* larva. It is probable that the plants on which the adult weevils feed and lay their eggs are even more varied than those which support the larvae at their roots. In Haiti the related *Prepodes* (*Exophthalmodes*) *quadrivittatus* was intensively studied. This insect attacks a variety of crops, including cane, but is apparently not sufficiently abundant to be a serious pest. As we shall see later, it is very heavily attacked by natural enemies.

Natural Enemies.—This is one of the few cases in which little is to be expected from the mainland, for the Antilles seem to be the headquarters of both genera, *Diaprepes* and *Prepodes* (*Exophthalmodes*).

* Sir Guy Marshall informs me that *Exophthalmodes* is the modern name for the weevils formerly called *Exophthalmus* (a pre-occupied name); but that they are hardly separable from *Prepodes*.

No parasites of any stage of *Diaprepes abbreviatus* are known. At present the only method of control adopted is the hand collection of the adult weevils. During the last season several millions were thus destroyed, but data as to the proportion of the population thus killed are lacking.

The fiddler beetle (*Prepodes vittatus**) of the orange in Jamaica (Anon., 1904) is said, on the authority of Panton, to be attacked in the larval stage by the Scoliid wasp, *Elis atrata*. This badly needs confirmation.

A Chalcid egg-parasite (*Tetrastichus haitensis*) of *Prepodes quadrivittatus* (Wolcott, 1929*c*; Gahan, 1929) was closely studied in Haiti, and found to destroy on the average, about 6 per cent. of the eggs. The latter are deposited on folded-over leaves of various widely-different plants (*e.g.*, papaw (*Carica Papaya*), *Ipomoea crassicaulis*). This habit, which does not seem at all to embarrass the egg-parasites, renders it probable that the latter may be got to attack the eggs of *Diaprepes* in Barbados, which are usually laid between the tips of sugar-cane leaves, but also on a number of other plants.

The discovery, later, of the same species of egg-parasite attacking the eggs of *Diaprepes famelicus* (*esuriens*) on citrus (lime) leaves in the island of Montserrat raised the question of the possible existence of the parasite in Barbados already. This has been solved by Mr. Tucker's examination of a very large series of eggs of *Diaprepes* in Barbados—with entirely negative results. A specific parasite actually found attacking *D. abbreviatus* would perhaps be preferable, but since *Tetrastichus* is already known to parasitise a representative of both genera (*Prepodes* and *Diaprepes*) it is very likely to attack *D. abbreviatus* as well. It is therefore proposed to introduce *Tetrastichus* into Barbados.

A predatory enemy of *Prepodes quadrivittatus* was found in Haiti in the shape of a spider (*Latrodectes mactans*), in a web of which one of the adults was found dead.

5. *Minor Sugar-cane Insects.*

Some attention has been paid, when opportunity offered material, to six minor sugar-cane pests.

* In Gowdey's (1923) account of Jamaican insect pests the citrus root weevil is given as *Pachnaeus litus*, and *Prepodes* is not listed as a pest.

Many larvae of the cane-weevils (*Metamasius sericeus* and *M. hemipterus*) were dissected in British Guiana, Trinidad and Cuba, without finding any parasites. Apparently the only instance of parasitism recorded is that of F. X. Williams and Box, who reared one specimen of an *Ipobracon*, believed to be *I. puberulus*, in British Guiana. *Metamasius* is usually secondary, but may be a primary pest of cane. It ruins completely many canes otherwise only slightly bored by *Diatraea* or gnawed by rats.

Aphis maidis, the only known vector of mosaic disease of sugar-cane, was found on *Paspalum millegrana* in British Guiana, very heavily attacked by a Syrphid fly, which may be useful in regions further north.

An outbreak of the yellow cane aphis (*Sipha flava*) was examined in British Guiana, and widespread species of Coccinellids observed attacking it. It occurs throughout the West Indies, but is subject to serious outbreaks only in British Guiana and Porto Rico.

The West Indian cane-fly (*Saccharosydne saccharivora*) is widespread in the Greater Antilles, but becomes serious, and then merely locally and periodically, only in Jamaica. The Jamaican outbreaks are usually terminated by fungous and insect parasites, but the planters desire a more efficient natural enemy which will check the damage sooner. This has not yet been found, but the sparse population of cane-fly in Cuba and Haiti rendered it difficult to collect enough material for adequate study.

Considerable numbers of larvae of *Laphygma frugiperda*, a species of army-worm, were dissected during an outbreak on cane in Trinidad, but no parasites were found. The two parasites, *Chelonus insularis** and *Euplectrus platyhypenae* were reared in Cuba, where they destroy a large proportion of the larvae, which are practically never a pest of cane there, though frequent on weed-grasses. The distribution of these parasites in the British colonies has not yet been worked out. Jamaica is anxious to receive parasites of this pest, but nothing can be done until the parasites already in Jamaica have been recognised.

* My specimens agree exactly with Cresson's description of his *C. insularis*, described in 1865. *C. texanus* (Cresson, 1872), if the specimen in the British Museum is correctly named, is quite a different species, with the basal abdominal spots tinged with rufous and almost touching medially. There is in the same collection one specimen of a *Chelonus* from Jamaica (taken at electric light, Kingston, by Cockerell, 20th July, 1891) like the Cuban *C. insularis*, but with no trace of the basal abdominal spots and with more rufous legs. It carries no host data.

Gowdey (1921), has listed the following as already attacking this pest in Jamaica—the predacious beetle, *Calosoma laterale;* the Tachinid flies, *Frontina aletiae,* and *Archytas piliventris;* and the Hymenoptera, *Henicospilus purgatus, Chalcis robusta, Chalcis* sp. and *Spilochalcis femorata.* It is noteworthy that he does not mention *Chelonus.* If this efficient parasite be really absent on *Laphygma* in Jamaica, it would be well worth while introducing it from Cuba.

A less frequent, non gregarious leaf-caterpillar of cane (*Cirphis* sp.) in Trinidad has been found heavily parasitised by *Euplectrus platyhypenae,* but this parasite is already well-distributed throughout tropical America.

A new insect pest of cane was discovered in Antigua. This was a Lamiid beetle larva boring in some numbers in dry dead shoots from a field suffering very badly from drought. It is probable that the attack was entirely secondary. An adult, reared from one of these larvae, was kindly determined by Mr. K. G. Blair at the British Museum, as *Leptostylus testaceus.*

(b) *Cacao Pests.*

Cacao is an important crop in the British colonies of Trinidad, Tobago, and Grenada, and is grown also in St. Lucia, St. Vincent, Dominica and Jamaica. Only two insect pests have been considered sufficiently important to be specially investigated. Of these the cacao thrips (*Heliothrips rubrocinctus*) is widespread, while the cacao-beetle (*Stirastoma depressum*) is important among the British islands, only in Trinidad, Tobago, and, to a less extent, in Grenada. Both are serious pests in Suriname.

In the study of the cacao pests the method of tracing the primitive environment of the insects is especially fruitful. Advantage was taken of Professor Stahel's discovery ten years ago of a large stand of true wild cacao (*Theobroma Cacao*) in the uninhabited forest near the Kwamma Kreek, a tributary of the Coppename River in Dutch Guiana. The Dutch Government, through Professor Stahel, very kindly arranged an expedition to enable the writer to examine in detail these wild cacao trees in a primitive environment. Some botanical observations on this expedition have been published in the *Kew Bulletin* (January, 1930). Neither cacao thrips nor cacao beetle were found on the wild trees,* nor were there any of the usual signs

* The only striking insect feeding on these trees was a huge Sphingid caterpillar, of which we succeeded in bringing back two live specimens, neither of which, though nearly full-fed, lived to maturity.

of their former attack, which, in the case of the beetle, persist during the life of the tree. This was in marked contrast to the great abundance of both pests in the coastal plantations of Suriname. The conditions under which the wild cacao was growing were such as are usually recognised in plantations as entirely unfavourable to attack by either thrips or beetle. For these three reasons, then, we are fairly safe in assuming that both these major pests of cacao were not originally attached to this tree; but only gradually learned to attack it. Their parasites must be sought in the original habitat, whence they have in all probability not followed the pests into the cultivations.

The wild tree grows as a constituent of one of the lower tiers of true rain-forest. The cultivated tree is commonly grown under the shade of much taller trees, which, in the early days, were usually sand-box (*Hura crepitans*), but are now chiefly water immortelle (*Erythrina glauca*) on the lowlands, and immortelle (*E. micropteryx*) on the higher lands. The ecological conditions of a well-kept cacao plantation tend, therefore, to approximate very closely that of the rain-forest itself upon which, more often than not in Trinidad, the cacao fields abut. In Trinidad the undergrowth, which is kept within reasonable limits by periodical cutlassing, consists very largely of various ferns and gamalote grass (*Chaetochloa sulcata*). The fauna and flora of a cacao field, in response to these conditions, are usually much more varied and probably more balanced than those of most other cultivations. Birds*, for example, are generally plentiful, while the richness in insect species renders these plantations good hunting-grounds for the general entomologist. To these facts, and the resulting natural balance, may probably be attributed the general freedom of cacao from serious insect pests (as distinct from fungous diseases) save in patches where the trees are palpably growing under unfavourable conditions of soil, shade or cultivation, or have suffered from the effects of untoward meteorological variations such as drought.

There has been so far insufficient opportunity to compare in detail, as in the cane-lands, the Trinidad cacao plantation conditions with those of other countries such as Suriname and Grenada. But a brief preliminary examination indicates that cacao itself is so exacting

* An analysis of the food-habits of common cacao-field birds has been presented by Guppy (1914).

in its requirements that we must not expect such a wide variation in different regions as we are accustomed to in cane-fields. It has been a general practice to cultivate cane in the West Indies where no other crop would grow.

1. *Cacao thrips* (*Heliothrips rubrocinctus*). *History and Status.*—There is very considerable evidence, as Ballou (1915*b*, 1924) has long emphasized, that this insect is not a pest of healthy cacao trees, growing under optimum conditions of shade and drainage. Observations in Grenada showed that severe thrips attack coincided with (*a*) the presence of root disease ; (*b*) insufficient drainage ; (*c*) shallow soil ; (*d*) an evident lack of humus ; (*e*) exposure to wind ; or (*f*) lack of shade. In St. Vincent, where Ballou and Nowell investigated an outbreak (Ballou, 1916) they came to the conclusion that, as a result of the very light soil, the atmospheric humidity is much below what would be expected from the high rainfall and the conditions are those of a relatively dry island where cacao is grown near the margin of permissible dryness. This renders it liable to thrips attack, which may be eliminated entirely by mulching with abundant organic matter (Ballou, 1924). Urich, however, claims that thrips is often injurious in Trinidad to cacao in a favourable environment, while Reyne (1921), who made a very intensive study of the pest in Dutch Guiana, states that even the most healthy and vigorous trees are attacked. Professor Stahel (in conversation, 1929) believes, however, that repeated droughts and unsuitable soil conditions were important contributory factors in Suriname, and thus agrees more nearly with Ballou, whose theory certainly seems to have the weight of evidence in its favour, at least so far as the northern islands are concerned. It is, nevertheless, during the present depression, not always possible to maintain optimum agricultural conditions, while drought and other abnormal changes may, as in Suriname in 1926, cause severe outbreaks in the best plantations. Measures taken against witch-broom disease, in the direction of lessening shade, are likely also to render the trees more liable to thrips attack.

In these circumstances the biological control of thrips is certainly to be desired.

As we have seen above, this is apparently not a pest of wild cacao. As a matter of fact, nearly 30 years ago Maxwell Lefroy, from his investigations in Grenada, came to the conclusion that its original

host-plant was probably guava (*Psidium Guajava*). He wrote (1901*b*, p. 339), "It is reasonable to suppose that this insect may have lived on the wild guava and cashew in these islands before the first cacao was planted. As the land was brought into cultivation, the amount of its native food plants grew less, with the increasing number of established cacao trees. There is now a very large area under cacao, and this insect, having once accustomed itself to its new food plant, has thriven abundantly under such favourable conditions." Guava still remains one of its favourite food-plants both in the West Indies and in West Africa. In many of the northern islands where cacao does not occur, it is plentiful on guava and other wild hosts. That guava is perhaps the original host is also strongly suggested by Reyne's discovery of the insect on *Psidium polycarpon* growing in the open stream-bed of the Kwamma Kreek, in Suriname, not many miles from the wild cacao which Stahel, Reyne, and the writer found entirely free from attack.

"Brown pods" caused by thrips attack, were first noticed in Suriname in 1884 (Reyne). It was first reported as a serious pest in Grenada in 1898 (Ballou, 1906*b*).

Natural Enemies.—Among predatory enemies Reyne records five species of Chrysopid larvae which are rare—occurring in the proportion of only 13 to 13210 thrips; and two species of predacious thrips (*Franklinothrips*) with an incidence of 15 to 14279 thrips. In the West Indies he mentions ants and several predacious bugs—*Triphleps* in Grenada (and Brazil), Reduviids (Trinidad) and a Capsid, *Paracarnus*, in Grenada and St. Lucia.

Parasites of thrips in general are extremely scarce. They include the Chalcids, *Tetrastichus thripophonus* in a thrips on *Clidemia hirta* in Trinidad (Waterston, 1923) and two species of *Thripoctonus*, on various thrips in France, North America and Java (Russell, 1912; Williaume, 1925; van Heurn, 1923).

Only two parasites are known actually from the cacao thrips—the one, *Baryconus* sp., is a Scelionid egg-parasite reported by Bondar from Brazil. More promising is the second, a West African species. On the Gold Coast, according to Cotterell (1927), this parasite, *Dasyscapus parvipennis*, may kill as many as 80 per cent. of the host. It does not apparently occur in the Portuguese island of San Thomé, where, according to Cotterell and to Urich, cacao

thrips is a very serious pest under all conditions of cultivation and physiography. On the Gold Coast Cotterell states that the thrips is never responsible for important damage. Sooner or later it will probably be necessary to consider the possibility of importing this parasite into the West Indies. Under the present transport conditions a consignment could either be brought *via* the Canary Islands or relayed to Farnham Royal. At present, however, we know next to nothing of its biology or living requirements.

The well-known chinch-bug fungus (*Sporotrichum globuliferum*) attacks cacao thrips in Grenada and St. Vincent, and unsuccessful attempts have been made to utilise it artificially (Nowell, 1916, 1917). A similar fungus occurs in Trinidad, while Reyne mentions a *Cephalosporium* in Suriname.

During the present investigation several thousand adult and nymphal thrips in various stages have been examined in Trinidad, Jamaica, and Haiti for parasites, but without success. In Jamaica the nymphs of a small Capsid bug were found in small numbers feeding on the young thrips, on the leaves of cacao itself. Unfortunately, owing to hardships of travelling, those taken all failed to reach maturity. Further studies of this predatory enemy are eminently desirable and will be undertaken when opportunity offers. Its relative abundance compared with that of the host was only about ·67 per cent.

2. *Cacao-beetle* (*Stirastoma depressum*). *History and Status.*—This is an exceedingly serious pest of cacao trees in certain parts of Trinidad, especially in the South, where very large sums of money have been annually spent for the last 18 years on the hand-collection of the larvae. This whole question of hand-collecting—a measure so often adopted as a last resort—is an extremely dubious one. We have no critical data whatever as to its effect on the pest population.

In drought years the beetle is especially injurious, and in fact virtually devastating. At its worst in Trinidad, it is also a pest in Tobago and Grenada, which have been, as yet, only slightly touched in the present investigation. Outside the British colonies it inflicts great damage on the Suriname cacao plantations, or, rather, did so before they were changed into coffee. Van Hall (1914) characterises it, in fact, as the worst cacao pest in the New World. In Ecuador, where much cacao is grown under half-wild conditions,

Stirastoma depressum occurs relatively sparingly. This would, so far as our present knowledge goes, be the most likely area to search for a parasite more promising than those described below.

The cacao-beetle is said to have been a pest for many years. It does not, however, seem to have attracted much attention previous to 1891. In that year Morris made some observations on its habits in Grenada, remarking that it was probably introduced from South America, since it was a well-known pest of cacao in Suriname. He optimistically assured the Grenada planters that if children were regularly and systematically employed to catch the beetles in the early morning " during one or two seasons there would soon be an end to them " ! Carr reported in 1894 that in Trinidad their numbers seemed to have increased.

Host-plants and Original Habitat.—We have given reasons for believing that *Stirastoma* was not originally a pest of cacao. On the rivers of British and Dutch Guiana the banks from the mouth up to a distance varying with the size of the stream are fringed almost continuously with mangroves (*Rhizophora Mangle*). Above that for another stretch, likewise varying with the size of the river, there is a rather less pure and certainly narrower fringe of *Pachira aquatica.* This is the only unequivocally primitive plant-association in which *Stirastoma* has been found, and this is still many miles below the nearest true wild cacao. *P. aquatica,* both on these river banks and in the coast-lands, is certainly a favourite and probably an original host of the cacao-beetle. Branches of this and of two other wild food-plants, *Pachira insignis** and *Ceiba pentandra* (silk-cotton tree) are used in Suriname and Trinidad as beetle traps. Some planters in Trinidad have been trapping regularly for over 20 years.

Another very important wild host-plant of the beetle is the waste-land weed, *Malachra capitata,* which is usually only at the most suffruticose, but becomes under favourable conditions not only woody, but quite thick-stemmed.

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* The large upstanding tree growing commonly in rain-forest and cacao-fields in Trinidad, and commonly identified as *Pachira aquatica,* is really *P. insignis.* It is the wood of this tree which is used for trapping cacao-beetles (Freeman and Williams, 1928). The true *P. aquatica* of Aublet, as decided by Kew (1930) on the basis of specimens compared with his type in the British Museum, is the small, straggling tree which fringes river-banks in British Guiana, and occurs also in Trinidad. The tree known as *P. aquatica* in Haiti (Ekman, Barker) is really *P. insignis.*

In addition Carr, Urich and Guppy list in Trinidad okra (*Hibiscus esculentus*), forest mahoe (*Sterculia caribaea*), and cannon-ball tree (*Couroupita guianensis*). Guppy's record of immortelle (*Erythrina*) as a host is based on an error which the borer gangs have exploited to their profit. Decaying trunks and branches of this common shade tree are often infested by grubs of another, unrelated Longicorn beetle, many thousands of which have been collected and paid for as cacao "worms."

Natural Enemies.—Birds were the first cacao-beetle predators to be noticed. Carr recorded the following feeding on it—the so-called "mangeur de cacao" (*Xiphorhynchus susurrans*), the tick-bird or merle corbeau (*Crotophaga ani*) and the big-billed kiskadee (*Megarhynchus pitangua*); Urich and Guppy mention the King of the Woods (*Momotus bahamensis*) as one of the most important. Various woodpeckers (of which seven species occur in Trinidad and Tobago) dig out and devour the "worms." It is noteworthy that Guppy (1914) lists three of these birds as so injurious to cacao pods that the planter is advised to treat them as vermin. I find, however, that planting opinion is changing, and on at least some estates (notably those of Mr. E. Herrera) all woodpeckers, as well as all other birds, are rigorously protected. Mr. R. Herrera has seen the long-tailed cacique (*Ostinops decumanus*) capturing the adult beetles.

The only insect predator worth mentioning is the larva of a large Elaterid beetle, which has been recorded by Guppy, but not yet reared to maturity. I have found it in abandoned *Stirastoma* borings at Moruga.

Ants are credited by many planters with destroying cacao-beetle larvae. They are certainly more plentiful on badly-infested trees—possibly attracted by the exudations from the borings—and I have seen them fasten on "worms" that were being cut out. They often inhabit abandoned burrows. There is no evidence, however, that they ever attack the larvae unaided.

We come now to parasites. Two species of parasitic wasps (*Ipobracon*) were discovered by Guppy and, according to Mr. Urich, were rather intensively studied. There is, however, practically nothing on record concerning their biology. They were described by Viereck in 1912 (in the genus *Cyanopterus*). In addition, a Chalcid parasite (*Pseudomphale steirastomae*) of cacao-beetle larvae was described by Girault (1916).

In the south of Trinidad considerable numbers of beetles in the larval, pupal and adult stages have been dissected, and the following parasites studied :—

Braconidae.—*Ipobracon steirastomae; Ipobracon peronatus; Ipobracon depressi; Ipobracon* sp.; *Ipobracon* sp. Eulophidae.—*Pseudomphale steirastomae ?*

Of these, *I. peronatus* (Wilkinson, 1929) has not yet been actually reared; but has been captured on and about infested trunks so often that there can be little doubt of its parasitism. *Pseudomphale* has also not been reared, but Chalcid larvae which may be attributed to it have been dissected from " worms." *Ipobracon steirastomae* was obtained only from " worms " in cacao, *I. depressi* from both cacao and wild okra (*Malachra*), while the two undetermined *Ipobracon* were secured only from wild okra. The species of *Ipobracon* are external parasites and the Chalcid internal.

Of 556 larvae from cacao dissected in February, 1929, ·90 per cent. only were parasitised—·18 per cent. by *Ipobracon* (not yet distinguishable in the larval stage), ·72 per cent. by the Chalcid. No parasites were found in pupae or adults. It is possible that some of the smaller *Ipobracon* larvae were lost by the borer gang.

A smaller collection, 68 " worms," made by Mr. R. Herrera and myself, without the aid of the borer gang, in March, 1930, showed a parasitism of 8·9 per cent.—4·5 per cent. due to *Ipobracon*, and 4·4 attributed to the Chalcid. It will be noticed that the Chalcid also was much more abundant than in the previous year, and this would not be affected by the method of collecting. It is significant that the borer was very much more plentiful in the first of these two seasons. It may be supposed that under favourable conditions, especially drought, the beetle multiplies too quickly for its parasites.

In *Malachra*, the only other host from which sufficient material for comparison has yet been obtained, the rate of parasitism (March, 1930) was 3·6 per cent.; thus much lower than that prevailing in cacao, in the same part of Trinidad at the same season. Neither *Ipobracon steirastomae* nor the Chalcid was found. It is possible that the " worms " are harder to reach in wild okra than in cacao. In the latter they are very generally not far beneath the bark, while in the smaller and softer plant they frequently bore the very centre of stems three inches thick. It is noteworthy that all the *Ipobracon* larvae found in *Malachra* were upon " worms " in cells just beneath the bark. Those boring in the centre seemed free from attack.

(c) *Cotton Pests.*

Cotton is an important crop in the Grenadines, Barbados, St. Vincent, Montserrat, Antigua, Nevis, and St. Kitts. These have all been visited save the Grenadines. Outside the British islands, it is grown extensively in Porto Rico and Haiti. It has been studied in the latter republic.

A brief consideration of the curious history of cotton in the West Indies is useful for an understanding of the present pest situation.

The earliest settlers in the West Indies and Guiana found cotton wild, and included it among their first crops. At one time (Anon., 1902*c*), the West Indies supplied 70 per cent. of the cotton used in England. Early in the eighteenth century (Anon., 1907*b*) the cotton-worm (*Alabama argillacea*) began to inflict serious damage; in the Bahamas becoming so bad towards the end of the century as to destroy almost the whole crop in certain years (1788, 1794). In 1801–2 many cotton planters left Martinique for S.W. Georgia on account of this, the first serious pest of cotton to make itself known. It was followed, in all the islands save Barbados, by outbreaks of cotton-stainers (*Dysdercus* spp.). Finally cotton, as a staple industry, was almost completely given up for sugar-cane.

In 1903 the Imperial Department of Agriculture set about reviving the British West Indian cotton industry on a large scale. Sea Island cotton was imported direct from the Sea Islands of South Carolina. Short staple cotton had been grown in the United States since about the mid-seventeenth century, but long staple, from which the present Sea Island cotton was developed, was introduced into Georgia in 1786 from the Bahamas, to which it had been brought in 1785 from Anguilla.

But, " although originally indigenous to these islands, Sea Island cotton in its present condition is an exotic " (Ballou, 1905) and any attempt to ratoon it means an increase of pests. This was experienced even before the introduction of the pink bollworm, which to-day renders a close season still more necessary.

The history of West Indian cotton since its revival has been a history of successively appearing or re-appearing pests. Thus cotton leaf blister-mite (*Eriophyes gossypii*), first found attacking cotton in Montserrat, and later a serious pest in several of the other islands, was not seen in Barbados until 1912 (Ballou, 1913*a*).

A curious case is that of the black scale (*Saissetia nigra*). According to Ballou (1912*b*, p. 56) this formerly caused great damage. In Barbados, in 1905, " several fields of cotton were a total loss owing to the severity of the attack of this pest. At the present time, black scale attracts very little attention and has ceased to be regarded as a pest by most planters. This changed condition has been brought about by the development of the parasite of the black scale. This beneficial insect is now known to occur throughout the West Indies."

The parasite in question was first noticed in Barbados in 1906, but was not reared until 1907, when Crawford described it as *Zalophothrix mirum*.* There was an outbreak of scale again in Barbados in 1907–8, but since then, and throughout the Leeward and Windward Islands, it has not ranked as a pest.

Thanks to the labours of Maxwell Lefroy and especially of Ballou, recorded in the *Agricultural News* and the *West Indian Bulletin*, much more is known of cotton pests than of cane pests in the West Indies. I have not yet had the opportunity to spend sufficient time in the cotton islands, and have therefore made observations practically only on four main pests. Previously—in 1928—a general account of the biological control of cotton pests was published.

Cotton-field conditions, in keeping with the edaphic limitations of the cotton plant, show much less variation than those of cane-fields. A detailed survey has not yet been made, but it seems probable that the most important differences depend upon (*a*) whether the cotton is grown as a catch-crop with cane (as in St. Kitts), or separately (most other regions), and (*b*) whether there is an extensive forested or scrubby hinterland (as in St. Vincent), or much less (as in St. Kitts, Antigua, Montserrat) or none at all (as in Barbados). Harland lays great stress on the influence, on the pest situation generally, of the varied parasite fauna of St. Vincent, due largely to this hinterland. His theory depends, however, on the greater agricultural efficacy of polyphagous parasites which maintain a steady population by subsisting on wild hosts, as compared with specific parasites of the pests in question. This applies certainly to insect-eating birds, which are thus brought to concentrate on the pests whenever the latter tend to increase; and it perhaps holds also in the case of

* Later, synonymised with *Lecanobius cockerelli* (Ballou, 1912*a*).

insect predators;* but I am aware of no data which support the application of this theory to parasitic relations. I would emphasise again that practically all the greater successes of biological control have been won with *specific* insect-predators (e.g., *Novius cardinalis*) and parasites.

Another question largely linked up with the hinterland is that of alternate host-plants for the pest-insects themselves. This is especially important in the case of cotton-stainers (*Dysdercus* spp.) and has been a serious problem in St. Vincent.

The time of planting varies in different islands. It is, for instance, early November in Nevis, and March in the neighbouring island of St. Kitts (Kelsick and Howell, 1928). This exerts considerable influence on the incidence of pests.

We must now turn to a discussion of the more important cotton insects.

1. *Pink Bollworm* (*Platyedra gossypiella*).

History and Status.—The pink bollworm in the West Indies presents many mysteries to the investigator. Not till 1920 was this almost world-wide pest first noticed in the British West Indies, where it had almost certainly been introduced by some accidental human agency. It has been on the mainland of Central and South America for a much longer period, but came originally, of course, from the East.

From the time it was first observed until the end of the 1928 crop, the pink bollworm was an extremely serious pest of cotton. Largely on account of its attacks, no second picking of bolls could be depended upon, and it was, in fact, soon made a rule that the plants be destroyed after the first picking and a close season thus instituted. In spite of these and other measures, including the wholesale fumigation of seed, both that used for sowing and that intended to be crushed for oil, the pink bollworm continued at a high rate of infestation throughout the British islands. The infestation in Montserrat, where careful

* Thus the long-continued freedom of St. Vincent (until very recent years) from severe attacks of the cotton leaf-worm has been attributed by Ballou and others to a heavy rate of predatism by a local wasp (*Polistes annularis*). Whether this species is really more efficient than those occurring in the other islands, or whether, as seems to be more probable, a larger population of wasps is maintained by a hinterland so much more extensive that that of the other cotton islands, is not known.

graphs of infestation* were drawn up annually, may be taken as typical, and there the bolls at the end of the season were regularly infested at the rate of over 90 per cent. (e.g., 1927, 93 per cent.). In 1928 the infestation had decreased to 73 per cent., a result which the Curator of the Botanic Station considered entirely due to " early methods of cleaning up and planting coupled with the strict observance of the close season." Then in the 1929 season there was a sudden and really catastrophic drop, the corresponding figures for Montserrat being under 2 per cent. This very abrupt decrease has been variously attributed in Montserrat to the cleaning-up campaign aided in some way unknown by the 1928 hurricane and elsewhere to the change of planting-season and fumigation, plus close season measures, to the 1928 hurricane, to natural enemies, and to other factors, but the truth is that we are at present entirely in the dark as to the cause. None of the suggested conditions prevails in all the islands.

The position in Haiti is entirely different. It has been studied intensively by Wolcott during three years' residence, and I saw nothing during my visit to invalidate his conclusions. I therefore offer no apology for quoting at length from his interesting report (1929*d*). Cotton has long been grown in southern Haiti under semi-wild conditions to which it seems well-adapted. " Indeed it can scarcely be considered a cultivated crop, in any ordinary sense of the word, for all the care that it receives from the grower, aside from picking the crop and transporting it to a market, is that, when the crop has been harvested, the bushes are cut down and burned, together with any other high weeds, bushes or trees that may happen to be in the fields, so that all have an even start to ' ratoon ' from their roots. Incidentally, cutting out and burning all the aerial portions of the cotton plants each year exercises a most beneficial effect in preventing the white scale, *Hemichionaspis minor* Maskell, from becoming sufficiently abundant in the cotton fields to cause any appreciable damage, but whether it is purposely done for this reason, or merely because of tradition and custom, cannot be stated.

" Without attempting to discuss the botanical characters of the native Haitian cotton, or to consider whether, because it often displays all sorts of variations from the rather long-linted, free-seeded norm, it represents a single species or variety, or several, it may be

* I am deeply indebted, for these graphs, to Mr. C. A. Gomez, Curator of the Botanic Station.

stated that in one respect, at least, it shows almost surprising uniformity. No matter at what season of the year it may be planted in Southern Haiti, the plants do not begin to produce flowers until December. Bolls begin to mature in late January on plants growing from seeds, or possibly a week or two earlier on ratoon plants. Within two months, or three months at the most, all the bolls have matured and the picking season is over.....Ordinarily, only a single winter crop is produced, vegetative growth taking place throughout the rest of the year."

The pink bollworm was first noticed in Haiti in 1923, and in the following year Wolcott ascertained its presence throughout the Republic. But this was practically only in imported varieties of cotton, such as Sea Island and Meade. It has never become a pest on the "native" cottons, though occasionally abundant on a large tree cotton (*coton violet*) grown in the peasant gardens largely for medicinal purposes. "Indeed, if one tries to demonstrate the presence of the pink bollworm in Haiti, it takes hours of search to find infested bolls of native cotton. . . . The scarcity of the pink bollworm in native cotton is not due to exceptional climatic conditions in Haiti, for other varieties, such as Sea Island, Violet, Peruvian and Meade growing there, are heavily infested, just as they are in other countries. Nor is it, in any large measure at least, and as might at first appear likely, due to the short crop season of the native cotton. As January* to March are the only months when native cotton has bolls on which the larvae might feed, the absence of a suitable host during the remainder of the year might, and in some cases very probably does, exercise a rather considerable check on its increase. Despite the fact that native cotton is the only commercial variety successfully grown in Haiti, yet throughout the country there are scattered plants of Sea Island cotton, and of a purplish variety called 'Violet.' These are not restricted to the winter months for maturing bolls, and almost invariably the bolls on these plants are heavily infested. In fields of native cotton near by, or even interspersed with such plants, or near experimental plantings of Peruvian or Meade cotton, the bolls of the native cotton are practically as free from pink bollworm injury as though no heavily infested plants were near. The contrast between field after field of native cotton so lightly infested that one can only by persistent

* I had, however, no difficulty in finding green bolls in December, near Port-au-Prince. J. G. M.

search find an average of one typically infested boll an hour, and a field of Meade cotton so heavily infested that uninfested bolls are found only after protracted search, is too striking to be ignored. Such high resistance of the native cotton is not merely an occasional accident caused by some vagary of climate, by exceptional care in cultivation, fumigation of seed, or carrying out some other of the recommendations designed to limit the depredations of the pink bollworm, but is the regular and accepted rule, and occurs without any conscious effort on the part of the persons growing cotton."

After three years of observation and experiment Wolcott concluded that :—

(1) " When foreign varieties of cotton are heavily infested with the pink bollworm and they cease to produce bolls that might be infested, bolls of native cotton are attacked. That is, the pink bollworm can be forced to attack native cotton."

(2) " Native cotton is so unattractive to the pink bollworm that an artificially induced heavy infestation tends to decrease as the season advances. This is so unprecedented as to mark native Haitian cotton as being unique among all known varieties of cotton."

(3) " The cause of this comparative freedom from attack has not yet been determined, but it appears to be inherent in the cotton itself and not due to outside factors."

Although green bolls at the right stage were plentiful towards the end of my stay in Haiti, scarcely a single infested one could be found, although a few odd plants of Meade cotton had been attacked in every boll.

Natural Enemies.—A small quantity of material for dissection* was obtained from *coton violet* but no parasites were found.

As to parasites in the British islands, the investigation was again hampered by shortage of material. A reasonable number of larvae has been dissected only in Nevis and in Trinidad. In the latter island cotton is not a commercial crop, but Mr. J. B. Hutchinson, of the Cotton Research Station, kindly supplied us with material. The few obtained in Antigua and St. Vincent yielded no parasites,

* For information and kind assistance of every sort during our stay in Haiti, I should like here to thank Dr. H. D. Barker, Head of the Department of Botany in the Agricultural Service.

nor did those collected at Nevis. In Barbados, Mr. Tucker has discovered a new species of *Apanteles* attacking pink bollworm, while in Trinidad some six per cent. are destroyed by another, *Apanteles thurberiae*, which was originally described from Mexico, parasitising an unknown larva in a *Thurberia* plant.

Mr. Tucker of Barbados arranged, through the Imperial Institute of Entomology, Farnham House Laboratory, to introduce into that island the parasite, *Microbracon kirkpatricki*, from the Sudan. When the first consignment reached Barbados, no pink bollworms could be obtained for their consumption and further breeding was impossible. The second lot arrived while Mr. Tucker was on sick leave and were sent on to Trinidad, where a second generation was reared by Mrs. Myers at the Imperial College, upon bollworms kindly supplied by the Cotton Research Station. The second generation unfortunately consisted solely of males, and thus the experiment failed the second time. There will be no incentive to repeat it while the pink bollworm continues in its present scanty numbers. In any case the Trinidad *Apanteles* is apparently a more efficient parasite. Promising parasites are also known in Brazil and Mexico (see Myers, 1928), where they will be investigated as opportunity offers.

2. *Cotton leaf-worm* (*Alabama argillacea*)—*History and Status.*—As we have already referred to the earlier history of this moth as a cotton pest, we are concerned here only with its incidence in the West Indies since the revival of the cotton industry.

It appears that, in the West Indies and North America, the new infestation every season is begun by migrant swarms of moths which arrive from some unknown focus in the south. In Peru, according to Wolcott (1929*a*) the swarms arrive from the north. Their provenience is, it is understood, to be the subject of exploration by United States Federal entomologists during the coming season. We shall await their results with the greatest interest.

In 1903, at the very beginning of the new West Indian cotton industry, the cotton worm appeared in large numbers (Ballou, 1929). In all the British islands where cotton is grown, in Haiti and in Porto Rico (Wolcott), it is periodically responsible for serious damage. St. Vincent long remained an exception. It did not appear in St. Vincent cotton fields till 1907 (Ballou, 1909), and there was never a general outbreak comparable in severity with that of the

other islands until 1926. Planters had kept no stocks of insecticides, and the damage was great. The relative freedom of St. Vincent from this pest has been attributed to the work of natural enemies, chiefly the Jack Spaniard wasp (*Polistes annularis*) (Ballou, 1909).

Natural Enemies.—Parasites tend to increase to large proportions towards the end of an outbreak. They include in our area the following :—

Lesser Antilles.—*Trichogramma minutum* (*pretiosa*) (Ballou, 1913*b*) : *Telenomus* sp. (*l.c.*) ; *Sarcophaga trivittata* (*l.c.*) ; *Tachinid* (*l.c.*) ; *Brachymeria annulata* (*l.c.*) ; *Chalcis* sp. (*l.c.*) ; *Chalcis ovata* (Jemmett, 1909).

Porto Rico.—*Apanteles aletiae* (Wolcott, 1924*c*) ; *Sarcophaga sternodontis* (*l.c.*) ; *Chalcis incerta* (*l.c.*).

Haiti.—*Brachymeria annulata* (J.G.M.) ; *Tachinid* (J.G.M.).

Trinidad.—*Phorocera* sp. (Urich, 1916).

Tobago.—*Chalcis ovata* (Jemmett, 1909) ; *Spilochalcis* sp. (*l.c.*) ; *Sarcophaga* sp. (*l.c.*).

Jamaica.—*Trichogramma minutum* (Gowdey, 1923) ; *Chalcis flavipes* (*l.c.*).

Peru.—*Eucelatoria australis* (Townsend, 1913).

Predators on the cotton worm include the gaulding or heron (*Florida caerulea*) in Antigua (Ballou, 1904*b*)—a bird, the unusual frequency and usefulness of which in Antigua fields have been described in the ecological introduction. Tempany (1913) reports that the ani (*Crotophaga ani*) eats the larvae in the Virgin Islands. The toad (*Bufo narinus*) devours them readily (Anon., 1907*a*). Predacious ground-beetles (*Calosoma* spp.) are useful in St. Vincent (Ballou) and Jamaica (Gowdey). The most important predatory enemies are, however, the wasps of the genus *Polistes*, commonly known as "wild bees," "Jack Spaniards" and "marabuntas." On these, largely owing to their good work in St. Vincent, a voluminous literature has already grown up. In St. Vincent (Ballou, 1915*a*) *Polistes annularis* "was of so much value that for some ten years cotton was grown in that island without resort to the use of Paris green or other poison for the control of this pest which, during these same years, caused so much loss and expense in other islands." Substantial sheds for it to nest in, were erected in the fields by the planters. As we have seen, it is by no means certain that the

especially good work of the St. Vincent Jack Spaniards is due to a greater efficiency of the local species rather than to an environment especially favourable to the maintenance of a large population of these wasps. Nevertheless, attempts were frequently made to introduce the St. Vincent species into other islands, including Montserrat, Grenada, Antigua, Nevis, St. Lucia. In Montserrat and St. Lucia it is established in certain more or less restricted localities ; but the other attempts were largely failures (Ballou, 1910, 1915*a*, 1917). Failures have been in part attributed to the moth, *Dicymolomia pegasalis*, which destroys the combs of these wasps, but this, or a similar species, occurs also in St. Vincent (Harland, 1916*a*).

The distribution of the various parasites has been but little investigated. During the present investigation the only country in which the season of visit gave an opportunity of studying this migrant pest was Haiti. There an infestation was just finishing and an opportunity was taken to collect some pupae—the only stage present. These were parasitised at the rate of 7·2 per cent., being 4·8 per cent. by the Chalcid, *Brachymeria annulata*, and 2·4 per cent. by a large Tachinid not yet identified. In Nevis, according to Ballou (1913*c*, 1922*a*), a Chalcid is especially abundant, parasitising up to 80 per cent. of the pupae. It is noteworthy that the parasites of the cotton worm are usually, and in fact almost necessarily, rather general in their host relations, and, probably partly on this account, they normally fail to catch up with their hosts until the infestation is nearly at an end and the damage—which may amount to complete defoliation—done. And since the infestation of the succeeding year is derived solely from fresh immigrants to the island, the chances of biological control seem rather remote. An opportunity will be taken, however, to study special parasites of this pest on the mainland.

3. *Cotton-stainers* (*Dysdercus* spp.).

Some one or more species of these brilliantly-coloured plant-bugs occur throughout the West Indies, whether cotton is grown or not. They are closely attached to plants of the allied families Malvaceae, Bombacaceae, and Sterculiaceae. The writer has already published an extended study of the biology of the Cuban species (Myers, 1927).

One Tachinid fly parasite (*Trichopoda* sp.) (Urich, 1916) has been recorded from the West Indies (Trinidad), but the rate of parasitism must be extremely low, for the several thousands of adults and

nymphs of all ages dissected during the present investigation in Trinidad, Nevis, St. Kitts, Montserrat, Haiti, Cuba, and Jamaica, failed to show a single parasite.

It may eventually be found necessary to look outside the New World for effective parasites of *Dysdercus*. We know three main types of utilizable natural enemies elsewhere—predacious bugs (*Phonoctonus* spp.) attacking nearly all stages, Tachinid flies parasitising the adults, and a Chalcid parasite destroying the eggs. Furthermore we have the testimony of Ritchie (1925) that he has not seen, in Africa, mass infestations of cotton-stainers like those he was familiar with in the West Indies. Is it not significant that it is in Africa that the numerous species of *Phonoctonus* are widespread, and at least five parasitic Tachinid flies occur, while in the West Indies, on the other hand, there is the evidence of Ballou, the present writer, and other observers, that natural enemies, other than lizards, are extremely rare?

Two efficient Tachinid parasites have been reported (Ballard and Evans, 1928) also from Queensland, whence it might, as suggested by Dr. Thompson, be more feasible to import them than from West Africa. Negotiations towards this end are now proceeding.

4. *The Green Bug* (*Nezara viridula*).

History and Status.—This large and particularly evil-smelling indigenous plant-bug is, at least in some areas (e.g., Nevis), a more serious pest of cotton than the stainers. It attacks the green bolls.

It is, however, even more important as a pest of other crops. Everywhere crops alternative to sugar-cane are being suggested with a view to mitigating the present depression. An energetic effort is now being made in the Leeward and Windward Islands to build up an export vegetable trade with Canada. This has already reached promising proportions, especially in the case of tomatoes, but the green bug is well known as a vegetable pest and renders a large percentage of the green tomatoes useless. The nymphs, during and after the second stadium, and the adults, suck the fruit and cause first, collapsed and discoloured areas, and later rotting. The only remedy at present is hand-picking.

The green bug is widely distributed in the tropics and has long been an important vegetable pest in Eastern Australia. Lately it

has reached West Australia where it is already doing great damage. An effective parasite would thus be of value not only to the West Indies but to the Southern Dominion.

Natural Enemies.—The position of the green bug in tropical America is curious, and not fully understood. In Florida it is said by Jones (1918), Drake (1920) and Watson (1929) to be heavily parasitised by a Tachinid fly, *Trichopoda pennipes*, which may in some localities (Watson) control and even exterminate it. Drake, who records a parasitism of from 10–80 per cent. by the same fly, reared also one specimen of *Trichopoda lanipes*, and observed further a parasitism of about 6 per cent. by the fly, *Sarcophaga sternodontis*. He found an occasional Chalcid egg-parasite, *Ooencyrtus* sp., while Miller (1928) records another, *Telenomus* (*Microphanurus*) *megacephalus*.*

Wilson (1923) observed the green bug in St. Croix parasitised up to 93 per cent. by *Trichopoda pennipes*, but still recommended hand-picking.

In St. Vincent the green bug is well controlled by egg parasites (Ballou, 1922*a*), including *Habrolepoidea submetallica* (Harland, 1917) and an unidentified species.

In the Guianas this pest seems rare, and hardly less so in Trinidad, where the scanty material obtained yielded no parasites. More extensive series of adults and nymphs were collected in Nevis (from cotton), in St. Kitts (from okra), in Montserrat (from tomatoes and *Crotalaria*) and in Antigua (from cotton). Dissection of these showed the adults to be parasitised at the average rate of 8 per cent. (5·9 per cent. in Antigua, 8·3 per cent. in Nevis, 9·4 per cent. in Montserrat and less than 3 per cent in St. Kitts) by a Tachinid fly, *Trichopoda pilipes*.†

A fungus parasite, *Isaria Pattersonii*, originally described from the Gold Coast, has been recorded in Grenada (Anon., 1913).

The most efficient known parasite is obviously the Tachinid fly, *Trichopoda pennipes*. Drake found that a species of *Crotalaria* attracted these flies in Florida, so that bugs feeding upon this plant

* This species occurs also in Grenada and St. Vincent, having been originally described from the latter island. We have recently received it from South Africa, where Mr. Ullyett records that it frequently parasitises 100% of the eggs in egg-batches of *Nezara viridula*.—G.A.K.M.

† Kindly determined by Miss D. Aubertin, of the British Museum.

were uniformly more highly parasitised. It is perhaps significant that a large proportion of the green bugs dissected in Montserrat, where the rate of parasitism by *Trichopoda pilipes* was higher than in the other islands, were collected on *Crotalaria.*

To sum up, it appears that on the whole considerably fewer adult green bugs are parasitised in the British West Indies than in St. Croix and Florida, but egg parasites are said to be highly efficient in St. Vincent. It is hoped that a study of the green bug situation in St. Vincent and on the mainland will throw light on the problem in the other British islands.

Miscellaneous Cotton Pests.—Incidental attention has been paid to cotton aphis (*Aphis gossypii*), which is heavily attacked in Trinidad by the larvae and adults of the ladybird *Cycloneda* sp. and the larvae of the Syrphid fly (*Ocyptamus dimidiatus*). Unfortunately these efficient predators were themselves destroyed, the former at a high rate, by the Encyrtid, *Homalotylus terminalis,* and the Pteromalid, *Neocatolaccus syrphidis,* respectively. Outbreaks of cotton aphis are always sooner or later checked by natural enemies.

Considerable numbers of a small green Typhlocybid leafhopper (*Empoasca* sp.) infesting cotton, at times badly, at the Cotton Research Station, Trinidad, were dissected. The adults showed a parasitism of about 8 per cent. by a Dryinid wasp which was unfortunately not reared to maturity. The eggs were not investigated.

(d) *Mahogany and Cedar Pests.*

In 1927 Mr. Oliphant, then Conservator of Forests in British Honduras, called at the Farnham House Laboratory to ask for advice and assistance in the biological control of the mahogany-shoot borer (*Hypsipyla*). This moth still remains the chief insect pest of British Honduras, where the export of mahogany is of paramount importance. Meliaceous timbers are exported also from British Guiana, and are of economic interest in Trinidad and Barbados as well, hence the inclusion of *Hypsipyla* in the present investigation.

1. *Mahogany-shoot Borer* (*Hypsipyla* spp.). *Status.*—Soon after arrival in Trinidad the writer was asked by the Conservator of Forests to advise as to the possibility of biological control for this pest. Fairly adequate preliminary ecological and parasitological studies have now been made in Trinidad, British Guiana, Cuba, Santo Domingo and Jamaica, with cursory examinations in the

smaller islands, but the main sphere of activity, British Honduras, has not yet been visited. Until this has been done, it is proposed to defer a detailed comparison of the ecological conditions under which Meliaceous timbers are grown in the various countries visited.

Not a single natural enemy of *Hypsipyla* has heretofore been recorded from the New World. Some half-dozen more or less efficient parasites are known in India and the Far East, but toon (*Cedrela toona*) is still heavily attacked by the borer, *Hypsipyla robusta*.

The known host-trees, in order of infestation, are as follows :— Crabwood (British Guiana) or Crappo (Trinidad) (*Carapa guianensis*); Honduras mahogany (*Swietenia macrophylla*); cedar (*Cedrela mexicana*); West Indian mahogany (*Swietenia Mahagoni*). Of these the last, as we shall see, is hardly attacked at all. In Trinidad no infestation has been found on it.

The injury consequent on *Hypsipyla* attack is out of all proportion to the actual killing of shoots. The greatest economic damage is inflicted on young trees or saplings before they have branched very much, the leader being killed time after time and replaced by side-shoots until the main stem is bent into the most tortuous shapes and the tree, from a timber viewpoint, utterly ruined.

The main Trinidad species of *Hypsipyla* is *H. ferrealis*, while the British Guiana one investigated is *H. grandella*. None of the forms studied in the northern islands has yet been reared to the adult and are thus not determined specifically. Locally they have received no study whatever. The species are, however, extremely close and the habits strikingly similar.

To begin with ecological considerations, *Hypsipyla* is essentially, wherever it occurs, a rain-forest insect, save possibly in Barbados and St. Kitts where it has almost certainly been introduced, and has been found attacking cedar (*Cedrela mexicana*) and mahogany (*Swietenia macrophylla*) only under cultivated conditions.

In Trinidad it was thought by the local Forestry Department officers that it occurred only in the plantations, but a search in the virgin forest of the Central Range showed it to be attacking quite plentifully crappo (*Carapa guianensis*) and cedar (*Cedrela mexicana*) under purely primitive conditions. It was found also, under these circumstances, that the power of recovery of the young tree, both

in speedily occluding* the cavities of the borings and in straightening its stem after the killing of successive main shoots, was much greater than plantation experience had indicated. No parasites were found in the forest material, but collections from this source have not yet been adequate. Other Meliaceous trees, such as those of the genera *Guarea* and *Trichilia*, were found not to be attacked, and this was confirmed later in British Guiana and throughout the Greater and Lesser Antilles wherever they occur. Nor was the common cultivated or escaped and naturalised *Melia Azedarach* (*M. sempervirens*) infested in any of the same localities.

In plantations in Trinidad both Honduras mahogany and crappo are so greatly injured that their commercial growing is at present severely handicapped. Cedar is only somewhat less attacked. The life-history has been only partially worked out, and the eggs of the insect and the way in which it passes the dry season were alike unknown. Both these points were cleared up in British Guiana by the discovery that the flat, inconspicuous eggs are laid in one generation on the shoots themselves and in another on the fruits, either on the trees or fallen to the ground, and that at least one generation is passed boring in the fallen seeds.

Trinidad.

Much material for dissection was collected in Trinidad plantations or sent in by Forestry officers through the kind assistance of the Conservator of Forests. Most of this was from crappo (*Carapa*). It was found difficult to secure adequate material from other hosts.

Three insect parasites and a fungus, in addition to an occasionally predatory earwig, were found. These accounted for 3·80 per cent. of the larvae and pupae dissected—a very low rate of parasitism.

One of these, which is extremely rare, and was not reared to maturity, is a Microgasterine Braconid, apparently a solitary species of *Apanteles*. The larvae and pupae dissected showed a parasitism of only ·38 per cent. A Tachinid fly, which has been reared but not identified, accounted for·76 per cent., and a similarly undetermined *Sarcophaga* killed 1·14 per cent. A fungus—apparently a *Cordyceps*—showed a parasitism of 1·52 per cent.

* A remarkable instance of this was seen in a small cedar growing in virgin forest in the Central Range, Trinidad. An old *Hypsipyla* boring, containing the remains of a green bee (*Augochlora* sp.) and its nest, had closed over completely, leaving no external trace of the opening.

To sum up the position in Trinidad then, *Hypsipyla* is not uncommon in the virgin forest, but does not become a really serious pest until the institution of plantation conditions brings about an ecological upheaval, the attempted mitigation of which by supplying such shade as that of bananas and balisier (*Heliconia Bihai*) has not yet been successful. Captain Marshall, Conservator of Forests, is now encouraging a growth of woody plants beneath the trees of his plantations, and is thus regenerating under more natural conditions. This is almost certain to lead to some decrease of borer. At the same time a more efficient parasite than any of the indigenous ones would be desirable.

Suriname.

Professor Stahel informed me that introduced mahogany (*Swietenia macrophylla*) is badly bored by an insect which I think must be *Hypsipyla*. I saw none of this insect in the interior (Coppename River), but I had no opportunity to examine much cedar or crabwood.

British Guiana.

In British Guiana, there has been so far practically no attempt to grow any timber trees commercially. The hosts of *Hypsipyla*, which were investigated in the virgin forest of the North-West District, notably on the Barima and Waini Rivers, are practically the same as in the Trinidad forest save that there are two distinct species of cedar (*Cedrela*), one of which is apparently *C. mexicana*, but neither of which has yet been authoritatively determined. Neither was found attacked by *Hypsipyla*. Both cedar and crabwood (*Carapa guianensis*) are exported. Of the latter there is probably more than one species.

Now that the agricultural possibilities of the vast forested hinterland of British Guiana are on pedological grounds definitely called in question, the timber resources deserve more attention than ever; and here as in British Honduras, *Hypsipyla* is undoubtedly the chief insect enemy of the most valuable of the timber trees.

The discovery of at least an entire generation of this insect subsisting on the fallen fruits has been already mentioned. Although broken valves of the fruit capsule were plentifully scattered wherever crabwood grew, great difficulty was experienced in collecting any

considerable quantities of seeds from the floor of the virgin forest. It was found that these were very quickly sought out and devoured, whether infested by *Hypsipyla* or not, by agoutis or acuris (*Dasyprocta aguti*). On a small experimental plantation of crabwood and other trees just outside the Government Compound at Mabaruma (North-West District) fallen fruit was plentiful and remained on the ground long enough for *Hypsipyla* to pupate within the hollowed seed and to emerge as a moth, as was repeatedly found. Later, however, the Indians collect large quantities of the seed to obtain the oil Here agoutis, if they came at all, were evidently rare ; and it would appear that in the virgin forest a very important, if not the most important, agent of natural control, is this small rodent, which destroys a certain number of the actual grubs and greatly reduces the food supply of the remainder. The agouti occurs also, of course, in Trinidad, but more rarely, and it invariably retreats before the advance of settlement.

Two new parasites were found in British Guiana, both exceedingly rare, there being only one case of parasitism by each. One was a Mesostenine Ichneumonid of the genus *Stenarella*, indistinguishable from *S. brevicaudis* described from Peru, and attacking the full-fed larvae within the cocoon, in which it builds its own. The rate of parasitism was only ·14 per cent. The other was an egg parasite of the family Trichogrammatidae, not yet determined. This parasitised ·97 per cent of the eggs. Neither of these seems very promising so far as our present knowledge goes.

Cuba.

Hypsipyla was next studied in Cuba. We have seen that this insect is essentially a denizen of true rain-forest in the strictest sense of the term. And this hardly exists in Cuba. Both cedar (*Cedrela mexicana*) and mahogany (*Swietenia Mahagoni*) are common trees, but no sign of *Hypsipyla* was found in the coastal, lowland, or mountain forests. The West Indian mahogany is markedly more xerophytic than its Honduras cousin. It has smaller, drier and more leathery leaves and thinner, harder twigs and shoots. The tendency towards extreme mesophytism reaches its limit in *Carapa*, which has very thick juicy shoots, and is, as we have seen, the favourite host of *Hypsipyla*. *Carapa* is said to occur in Cuba only in one restricted locality in the extreme east.* In the time available it was not

* I am indebted to Brother Leon for information on this.

possible to make the necessary boat and horse-back journey. It was possible, however, at the Harvard Botanical Garden, Soledad (southern Santa Clara), to examine a number of specimens of imported Meliaceous trees, including many very healthy Honduras mahogany, some toon (*Cedrela Toona*) and various American species of *Cedrela*. None of these had been attacked by *Hypsipyla*, and since many were in the highly susceptible stages of growth this can be taken as evidence that *Hypsipyla* is absent from this part of Cuba at least.

West of here, a special journey was made to the extraordinary hardwood forest growing on almost bare limestone at the Ensenada de Cochinos, south of the Cienaga de Zapata, but no trace of *Hypsipyla* was found in the abundant mahogany (*Swietenia Mahagoni*) there.

Haiti.

In Haiti, at least in the localities visited, conditions were much more xerophytic. Mahogany (*S. Mahagoni*) was a common tree both in forest and scattered in pastures. Cedar (*C. mexicana*) also occurs. No traces of *Hypsipyla* were found.

Santo Domingo.

In Santo Domingo, through the kindness and botanical knowledge of Dr. Ekman, a visit was paid to a locality where, almost alone in the Greater Antilles, an extensive area of true rain-forest occurs. In this, *Carapa guianensis* was one of the dominant trees, and was found to be suffering from *Hysipyla* attack to an extent most unusual in virgin forest. Unfortunately the time was between broods, and no living material was obtained, but an empty puparium showed the presence of a Tachinid parasite similar to, if not identical with the Trinidad species.

Jamaica.

In Jamaica, mahogany is not now a very common tree, but cedar (*Cedrela mexicana* ?) is abundant—sometimes exceedingly so. It is especially common at 2,000 feet in the Blue Mountain valleys, and occurs up to 3,700 feet; but as no virgin forest was examined below that elevation it was not seen under really primitive conditions. Scattered signs of *Hypsipyla* injury to cedar were seen, but the infestation was extremely low, and the power of recovery of this

species apparently greater than that of *Cedrela* in Trinidad. At any rate the economic damage was negligible. Whether it would continue so were cedar to be grown under commercial plantation conditions, it would be unsafe to prophesy. It was hard to collect sufficient material of *Hypsipyla* for dissection, but three larvae finally obtained showed two parasitised by a solitary-living *Apanteles* species, perhaps the same as the un-reared Trinidad form.

The Lesser Antilles.

In the Lesser Antilles *Hypsipyla* was found in cultivated districts on road-sides and fence-lines, attacking cedar (*Cedrela mexicana*) in St. Kitts, and mahogany (*Swietenia Mahagoni*) in Antigua, in the former not commonly and in the latter extremely rarely. Mahogany thrives exceedingly in Antigua and might well receive more commercial attention seeing that it does so in the presence of such an unusually serious pest. One tree of *Carapa guianensis* in the Antigua Botanic Gardens and another in that of Grenada were fairly heavily infested. In Barbados *Hypsipyla* is responsible for constant heavy damage to plantations of Honduras mahogany, in the vicinity of which West Indian mahogany is occasionally, though very rarely and slightly attacked. In Montserrat, Honduras mahogany was badly attacked by *Hypsipyla*, but West Indian mahogany looked exceedingly well, and showed no signs of infestation. The old, gnarled *Cedrela* trees growing about the fields seemed also free from *Hypsipyla*. In St. Lucia I saw *Cedrela* seedlings at the Union Nursery heavily bored. It there attacks also Honduras mahogany, and to a much less extent the West Indian species (Ballou, 1918; Hutson, 1920). The cedar is said to be preferred.

Summary.

The present position then is, that at least five different species of parasites have been discovered and partially studied, but the more promising of them seem to be already present in Trinidad, and the rate of parasitism is everywhere, save perhaps in Jamaica, very low.

But little can be done to further the *Hypsipyla* investigation until conditions in British Honduras have been examined personally, and the incidence of local parasites studied. The search for new parasites will be continued as opportunity offers during other investigations.

(e) *Arrowroot Pests.*

Leaf-roller (*Calpodes ethlius*).—Arrowroot is the chief crop of St. Vincent, but is not important in any of the other colonies. By far the most injurious insect pest is the arrowroot skipper (*Calpodes ethlius*), the larvae of which roll and eat the leaves.

This insect attacks a number of other plants of the related families Marantaceae and Cannaceae. Indigenous species of *Canna*, serving as host, are very plentiful in some of the islands, but so far these have not been visited at a time when the pest is active. Neither has it yet been possible to spend a few weeks in St. Vincent at the season when *Calpodes* is most abundant. Until this has been done it will not be possible to suggest introductions; but a number of dissections have been made of material from garden *Cannae* in Cuba, and two parasites have been found attacking the larva with a combined parasitism of only 1·98 per cent. (·99 each). One is a Chalcid (*Euplectrus* sp.) and the other a Tachinid, but the latter is attacked by hyperparasites (a small Braconid—*Aphaereta apicalis*).

Harland (1917) has recorded three flies attacking the arrowroot worm in St. Vincent, the Tachinid fly, *Eucelatoria australis* (a parasite of the cotton worm too), and a Sarcophagid (*Sarcophaga* (*Sarcodexia*) *sternodontis*) and a third not determined. There are also in St. Vincent two egg parasites—*Trichogramma minutum* (rarely) and an undetermined species (Harland, 1916*b*). Parasitising the eggs in British Guiana are the two Chalcids, *Holcencyrtus calypso* and *Elachertus meridionalis* (Crawford, 1914).

(f) *Sweet Potato Pests.*

Sweet potatoes (*Ipomoea Batatas*), although not to any great extent an export crop, are of first-rate importance in the local food-supply throughout the islands. Their most destructive pests are two species of weevils, of which one (*Cylas formicarius*) is of almost world-wide distribution, while the other (*Euscepes batatae*), which does much more damage where it occurs, is confined to tropical America.

Scarabée or Jacobs (*Euscepes batatae*).—Although fairly generally distributed, this insect is a serious pest only in Barbados and in certain of the Leeward and Windward Islands such as St. Kitts, Nevis, and Antigua, and to a less extent in Jamaica. It does

much damage in Montserrat. In British Guiana it is very rare—so much so that it was impossible to collect adequate material for study. In Trinidad it apparently does not occur, though introduced more than once in sweet potatoes from the Grenadines.

Ballou finds that the infestation can be reduced by scrupulous care in the planting of uninfested slips and later by rotation of crops. Even with these precautions, however, it seriously limits the sweet potato crop in Barbados.

In Haiti none was found though *Cylas* is plentiful. In fact, although *Cylas* and *Euscepes* are definitely known to occur in some cases in the same colony (e.g. British Guiana and Jamaica) no single instance was observed of their simultaneous occurrence in the same potato or even the same field. This is curious and unexplained.

Fairly abundant material of the larvae and pupae was dissected in Nevis and Antigua, but no parasites or predators were found. A curious disease, apparently bacterial in origin, was killing a small percentage in Antigua; but in view of the repeated failures to spread insect bacterial diseases artificially, this was not considered to be of any economic promise.

The most favourable field for the search of new effective parasites will undoubtedly be the mainland, notably Brazil, where the insect occurs but does not become to any extent a pest.

(g) *Coconut Pests.*

Although coconuts are among the most valuable crops of the West Indies, their insect pests are neither numerous nor very serious. being swamped in importance by certain obscure diseases which fall within the province of the mycologist and physiologist rather than the entomologist.

The gigantic larvae of *Castnia daedalus* are at times very injurious, but in the British colonies only in British Guiana. There they have recently been the subject of an admirable and detailed study by Mr. Cleare, Government Entomologist. They do not occur in any other area yet visited in the present investigation, but a search for suitable parasites will be duly made on the mainland.

Butterfly larvae of the genus *Brassolis* (*B. sophorae*) occasionally increase to the proportions of serious outbreaks causing wholesale defoliation. A considerable list of parasites has been compiled by Mr. Urich (1915) in Trinidad and Mr. Cleare (1915) in British Guiana, but no opportunity for studying this complex has offered during the present mission. It is interesting that de Andrade (1929) reports the related insect, *Brassolis astyra*, to be parasitised at the rate of 75 per cent. in Brazil by a fly, *Xanthozona*.

The transparent coconut scale (*Aspidiotus destructor*) is present throughout, and at times highly injurious, more in the northern islands than in Trinidad and British Guiana. In Trinidad a study of the predatory enemies has been made by Mr. Taylor, on behalf of the Fiji Government. The most important are three species of Coccinellids or ladybird beetles, of which the most effective, *Cryptognatha nodiceps*, has been already established in Fiji.

Examples of this scale studied at St. Augustine were found to be heavily parasitised by the Chalcid, *Aphelinus chrysomphali*.

(h) *Banana Pests.*

So far as the British colonies are concerned bananas as an export crop are now important only in Jamaica. There, however, they are an exceedingly valuable crop. The only insect pest of any importance which has yet reached the New World is the banana-borer (*Cosmopolites sordidus*).

Banana-borer (*Cosmopolites sordidus*).—This is an Eastern insect occurring also in Australia, Africa, and Madagascar, but introduced into the New World in comparatively recent times. It has been known in Brazil for eighty years, but in the West Indies for not more than twenty. In British Guiana it does not occur; in Trinidad it is by no means serious; in Jamaica its ravages on small plantations and peasant cultivations are very great, but on the larger plantations it is frequently controlled by clean cultivation and estate hygiene. In Haiti, where bananas are grown chiefly by peasants, it is a pest of the first order; while in Porto Rico it is causing increasing alarm. In Cuba it apparently does not occur. Confusion frequently arises with the attacks of the other weevil borers (*Metamasius* spp.) which bores cane as well, but in banana is certainly entirely secondary.

No parasites of the banana-borer are known. The only recorded predators are a Histerid beetle (*Plaesius javanicus*) and a Leptid fly (*Chrysopilus ferrugineus*) from Java. These have both been introduced into Queensland, but are apparently of very little value, although in Fiji, where *Plaesius* was also established many years ago, Mr. Simmonds, Government Entomologist, states that it is now increasing and doing good work. The same beetle was also imported into Jamaica, where it failed to establish itself. It is not recommended that this experiment be repeated, until a search has been made for an effective parasite. This would unquestionably be more promising. It has already been suggested above that the most likely field to search is New Guinea.

In the West Indies banana-borers have been studied and dissected whenever opportunities offered, notably in Jamaica and in Haiti. In the former island a local Histerid (*Lioderma 4-dentatus*) was found in very small numbers preying on the larvae. Suspected predators in Haiti include the larva of an Elaterid and a large earwig (*Anisolabis maritima*).

(i) *Coffee Pests.*

Coffee is important in British Guiana (North-West District), Trinidad, and Jamaica, but is not usually attacked by insect pests comparable in seriousness with those infesting cacao or sugar-cane. It was not therefore proposed to make a special study of coffee insects.

St. Lucia, however, is attempting to revive its coffee industry, which collapsed many years ago from indefinitely recorded causes. Local conditions seem eminently suitable for growing coffee, and a start has been made with stocks from the Blue Mountains of Jamaica. The young nursery plants are, however, very heavily attacked by leafminers (*Leucoptera coffeella*) and the Administrator made a special request for advice and assistance along biological lines.

1. *Leafminer* (*Leucoptera coffeella*).

When St. Lucia was visited in the course of sugar-cane pest studies opportunity was therefore taken to examine the various nurseries and to obtain material of the pest. *Coffea arabica* and *Coffea robusta* seemed equally attacked. It is to be doubted whether the damage will be so great when the trees are put out into plantations and are more fully grown; but this, of course, remains to be seen. In the meantime the young plants are very heavily checked.

Dissection of large quantities of larvae of all ages and of pupae revealed the presence of not a single parasite. Eggs were not studied.

A number of Hymenopterous parasites have been recorded from Porto Rico and from Venezuela, and it should be later possible to introduce some one or two of the most effective of these. The most promising seems to be the Chalcid, *Chrysocharis lividus*.

2. *Green scale* (*Coccus viridis*).

This scale insect, which is one of the worst coffee pests of the East, has been introduced into the West Indies not more than 30 years. In the Lesser Antilles, it was first identified in Dominica in 1905 (Ballou, 1911*b*). In Jamaica, where it was not even recorded until the present investigation, it is now widespread and serious both on coffee and on citrus. It is, moreover, assiduously fostered by the "Dugald Campbell Ant" (*Crematogaster* sp.) which is used locally to combat the citrus black-fly (*Aleurocanthus woglumi*). The citrus industry is becoming of increasing importance throughout the West Indies, and this is one of its gravest actual or potential pests. In the wetter islands like Dominica it need not be feared, for there, as noticed by many previous observers, parasitism of scales by fungi is in general so constant and effective as to preclude their becoming pests. In the others, the possibility of importing one or other of the known parasites of the green scale from the East should be eventually considered.

(j). *Cattle pests.*

Horn-fly (*Lyperosia irritans*).

It was suggested at the beginning of the investigation that attention should be paid to any parasites or other natural enemies of the horn-fly which might be utilised in Australia against that very serious allied pest, the buffalo fly (*Lyperosia exigua*).

Nothing but negative results are to be reported so far. This is the more disappointing in that considerable time has been spent, especially in Cuba, collecting and rearing fly larvae from dung. The distribution of the horn-fly in the West Indies is exceedingly patchy. This was known to be the case in Porto Rico, and has been found so in the other islands visited. It is felt that a thorough study of the factors limiting this distribution would be extremely valuable, but it has not yet been possible to take it up.

(k). *Miscellaneous pests.*

Incidental attention has been paid to a few other pests of agriculture.

Stingless Bees Damaging Citrus.—Hitherto the chief insect pests of citrus in the New World have been scale-insects. These have been referred to in general terms in several sections of this report. In many islands, especially Dominica, they are apparently regularly controlled by fungous parasites. In Grenada I found them doing more damage than one would expect under such humid conditions. The green scale has been dealt with under coffee insects, but is also an important pest of citrus. There has been no opportunity yet to investigate properly the citrus scales.

A preliminary study has, however, been made of a new citrus pest which is increasing in importance. This is an indigenous stingless bee of the genus *Melipona*, which attacks very severely the improved grape-fruit which is being brought into extensive cultivation in Trinidad, British Honduras and elsewhere. It bites the young shoots apparently to collect the resinous sap, and may in extreme cases completely kill three-quarters or more of the main shoots. The fruit also is attacked and ruined. The huge nests are placed often high up in trees, frequently at some distance from a cultivation, and are hard to locate. I am indebted to Mr. Horace Rapsey for the opportunity to examine in detail a large nest of the Trinidad species.

Unfortunately our ignorance of the biology of these bees is immense. We are only at the beginning of their study. This is exemplified by the fact that in a very valuable summary recently published by Salt (1929*b*) only some fifty-two parasites and nest associates are listed for the world; while in the Trinidad nest mentioned above we found nearly 30 species, several of which are new. We are as yet entirely ignorant as to the possible value of these nest-associates in biological control. Mr. Urich, however, informs me that he has seen weak colonies completely destroyed by a small Phorid fly parasite. It is hoped to investigate other natural enemies on the mainland. In the meantime the only feasible line of attack is to locate and destroy the nests with calcium cyanide. These are fortunately few and far between, and when found represent enormous centres of population. The efficiency of this method is, however, linked up with the distance the foraging bees ordinarily fly from the nest, and on this point we are entirely ignorant. If it be

necessary to search any great distance in the surrounding forest then this method is nearly hopeless. It is significant that attacks are only reported from localities (Trinidad, British Honduras), where there are often considerable areas of forest adjacent to cultivations.

Crotalaria Moth.—There is a growing tendency in West Indian agriculture towards the use of cover crops. One of the most useful of these is *Crotalaria* (various species), which is everywhere very heavily attacked by the caterpillars of several species of brilliantly coloured moths of the genus *Utetheisa*. Their eggs are extensively parasitised by the *Trichogramma* (*T. minutum*) which destroys also the eggs of the cane moth-borer (*Diatraea*), and it has been suggested, notably by Harland, that such alternate hosts are valuable in maintaining a steady population of the egg-parasites. It is questionable however, whether this theory is sound, and whether purely specific parasites are not, in every case, to be preferred. Larvae of *Utethesia ornatrix* in British Guiana showed a low rate of parasitism (less than 0·3 per cent.) by a Sarcophagid fly.

Cassava midge.—In Trinidad Mrs. Myers made a study of the cassava gall-midge (*Iatrophobia brasiliensis*) and its two Chalcid parasites, *Aprostocetus fidius* and *Aprostocetus* sp. The results have been embodied in a paper now in the press for the *Bulletin of Entomological Research*. The rate of parasitism was at times surprisingly high. Cassava, though of little export significance, is, like sweet potatoes, a crop of great importance in the local food supply.

Cassava and Pawpaw Hawkmoths.—An *Apanteles* was reared in large numbers from the cassava and pawpaw hawkmoths (*Erinnys ello* and *E. alope*) in Cuba and Haiti. A large number of hyperparasites were reared, but these have not yet been all determined.

Aethalion.—The leafhopper (*Aethalion reticulatum*), which is a pest in Brazil, and may become so in the British colonies, was found in British Guiana to be heavily parasitised in the adult stage, by an interesting new Encyrtid, belonging to an entirely new genus. The eggs were parasitised by another Chalcid.

Natural Enemies of Collembola.—In pursuit of a parasite which might be utilised against the lucerne flea (*Smynthurus viridis*) in Australia, two small wasps (*Microstigmus theridii* and *M. myersi*), discovered by Mr. Urich, were studied at some length in Trinidad.

They make small hanging nests which they provision with Collembola, chiefly of the family Entomobryidae, although I have found at least one Smynthurid among their prey.

The melon moth (*Diaphania hyalinata*).—A highly interesting parasite complex was found to centre round this moth in Cuba, and some ten species of parasites and hyperparasites were reared. These have not yet been all identified.

Finally, a systematic list of the parasites so far studied and identified on various pests during the present investigation has been presented for publication in the *Bulletin of Entomological Research.* A similar paper dealing with the biology of the parasites is in preparation.

V.—PARASITES FOR THE WEST INDIES FROM THE OLD WORLD TROPICS.

As mentioned incidentally in the preceding pages, there are several pests which are indigenous to the Old World and have been introduced into the West Indies within recent years. There are other cases in which the same pest, or closely allied species, are very much more effectively parasitised in Africa or the East than in the American tropics. The possibility of introducing these parasites into the West Indies from the Old World tropics must eventually be considered. Only by this means can we hope to control biologically and permanently the pests concerned. The most important of these, with the country in which desirable parasites are either known or suspected to exist, may be recapitulated as follows :—

Cacao thrips (*Heliothrips rubrocinctus*), Gold Coast.

Cotton-stainers (*Dysdercus* spp.), Nigeria, Queensland.

Citrus blackfly (*Aleurocanthus woglumi*), South-East Asia. (But some of these have already been brought to Cuba and may perhaps later be introduced into Jamaica from there. Negotiations have been opened with the United States Federal Authorities with this end in view.)

Green scale (*Coccus viridis*), South India.

Banana-borer (*Cosmopolites sordidus*), New Guinea.

VI.—SUMMARY.

1. The report covers a period of a year and a half actually spent in the field.

2. During this time, 17 major pests have been investigated, with special reference to their natural enemies or other limiting factors. In the course of this work some 30,000 dissections have been made, and numerous observations on ecological conditions. It is held that a very great aid in the eventual control of a pest is afforded by studying it whenever possible in the primitive conditions of its original habitat.

3. Advice has been given, on request, to local Governments, planters' organisations and individual planters, and schemes have been drawn up for intensive local research on cane-borers and on froghopper.

4. The most important pest of sugar-cane in the region as a whole is the small moth-borer (*Diatraea* sp.).

5. Only two of the numerous parasites have proved reasonably efficient. Of these, *Lixophaga*, which is more effective, is apparently ecologically suited only to the conditions prevailing in the northern islands. It has accordingly been introduced into Barbados and Antigua, whence it may later be taken to St. Kitts, and perhaps St. Lucia.

6. The other valuable parasite, *Paratheresia*, occurs already in all the areas where it is likely to thrive, save the British Guiana province of Berbice and the island of St. Lucia. It may be advisable to introduce it into these two places; but in the meantime the search for a more efficient parasite for Trinidad and British Guiana will be continued on the mainland.

7. Bulky data have been accumulated on the distribution of the small moth-borer and the complex of factors influencing it.

8. The large moth-borer of cane (*Castnia licoides*) is now serious only in Trinidad, since it is controlled by flooding in British Guiana. It is widespread and increasing in Trinidad and an effective parasite is badly needed. No parasites are at present known, but the original food-plant of *Castnia* has been found by Mrs. Myers, and the search for parasites can now be pursued with every hope of success.

9. The Trinidad cane froghopper (*Tomaspis saccharina*) remains a pest of the first order in spite of the excellent ecological work already done on it. A new and remarkably efficient froghopper parasite (*Carabunia*) studied in Cuba was found not to attack froghoppers of the genus *Tomaspis*. It is hoped to discover an effective parasite on the mainland.

10. Cane root-borer (*Diaprepes abbreviatus*) is a very serious pest in Barbados. An effective egg parasite of two allied species has been studied in Haiti and Montserrat, and its introduction into Barbados is being arranged.

11. Cacao thrips (*Heliothrips rubrocinctus*) has been studied in Trinidad, Haiti and Jamaica, and a new Capsid predator discovered in the latter island. It is not, however, very effective, and the introduction of the Gold Coast thrips' parasite is advised.

12. Cacao beetle (*Stirastoma depressum*) was investigated in Trinidad and the Guianas. Six parasites have been studied in Trinidad, but a more effective one is needed, and the most likely field to search for this is Ecuador.

13. A visit to a stand of true wild cacao in Suriname showed, in conjunction with other data, that neither thrips nor beetle are pests of the wild tree, but have become attached to it since its cultivation on the coastlands.

14. The pink bollworm (*Platyedra gossypiella*) was introduced into the British West Indies about 1920. It at once became a serious pest, but has lately, from unknown causes, decreased to economic negligibility. A promising new parasite has been discovered in Trinidad.

15. The cotton leafworm (*Alabama argillacea*) probably cannot be attacked by methods of biological control with any hope of success until the focus is discovered from which it makes its annual devastating migrations north and south of the Equator.

16. Cotton-stainers (*Dysdercus* spp.) are shown to have no effective natural enemies in the West Indies. The introduction of Tachinid flies from Queensland or Nigeria is suggested.

17. The green bug (*Nezara viridula*) is important not only as a pest of cotton, but also of the rapidly growing tomato and vegetable export industry. A Tachinid fly destroys about 8 per cent. of the adults, but a more efficient parasite is being sought.

18. The Mahogany shoot-borer (*Hypsipyla* spp.) is the most important pest of forestry in British Honduras and Trinidad. No parasites were known, but six species have now been discovered and studied.

19. The arrowroot leaf-roller (*Calpodes ethlius*) damages the principal crop of St. Vincent. It has not been possible yet to visit the island while the pest is active, but two new parasites have been discovered in Cuba.

20. The scarabée (*Euscepes batatae*) is by far the worst pest of sweet potatoes wherever it occurs in the West Indies. No parasites are known, and the search for them has been so far unsuccessful. High hopes, however, are held of finding one on the mainland.

21. The banana-borer (*Cosmopolites sordidus*) has been studied in Jamaica and Haiti. No parasites are known and it is doubtful whether any will be found in the American tropics, where the insect is not indigenous. It is suggested that a search be made in New Guinea.

22. The coffee leafminer (*Leucoptera coffeella*) was investigated by special request in St. Lucia. No natural enemies were found, and it is hoped to introduce a parasite from Venezuela or from Porto Rico, where several are known to occur.

23. A number of minor pests were studied when opportunity offered during other investigations.

24. Two short papers by Mrs. Myers and six by the writer have been published on the work so far, or are at present in the press.

25. Much of the work has so far been necessarily largely exploratory, and the search for new parasites must be continued with renewed vigour on the mainland; but two actual parasite introductions have been made, and at least three others can be attempted shortly.

VII. REFERENCES.

The list which follows is in no sense a bibliography, even a skeletal one, of West Indian entomology. Many valuable papers which I have not happened to use are omitted, while many more or less ephemeral notes which have yielded me an ecological fact have been listed.

Allen, G. M., 1911.
Mammals of the West Indies.
Bull. Mus. Comp. Zool., 54, 175–263.

de Andrade, E. Navarro, 1927.
Contribuição para o estudo da entomologia florestal Paulista.
Bol. biol., no. 6, pp. 66–72. S. Paulo [not seen].

Aspinall, A., 1927.
The pocket guide to the West Indies. London.

Ballard, E. and Evans, M. G., 1928.
Dysdercus sidae, Montr., in Queensland.
Bull. Ent. Res., 18, 405–432, 1 pl., 1 plan, 7 figs.

Ballou, H. A., 1904*a*.
Insects attacking cotton in the West Indies.
W. Indian Bull., 4, 268–286, 4 figs.

Ballou, H. A., 1904*b*.
Insect notes.
Agr. News, 3, 314.

Ballou, H. A., 1905.
Ratooning cotton.
Agr. News, 4, 262.

Ballou, H. A., 1906*a*.
Review of the insect pests affecting the sugar-cane.
W. Indian Bull., 6, 37–47.

Ballou, H. A., 1906*b*.
Insects attacking cacao in the West Indies.
W. Indian Bull., 6, 94–98.

Ballou, H. A., 1909.
Treatment of cotton pests in the West Indies in 1907.
W. Indian Bull., 9, 235–241, 10 figs.

Ballou, H. A., 1910.
Introduction of the St. Vincent " Jack Spaniard " into Montserrat.
Agr. News, 9, 378.

[Ballou, H. A.], 1911*a*.
The root-borer of the sugar-cane.
Agr. News, 10, 218, figs. 9–11.

Ballou, H. A., 1911*b*.
Notes on lime cultivation.
W. Indian Bull., 11, 39–49.

[Ballou, H. A.], 1912*a*.
Zalophothrix mirum.
Agr. News, 11, 298.

Ballou, H. A., 1912*b*.
Insect pests of the Lesser Antilles.
Imp. Dept. Agr., W. Indies, Barbados, x + 210 pp., 185 figs.

[Ballou, H. A.], 1913*a*.
Review of a report on insect pests in Barbados.
Agr. News, 12, 58–59.

Ballou, H. A., 1913*b*.
Notes on certain cotton pests.
W. Indian Bull., 13, 34–38.

Ballou, H. A., 1913*c*.
Report on the prevalence of some pests and diseases in the West Indies during 1912.
W. Indian Bull., 13, 333–357.

Ballou, H. A., 1915*a*.
West Indian Wasps.
Agric. News, Barbados, 14, 298, 4 figs.

B[allou], H. A., 1915*b*.
What cacao thrips signify in Grenada.
Agr. News, 14, 314–315.

Ballou, H. A., 1915*c*.
Report on the prevalence of some pests and diseases in the West Indies during 1914. Part I—Insect pests.
W. Indian Bull., 14, 123–133.

B[allou], H. A., 1916.
Cacao thrips and die-back in St. Vincent.
Agr. News, 15, 206–207, 222–223.

Ballou, H. A., 1917.
Report on the prevalence of some pests and diseases in the West Indies during 1915. Part I—Insect pests.
W. Indian Bull., 16, 3–16.

B[allou], H. A., 1918.
Insect pests in St. Lucia, 1917–18.
Agr. News, 17, 282–283.

B[allou], H. A., 1919.
Rats in the West Indies.
Agr. News, 18, 406–407.

Ballou, H. A., 1922*a*.
Report on the prevalence of some pests and diseases in the West Indies during 1919. Part I—Insect Pests.
W. Indian Bull., 19, 20–31.

Ballou, H. A., 1922*b*.
Report on the prevalence of some pests and diseases of crops in the West Indies during 1920. Part I—Insect pests of economic plants.
W. Indian Bull., 19, 242–257.

Ballou, H. A., 1924.
Some relationships of crop plants to insect pests.
Proc. Agr. Soc., Trin. and Tob., 24, 439–445.

Ballou, H. A., 1929.
The status of the Cotton Leaf Worm (*Alabama argillacea* Hbn.) in the West Indies.
4th Int. Cong. Ent. Ithaca, N.Y., 1928, ii (Trans.), 94–96.

Barbour, T., 1914.
Zoögeography of the West Indies.
Mem. Mus. Comp. Zool., 44.

Barbour, T. and Ramsden, C. T., 1919.
The Herpetology of Cuba.
Mem. Mus. Comp. Zool., 47, no. 2, pp. 69–213, 15 pls.

Barbour, T., 1922.
An annotated list of the Amphibia and Reptilia of Jamaica.
Handb. of Jamaica, 1922 (1922), 666–669.

Barbour, T., 1923.
Birds of Cuba.
Boston.

Barbour, T., 1930*a*.
The Anoles. I—The forms known to occur in the neotropical islands.
Bull. Mus. Comp. Zool., 70, 105–144.

Barbour, T., 1930*b*.
Some faunistic changes in the Lesser Antilles.
Proc. New Eng. Zool. Club, 11. 73–85.

Bennett, H. H. and Allison, R. V., 1928.
The soils of Cuba.
Trop. Plant Res. Found., Wash., xxiv + 410 pp., 3 maps, 101 figs.

Bodkin, G. E., 1912.
Report by Mr. G. E. Bodkin, Economic Biologist, on his recent visit to Trinidad, Barbados and Dominica.
Georgetown, 6 pp.

Bovell, J. R. and D'Albuquerque, J. P., 1922.
Report on the sugar-cane experiments for the season between 1920–22.
Barbados Dep. Agr., 67 pp., 51 tables.

Box, H. E., 1924.
Report upon a trip to Porto Rico, April–July, 1924.
S. Davson and Co., Ltd., Brit. Guiana, 22 pp. (Private Circulation).

Box, H. E., 1928*a*.
The introduction of Braconid parasites of *Diatraea saccharalis*, Fabr., into certain of the West Indian Islands.
Bull. Ent. Res., 18, 365–370, pl. 18.

Box, H. E., 1928*b*.
Los parásitos conocidos de las especies americanas de " Diatraea " (Lepidoptera, Pyralidae).
Bol. Estac. exp. agrícola de Tucumán, no. 5 (1927), 9 pp. Argentina.

Box, H. E., 1929.
Una relación de nuestros conocimientos de la familia Cercopidae en la Argentina. Con un informe sobre tres especies de *Tomaspis*, Am. and Serv., que atacan la caña de azúcar en las provincias del Norte.
Rev. ind. agric. Tucumán, 20, 5–17, 8 figs.

Bruner, S. C., 1929.
Reseña de las plagas del cafeto en Cuba.
Estac. Exp. Agron., Santiago de las Vegas, Circ. 68, 38 pp., 12 figs.

Cameron, T. W. M., 1929.
Parasitology in the Tropics.
Trop. Agric. 6, 100–103.

Cardin, P., 1915.
Informe del Departamento de Patologia vegetal y entomologia.
Estac. Exp. Agron. 3er Inf. An. Habana, 98–173, Lam. 1–5.

Cardin, P., 1917.
Informe de un viaje de inspeccion a los potreros de la finca " La Horqueta," Camaguëy, para investigar sobre una plaga en los pastos de " paraná."
Com. de Sanidad vegetal, Cuba, Bull. 1, pp. 39–44, Lam. 5–12.

Carr, A. B., 1894.
Notes on the cacao beetle (*Steirostoma* (*sic*) *depressum*).
J. Trin. F. N. Club, 2, 110–112.

las Casas, B. de.
A relation of the first Voyages and Discoveries made by the Spaniards in America.
Transl. 1699, London. [Bishop Las Casas in the early sixteenth century was an eye-witness of the events immediately following the colonisation of Hispaniola by the Spaniards.]

Census of the Republic of Cuba, 1919.
Havana, xii–968 pp., illus.

Chamberlain, W. P. and Curry, D. P., 1928.
Mosquito and malaria control work.
Rep. Hlth. Dep. Panama Canal 1927, 17–21 [not seen].

Cleare, L. D., 1915.
A Butterfly injurious to Coconut Palms in British Guiana.
Bull. Entom. Res. 6, no. 3, 273–278, 1 fig., 3 plates.

Cleare, L. D., 1923.
Notes on the small moth-borers of sugar-cane in British Guiana.
Bull. Ent. Res. 13, 457–468, pl. 24.

Cleare, L. D., Jr., 1925.
Report of the Biological Division.
British Guiana, Rep. Dep. Sci. and Agr. 1923, 47–51.

Cleare, L. D., Jr., 1926.
On the life-history of *Caligo illioneus illioneus*, Cram. (Lep. Morphidae).
Trans. Ent. Soc. London, Dec. 1926, 361–366, pls. 81–83.

Colonial Reports—Annual. No. 1458.
Jamaica. Report for 1928. London, 26 pp.

Cotterell, G. S., 1927*a*.
The red-banded cacao thrips, *Heliothrips rubrocinctus*, Giard.
Year book, 1927, Dept. Agr. Gold Coast, Bull. 13, Paper 16, 94–99, pl. 12.

Cotterell, G. S., 1927*b*.
Pests of cacao in the Gold Coast.
Proc. 1st W. Afr. Agr. Conf., Ibadan, Nigeria, 1927, 98–112.

Crawford, J. C., 1914.
New Parasitic Hymenoptera from British Guiana.
Proc. Entom. Soc., Washington, 16, no. 2, 85–88.

Croucher, H. H., 1929.
A report on some cultivated St. Lucia soils.
Govt. Printer, Castries, [ii] + 11 pp.

Croucher, H. H., 1930.
Some observations on meteorological conditions in Trinidad during the period January, 1929 to July, 1930.
Proc. Trinidad Froghopper Invest. Comm. Pt. 19, 168–173.

Cundall, F., 1924.
Jamaica in 1924.
Kingston, xiv + 209 pp., pls. figs. and maps.

Cundall, F., 1928.
The Handbook of Jamaica for 1928.
Kingston, 7 pls. and maps, xiii + 554 pp.

Drake, C. J., 1920.
The Southern Green Stink-bug in Florida.
Qtrly. Bull. Florida State Plant Bd. Gainesville, 4, No. 3, 41–94, 38 figs.

Fabien, E. E., 1922.
A brief sketch of the sugar cane and its cultivation in Naparima as exemplified on Cedar Hill estate.
Ste. Madeleine Review, Trinidad, No. 5, 14–15.

Fassig, O. L., 1925.
Rainfall and temperature of Cuba.
Trop. Plant Res. Found. Bull. I, 32 pp.

Freeman, W. G. and Williams, R. O., 1928.
The useful and ornamental plants of Trinidad and Tobago.
Dept. Agric. Trin. and Tob., Mem. 4, pp. 192.

Gahan, A. B., 1929.
Description of an egg-parasite of *Exophthalmus quadrivittatus* (Olivier).
Proc. Ent. Soc. Wash. 31, 17–18.

Girault, A. A., 1916.
Descriptiones Hymenopterorum Chalcidoidicorum variorum cum Observationibus iii.
Entom. News, Philadelphia, 27, No. 5, 223–228.

Gosse, P. H., 1851.
A naturalists' sojourn in Jamaica.
London.

Gowdey, C. C., 1921.
The fall army worm, *Laphygma frugiperda* (S. and A.).
Dept. Agric. Jamaica, Ent. Circ. 4, 4 pp.

Gowdey, C. C., 1923.
The principal agricultural pests of Jamaica.
Dept. Agric. Jamaica, Ent. Bull. 2, [vi] + 80 + vi pp., 7 pls.

Gowdey, C. C., 1926–1928.
Catalogus Insectorum Jamaicensis.
Dept. Agric. Jamaica, Ent. Bull. 4, pts. 1 and 2, 1926, pt. 3, 1928.

Grey, R. M., 1927.
Report of the Harvard Botanical Gardens, Soledad Estate, Cienfuegos, Cuba (Atkins Found.) 1900–1926.
Cambr., Harv. Univ. Pr., 113 pp.

Guppy, P. L., 1911.
The Life history and control of the cacao beetle.
Bd. of Agric. Trinidad, Circ. 1, 34 + iii, 4 figs., 3 pls.

Guppy, P. L., 1912*a*.
Cacao pests.
Dept. Agric. Trin. and Tob. Bull., 11, 36–46.

Guppy, P. L., 1912*b*.
Insect pests of cacao.
West Indian Bull. 12, 310–320.

Guppy, P. L., 1914.
Birds and their value to the agriculturist. Part I.
Bull. Dept. Agric. Trin. and Tob. 13, 116–128.

Hardy, F., 1922*a*.
Studies in West Indian soils. II.—The soils of Montserrat, their natural history and chief physical properties and the relationship of these to the problem of die-back of lime-trees.
W. Indian Bull. 19, 189–213, map.

Hardy, F., 1922*b*.
Studies in West Indian soils. I.—The soils of Dominica, their grasses and fertility considered in relation to reaction.
W. Indian Bull. 19, 86–123, map.

Hardy, F., 1929.
The soils of Trinidad Sugar Estates. The distribution of textural types. I.—Soils of the Central Plain.
Proc. Froghopper Investigation Comm. Pt. 15, 243–260.

Hardy, F. and Urich, F. W., 1930.
Progress report.
Proc. Frog. Invest. Comm. Trin. and Tob. Pt. 18, 27–31.

Harland, S. C., 1916*a*.
Report of the Assistant Superintendent of Agriculture on the entomological and mycological work carried out during the season under review.
Rept. Dept. Agric. St. Vincent, 1915–1916, Barbados, 7–34.

Harland, S. C., 1916*b*.
Notes on *Trichogramma minutum* (*pretiosa*).
W. Indian Bull, 15, 168–175.

Harland, S. C., 1917.
Special Entomological Investigations.
Rept. Agric. Dept. St. Vincent, 1916–17, Barbados, 10–11.

Harrison, J. B., 1920.
The extraneous materials in the coral-limestones of Barbados.
Quart. Jl. Geol. Soc. 75, 158–172.

Harrison, J. B., 1925.
The Climate of British Guiana.
British Guiana, Combined Court, C. S. O. No. 5679/25, 7 pp.

Harrison, J. B. and Jukes-Browne, A. J., 1890.
The geology of Barbados.
Barbados, 64 pp.

Harrison, J. B. and Stockdale, F. A., 1911.
Rubber and Balata in British Guiana.
Dept. Sci. and Agric. Georgetown, 46 pp., 2 maps, 24 figs.

van Heurn, W. C., 1923.
Over een waarschijnlijke parasiet (*Thripoctenus brui* Vuillet) en een vermoedelijke hyperparasiet (Genus ? species ?) van *Thrips tabaci* Lind.
Tijdschr. Ent., 66, 119–128, 2 figs. [not seen].

Hitchcock, A. S., 1921.
Floral aspects of British Guiana.
Smith's Rept. 1919, 293–305, 12 pls.

Hitchcock, A. S., 1922.
Grasses of British Guiana.
Contr. U.S. Nat. Herb. 22, i–v, 439–515, vi–x, pl. 63, figs. 77–86.

Holloway, T. E., 1929.
Local conditions as influencing recommendations for the control of sugar-cane insects.
4th Int. Congr. Ent. Ithaca, 1928, 2, trans. 448–451.

Holloway, T. E., Haley, W. E. and Loftin, U. C., 1928.
The sugar-cane moth-borer in the United States.
U.S. Dept. Agric. Tech. Bull. 41, 76 pp., 1 pl., 25 figs.

Hutson, J. C., 1917.
Some weevils of the genus *Diaprepes* in the West Indies.
Agric. News, 16, 186, 251.

Hutson, J. C., 1920.
Report on the prevalence of some pests and diseases in the West Indies during 1917. Part I—Insect pests.
W. Indian Bull, 17, 86–

Jackson, T. P., 1929.
Work connected with Insect and Fungus Pests and their Control.
Rept. Agric. Dept. St. Vincent, 1928, 8–14, Trinidad.

Jemmett, C. W., 1909.
Some parasites of the cotton worm.
Agric. News, 8, 74–75, figs. 11, 12.

Jones, G. A., *see* Rept. West Indian Sugar Commission, 1930.

Jones, G. A. and Potter, J., 1929.
Protection and preservation of bird life on the estates of the St. Madelein Sugar Co., Ltd.
Proc. Trin. Frogh. Invest. Comm., Pt. 16, 338–341.

Jones, T. H., 1918.
The southern green plant bug.
U.S.D.A. Washington, Bull. 689, 27 pp., 14 figs.

Kaye, W. J., 1921.
A catalogue of the Trinidad Lepidoptera Rhopalocera.
Mem. Dept. Agric. Trin. and Tob. 2, ii + 163 pp., 1 pl.

Kelsick, R. E. and Howell, W. I., 1928.
Work in connection with insect and fungus pests and their control.
Rept. Agric. Dept. St. Kitts–Nevis 1927–28, 4–6, 19–20.

Leake, H. M., 1929.
Rainfall and crop conditions.
Trop. Agric. 6, 43–45.

Marshall, R. C., 1930*a*.
Conservator of Forests. Administration Report for the year 1929.
Council Paper No. 57, 1929, Trin. and Tob., 22 pp.

Marshall, R. C., 1930*b*.
Notes on the silviculture of the more important timber trees of Trinidad and Tobago.
Forest Dept. Trinidad, 50 pp., 6 pls.

Maxwell-Lefroy, H., 1901*a*.
Suggestions for insect control in the West Indies.
W. Indian Bull. 2, 318–344.

Maxwell-Lefroy, H., 1901*b*.
Insect attack on cacao trees in Grenada.
Trinidad, Bull. Misc. Inform. Extra No. May, 337–346.

Maxwell-Lefroy, H., 1902.
Suggestions for controlling the importation of insect pests.
W. Indian Bull. 3, 140–150.

Maxwell-Lefroy, H., *et al.*, 1901.
"Thrips" on cacao trees.
W. Indian Bull. 2, 175–185.

Miller, R. L., 1928.
Telenomus megacephalus, Ashm., an egg-parasite of the green pumpkin bug, *Nezara viridula*, Linn., in Florida.
Florida Ent. 12, 17–20.

[Monte, O.], 1929.
Combate á cigarrinha dos cannaviaes.
Chacaras e Quintaes, 40, 407–408, 3 figs., S. Paulo.

Moore, H. W. B., 1919.
Reports for years, 1918, 1917.
Abstr. by H. A. B. in Agric. News, 18, 346–347.

Moreira, C., 1925.
A cigarrinha vermelha da canna de assucar, *Tomaspis liturata* Lep. et Serv.
Minist. Agric. Ind. e. Comm. Inst. biol. Defesa Agric. Bol. 4, 15 pp., 5 pls.
Rio de Janeiro.

Morris, D., 1891.
Report of a botanical mission to the West Indies.
Kew Bulletin, 1891, pp. 109–168.

Morris, D., 1897.
Subsidiary report on the agricultural resources and requirements of British Guiana and the West India Islands.
Report of the W. I. Royal Comm. 1897, 80–156.

Myers, I. H., 1930*a*.
Study of Froghopper Eggs for Parasites.
Proc. Frog. Invest. Comm. 3, 60–63.

Myers, I. H., 1930*b*.
Notes on Parasites of the Gall-midge (*Iatrophobia brasiliensis*) of Cassava (*Manihot utilissima* L.) in Trinidad.
Bull. Ent. Res. 21, 309–313.

Myers, J. G., 1926.
Dry season studies of cane Homoptera at Soledad, Cuba.
Contr. Harvard Inst. Trop. Biol. Med. 3, 69–110, 1 fig.

Myers, J. G., 1927.
Ethological observations on some Pyrrhocoridae of Cuba.
Ann. Ent. Soc. America, 20, 279–300.

Myers, J. G., 1928.
The biological control of cotton pests.
Empire Cotton Growing Rev. 5, 113–127.

Myers, J. G., 1929*a*.
Biological control of the froghopper, the present position.
Proc. Trin. Frog. Invest. Comm. 2, pt. 14, 217–219.

Myers, J. G., 1929*b*.
Biological control. The principles of biological control.
Trop. Agric. 6, 163–165.

Myers, J. G., 1929*c*.
Sugar-cane mothborers. Some work on parasites of the small moth borers (*Diatraea* of sugar-cane).
Trop. Agric. 6, 310–312. (*Corrected* reprint in: Agric. Jl. Brit. Guiana, 3, 45–50, 1930.)

Myers, J. G., 1930*a*.
Notes on wild cacao in Surinam and in British Guiana.
Bull. Misc. Inf. Kew, 1930, 1–10, pls. I, II.

Myers, J. G., 1930*b*.
Carabunia myersi (Hym., Encyrtidae) a parasite of nymphal froghoppers (Hom., Cercopidae).
Bull. Ent. Res. 21, 341–351.

Myers, J. G., 1930*c*.
Descriptions and records of parasitic Hymenoptera from British Guiana and the West Indies.
Bull. Ent. Res. [in press].

N[owell], W., 1916.
The fungus on cacao thrips.
Agric. News, 15, 430, 2 refs.

Nowell, W. and Williams, C. B., 1920.
Sugar-cane Blight in Trinidad: A summary of Conclusions.
Bull. Dept. Agric. Trin. and Tob. Port-of-Spain, 19, pt. 1, 8–10.

Pemberton, C. E., 1925.
The field rat in Hawaii and its control.
Haw. S. P. Ass. Exp. Sta. Ent. Ser. Bull. 17, [6] + 46 pp., 28 figs.

Pickles, A., 1930*a*.
Report on the search in Jamaica for Parasites of the Sugar-cane Froghopper (*Tomaspis saccharina* Dist.).
Proc. Frog. Invest. Comm. pt. 19, 145–149.

Pickles, A., 1930*b*.
Notes on Biological Studies on the Froghopper during the dry season, 1930.
Proc. Frog. Invest. Comm. pt. 19, 150–157.

Plank, H. K., 1929*a*.
A Summary of the Investigations of the Sugar-Cane Moth Stalkborer in Cuba.
Trop. Pl. Res. Found. Bull. 8, 16 pp., 5 figs.

Plank, H. K., 1929*b*.
Natural Enemies of the Sugar-Cane Moth Stalkborer in Cuba.
Ann. Ent. Soc. Amer. 22, No. 4, 621–640, 7 figs., 16 refs.

[Potter, T. I.], 1892.
Mr. Potter exhibited . . . a specimen of the *Castnia licus* . . .
Rept. Club Meetings J. Trin. F. N. Club, 1, 105.

Potter, T. I., 1893.
Castnia licus, a banana pest.
J. Trin. F. N. Club, 1, 141–142.

Pulliam, W. E., 1924.
Report of the 22nd Fiscal Period, Dominican Customs Receivership, Calendar Year 1928.
U.S. Govt. Printing Office, Wash. 1929.

Reed, F. R. C., 1921.
The geology of the British Empire.
London, viii + 480 pp., 25 maps and sections.

Quelch, J. J., 1910.
Report on the giant moth-borer.
Georgetown, Demerara, Argosy Co., 32 pp., 1 pl.

Réaumur, R. A. F. de, 1926.
The natural history of ants, from an unpublished manuscript in the archives of the Academy of Sciences of Paris.
Trans. annot. W. M. Wheeler, New York.

Report on the Botanic Station and Experiment Plots, Antigua, 1912–13, Barbados, 1913.
Imp. Dept. Agric. W. I.

Report on the Agricultural Department, Antigua, 1928–29.
Imp. Commissioner of Agric. W. I., 22 pp., 1930.

Report on the Agricultural Department, Dominica, 1928–29.
Imp. Commissioner of Agric. W. I., 34 pp., 1929.

Report on the Agricultural Department, Grenada, for the period 1926–28.
Imp. Commissioner of Agric. W. I., 12 pp., 1930.

Report on the Agricultural Department, Montserrat, 1926–27.
Imp. Commissioner of Agric. W. I., 23 pp., 1928.

Report on the Agricultural Department, St. Kitts-Nevis, 1923–24.
Imp. Dept. Agric. W. I., 39 pp., 1925.

Report on the Agricultural Department, St. Kitts-Nevis, 1928–29.
Commisioner of Agric. W. I., 28 pp., 1929.

Report on the Agricultural Department, St. Lucia, 1925.
Imp. Commissioner Agric. W. I., 33 pp.

Report on the Agricultural Department, St. Vincent, for the year 1928.
Imp. Commissioner of Agric. W. I., 30 pp., 1929.

Report on the Agricultural Department of Science and Agriculture, Barbados, for the year 1928–29.
Barbados, 89 pp., 1930.

Report of the West India Royal Commission, 1897.
vi + 174 pp., 1 map, London.

Report of the West Indian Sugar Commission, 1930.
Parts 1–3, 124 pp., part 4, 87 pp. London.

Reyne, A., 1921.
De Cacaothrips (*Heliothrips rubrocinctus*, Giard).
Dept. Landbouw, Suriname, Bull. 44, 214 pp., 20 pls., 6 figs.

Russell, H. M., 1912.
An internal parasite of Thysanoptera.
U.S. Dept. Agric. Bur. Entom. Techn. Ser. No. 23, pt. 2, 25–52, 11 figs.

Salt, G., 1926.
Report on Sugar-cane Borers at Soledad, Cuba.
Contrib. Harvard Inst. Trop. Biol. and Med. 3, 9–62, 4 pls.

Salt, G., 1929*a*.
Castniomera humboldti (Boisduval), a pest of bananas.
Bull. Ent. Res. 20, 187–193, 1 pl.

Salt, G., 1929*b*.
A contribution to the ethology of the Meliponinae.
Trans. Ent. Soc. London, 77, 431–470, pls. 20–29.

Sampson, H. C., 1927.
Report on Development of Agriculture in British Guiana.
E. M. B. 4, 26 pp.

Sampson, H. C., 1929.
Report on Development of Agriculture in British Honduras.
E. M. B. 16, 31 pp.

Skinner, H. M., 1929.
The Giant Moth-borer of Sugar-cane (*Castnia licus*, Drury).
Trop. Agric. [7, No. 1], Suppl. 8 pp., 1 pl., 2 figs., 4 refs.

Sweetman, H. L., 1929.
Field Studies of the Physical Ecology of the Alfalfa Weevil.
Bull. Wyoming Agric. Exp. Sta., No. 167, 32 pp., 6 graphs, 7 refs. [not seen].

Tempany, A. J., 1913.
Insect pests in the Virgin Islands.
Agric. News, Barbados, 12, 42–43.

Tempany, A. J., 1916.
The soils of Antigua.
W. Indian Bull. 15, 69–102.

Thompson, W. R., 1930.
The biological control of insect and plant pests. . . .
E. M. B. 29, London, 124 pp., 8 pls.

Townsend, C. H. T., 1913.
The 1912 outbreak of *Alabama argillacea* in Peru.
Jl. Econ. Ent. 6, 244–246.

Tucker, R. W. E., 1930*a*.
The Dr. Morris Bird.
Trop. Agric. 7, 68–69.

Tucker, R. W. E., 1930*b*.
The control of *Diatraea saccharalis* in Barbados by mass liberations of *Trichogramma minutum*.
Trop. Agric. 7, 292–295.

Urban, I., 1923.
Zur Pflanzengeographie von Hispaniola.
Symbolae Antillanae, 9, 1–54.

Urich, F. W., 1909.
The cane sucker (*Castnia licus*, Drury, 1773).
Dept. Agric. Trin. Bull. 61, 43–45, 1 pl.

Urich, F. W 1913.
The Sugar-cane Froghopper and Biological notes on some Cercopids of Trinidad.
Bull. Dept. Agric. Trin. and Tob. Port-of-Spain, 12, No. 72, 12–34, 7 figs., 6 pls., 3 diagms.

Urich, F. W., 1915.
Insects affecting the Coconut Palm in Trinidad.
Bull. Dept. Agric. Trin. and Tob. Port-of-Spain, 14, No. 6, 200–203.

Urich, F. W., 1916.
Insects affecting the cotton plant in Trinidad.
Bull. Dept. Agric. Trin. and Tob. Port-of-Spain, 14, No. 1, 18–19.

Urich, F. W., 1925.
The cacao beetle.
Bull. Dept. Agric. Trin. and Tob. Port-of-Spain, 21, 36–39, pls. 5–7.

Urich, F. W. and Pickles, A., 1930.
Studies in the Incubation of Eggs of the Sugar-cane Froghopper, *Tomaspis saccharina*, Dist.
Proc. Frog. Invest. Comm. 3, 64–70, 4 figs.

Van Dine, D. L., 1927.
Lista de los insectos de la Caña de Azúcar de Cuba.
Trop. Plant. Res. Found. Bol. 3, 28 pp., 18 figs.

Van Dine, D. L., 1929.
Parasites of sugar cane moth borers.
Journ. Econ. Ent. 22, 248–268.

Van Hall, C. J. J., 1914.
Cocoa.
London, 515 pp., 140 figs.

Vargas Vergara, J. M., 1918.
El mión (*Tomaspis bogotensis*).
Rev. Minist. Obras Publicas, Bogota, 12, Nos. 10, 11, 12, 470–472 and 547. [not seen.]

Walters, E. A., 1926.
Control of insect pests.
Rep. Agric. Dept. St. Lucia, 1924, 9–10.

Wardlaw, C. W., 1930.
Agriculture in Suriname.
Trop. Agric. 7, 31–37, 7 figs., 8 tables.

Waterston, J., 1923.
On an internal parasite (Hym. Chalcidoidea) of a thrips from Trinidad.
Bull. Ent. Res. 13, 457–468, 1 pl.

Watson, J. R., 1929.
Report of the Department of Entomology.
Rep. Florida Agric. Exp. Sta. 1927–28, 42R–49R [not seen].

Watson, Rev. N. B., 1904.
The root-borer of sugar-cane (*Diaprepes abbreviatus*).
West Indian Bull. 4, 37–47, 3 figs.

Wetmore, A., 1916.
Birds of Porto Rico.
Insular Exp. Sta. Rio Piédras, P. R. Bull. 14, 140 pp., 10 pls.

Wilkinson, D. S., 1929.
New species and host records of Braconidae.
Bull. Ent. Res. 20, 205–208, 1 fig.

Willaume, F., 1925.
Caractères généraux et position systématique des *Physapoda* Duméril-Burmeister.
Revue zool. Agric. and appl., Bordeaux, 24, 1–12, 36–46, 53–59, 17 figs.

Williams, C. B., 1917.
Notes on a Froghopper attacking Sugar-cane at Marienburg Estate, Suriname.
Bull. Ent. Res. London, 7, No. 3, 271–272.

Williams, C. B., 1918*a*.
The Sugar-cane Froghopper in Grenada.
Bull. Ent. Res. 9, pt. 1, 83–87.

Williams, C. B., 1918*b*.
A Froghopper on Sugar-cane in British Guiana.
Bull. Ent. Res. 9, No. 2, 163–173, 3 figs.

Williams, C. B., 1918*c*.
The food of the mongoose in Trinidad.
Bull. Dept. Agric. Trin. and Tob. 17, 167–186.

Williams, C. B., 1921.
Report on the Froghopper Blight of Sugar-cane in Trinidad.
Mem. Dept. Agric. Trin. and Tob. No. 1, 170 pp., 11 pls., 32 figs.

Williams, C. B., 1922.
Notes on the food and habits of some Trinidad birds.
Bull. Dept. Agric. Trin. and Tob. 20, 123–185, 5 figs., 3 pls.

Wilson, C. E., 1923.
Insect pests of cotton in St. Croix and means of combating them.
Virgin Islands Agric. Exp. Sta. St. Croix, Bull. 3, 20 pp., 21 figs.

Wolcott, G. N., 1915.
The influence of rainfall and the non-burning of trash on the abundance of *Diatraea saccharalis*.
Jl. Econ. Ent. 8, 496–498.

Wolcott, G. N., 1922.
The status of entomology in Porto Rico.
J. Dept. Agric. P.R. 6, No. 2, 11 pp., Rio Piédras.

Wolcott, G. N., 1923.
Insectae Portoricensis. [sic]. A preliminary annotated check-list of the insects of Porto Rico, with descriptions of some news [sic] species.
Jl. Dept. Agric. Porto Rico, Rio Piédras, 7, 1–313.

Wolcott, G. N., 1924*a*.
The food of Porto Rican lizards.
Jl. Dept. Agric. Porto Rico, 7, No. 4, 5–37.

Wolcott, G. N , 1924*b*.
Entomologia económica Puertoriqueña.
Dept. Agric. Estación Exp. Agron. Rio Piédras, Bol. 32, 176 pp., 12 pls., 98 figs.

Wolcott, G. N., 1924*c*.
Annual Report of the Division of Entomology for the Fiscal Year 1922–23.
Ann. Rep. Insular Exp. Sta., Rio Piédras, Porto Rico (1922–23), 51–57.

Wolcott, G. N., 1927*a*.
Haitian cotton and the pink bollworm.
Bull. Ent. Res., 18, 79–82.

Wolcott, G. N., 1927*b*.
Entomologie d'Haiti.
Port-au-Prince, 440 pp., 133 figs.

Wolcott, G. N., 1929*a*.
The mystery of *Alabama argillacea*.
Amer. Nat., 63, 82–87.

Wolcott, G. N., 1929*b*.
La Hormiga " Coqui " en Chanchamayo. Notas sobre el Arrebiatado en el Norte.
La vida agric., 6, no. 61, 11–15, 1 fig. Lima.

Wolcott, G. N., 1929*c*.
Notes on the life-history of *Exophthalmus quadrivittatus* Olivier (Coleoptera).
Proc. Ent. Soc. Wash., 31, 21–26, 1 ref.

Wolcott, G. N., 1929*d*.
The pink bollworm in Haiti.
4th Int. Cong. Ent. Ithaca, N.Y., 1928, 2 (Trans.), 68–72.

Wolcott, G. N., 1929*e*.
Weather and the non-burning of trash in Borer Control in Porto Rico.
4th Int. Cong. Ent. Ithaca, N.Y., 1928, 2 (Trans.), 62–64.

Woodring, W. P., Brown, J. S. and Burbank, W. S., 1924.
Géologie de la République d'Haïti.
Répub. d'Haïti, Dépt. Trav. Publ., Port-au-Prince, 710 pp., 40 pls., 37 figs.

Young, C. G., 1928–29.
A contribution to the ornithology of the coastland of British Guiana.
Ibis, Oct., 1928, 748–781; Jan., 1929, 1–38; April, 1929, 221–261; pls. 36–42, text-fig. 18.

Anon., 1901.
Insectivorous birds.
W. Indian Bull., 2, 243–250.

Anon., 1902*a*.
Blackbirds and toads as planters' friends.
Agric. News, 1, 246, 1902.

Anon., 1902*b*.
Agric. News, 1, 248, 1902.

Anon., 1902*c*.
Cotton in the West Indies.
Agric. News, 1, 273–274.

Anon., 1903.
The Barbados ground-lizard.
Agric. News, 2, 158.

Anon., 1904.
The fiddler beetle of the orange.
Agric. News, 3, 266.

Anon., 1905.
Mungoose and 'bull frogs."
Agric. News, 4, 90.

Anon., 1907*a*.
Toads and cotton worms.
Agric. News, 6, 26.

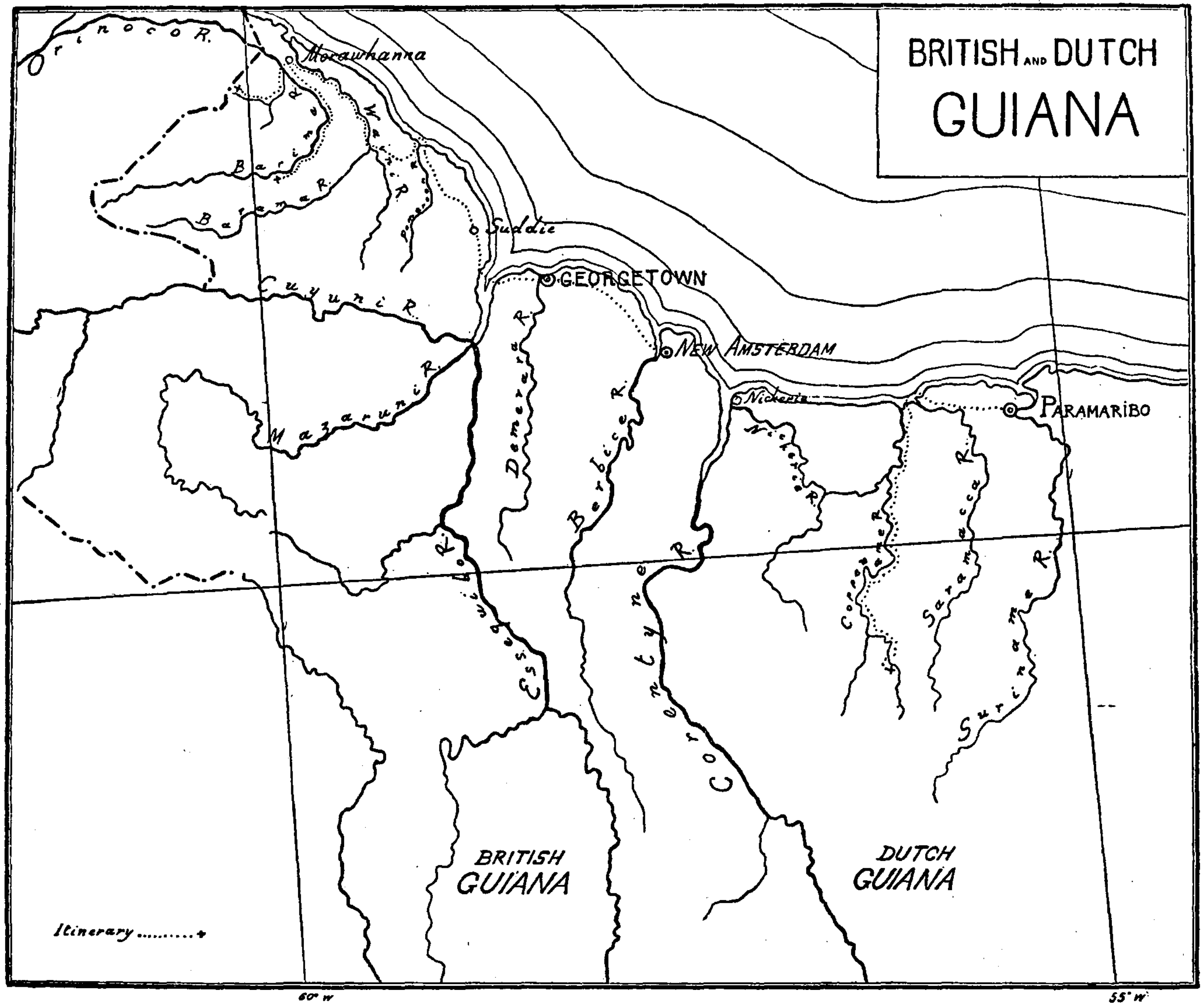
Anon., 1907*b*.
Treatment of cotton pests.'
Agric. News, 6, 289–290.

Anon., 1913.
Miscellaneous entomogenous fungi.
Agric. News, 12, 78.

Anon., 1915.
Introducing the Jack Spaniard into St. Lucia.
Agric. News, 14, 395. [Editorial.]

Anon., 1916.
Humidity and the growth of crops.
Agric. News, 15, 33–34. [Editorial.]

Anon., 1918.
Rats and mongoose in the West Indies.
Agric. News, 17, 337–339. [Editorial.]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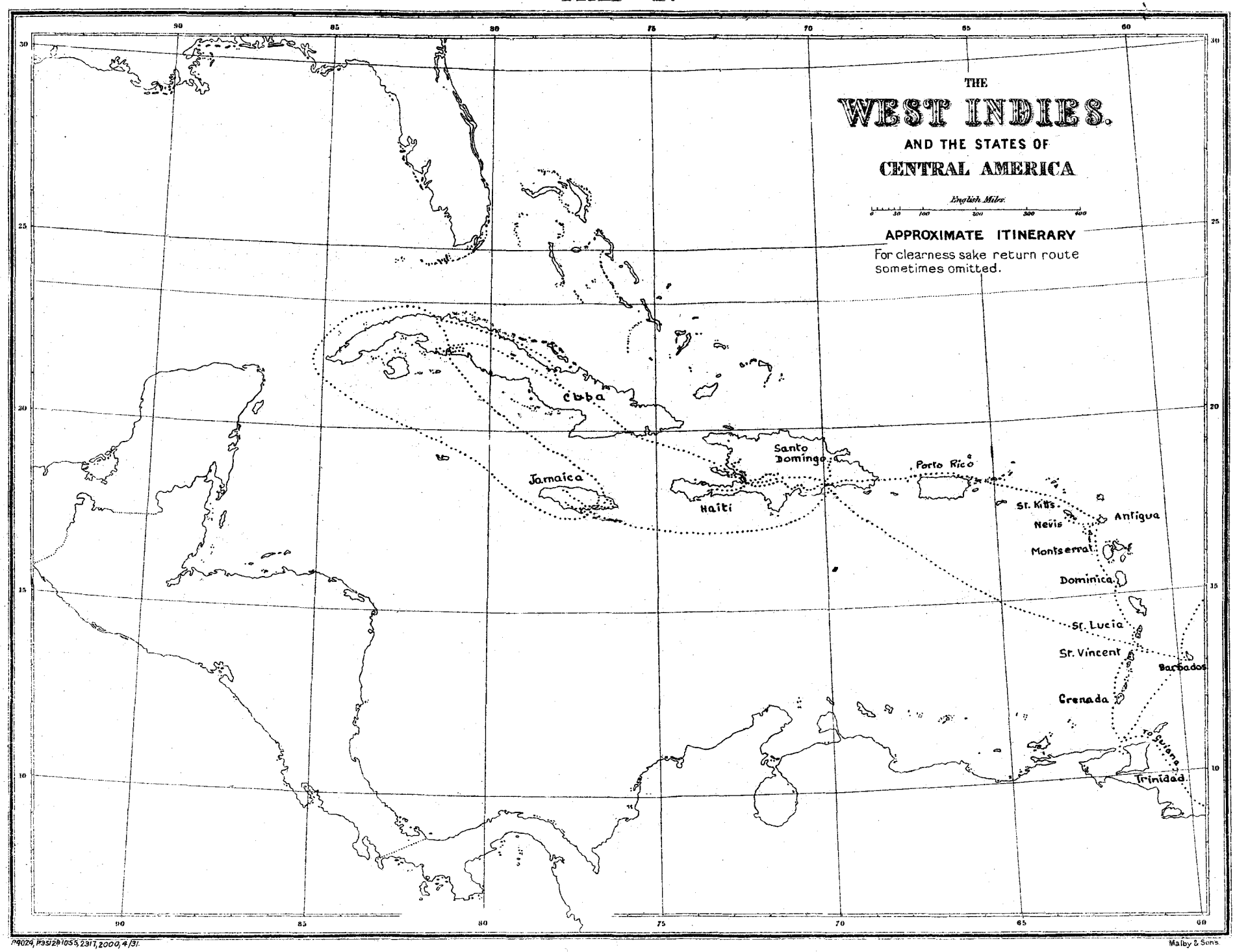
MAP I.



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