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THE DISTRIBUTION AND ABUNDANCE OF THE JAPANESE BEETLE FROM 1935 THROUGH 1943, WITH A DISCUSSION OF SOME OF THE KNOWN FACTORS THAT INFLUENCE ITS BEHAVIOR

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It has been 10 years since a paper treating of the distribution and abundance of the Japanese beetle (*Popillia japonica* Newm.) has been published. During this 10-year period the insect has been subjected to a variety of climatic conditions and has encountered a wide range of physiographic types that have influenced its behavior. The reaction of the beetle to the conditions encountered in its spread, the variations in its abundance, and the factors responsible for changes in numbers are discussed in this paper.

CHANGES IN THE GENERALLY INFESTED AREA AND FACTORS INFLUENCING THE RATE OF SPREAD

The progressive dispersal of the Japanese beetle in the United States prior to 1934 has been treated in several papers by Henry Fox (1, 2, 3),[1] who also carried on adult-beetle surveys within the generally infested area in 1934 and 1935. As pointed out by Fox (3), the total range of the Japanese beetle in the United States falls naturally into two subdivisions, the smaller of these consist-

[1] Numbers in parentheses refer to Literature Cited.

ing of an area, known as the area of general distribution, in which the beetle is present at nearly all points with suitable environmental conditions; whereas in the larger subdivision, or peripherally infested zone lying beyond this generally infested area, beetles occur only in localized colonies of various sizes separated by extensive areas free from the pest. Fox designated this large peripheral zone as the area of discontinuous infestation, but in recent years it has been more generally referred to as the outer

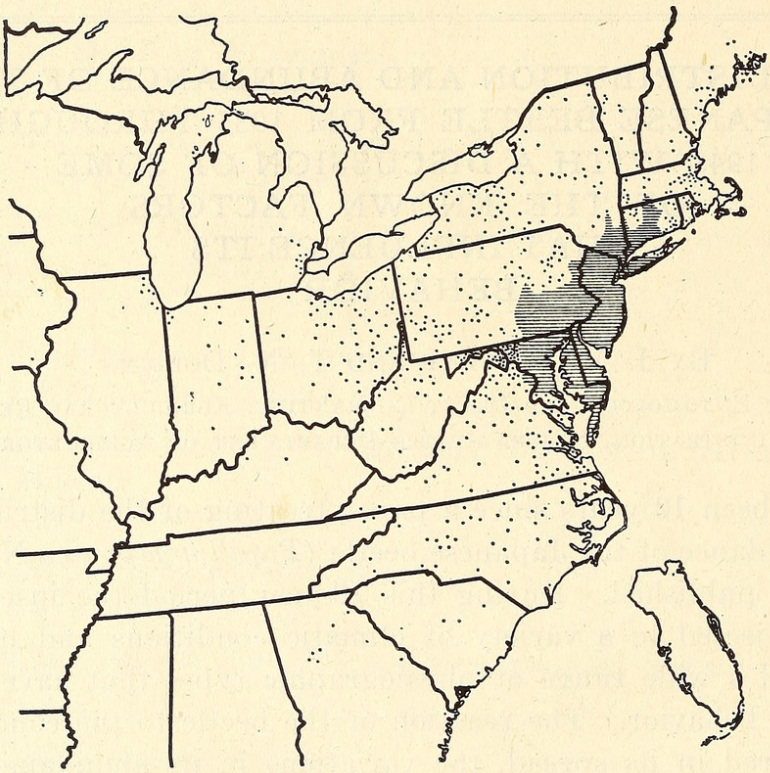

FIG. 1. Dots indicate all known points in the outer zone at which the Japanese beetle has been found prior to and during the summer of 1943.

zone. These two areas, as found in 1943, are shown graphically in Figure 1. Surveys of adult-beetle abundance were carried on in the area of general distribution each year from 1925 through 1939 by the staff of the Moorestown, N. J., laboratory of the Bureau of Entomology and Plant Quarantine, United States Department of Agriculture. In 1940 there was no scouting of this type, and since 1941 surveys have been more restricted and less thorough because of personnel and travel limitations; their continuance has been possible only because of the active cooperation

of entomological agencies in the states involved. Information relative to conditions in the outer zone has been obtained largely from the trapping activities of the Division of Japanese Beetle Control, of the Bureau.

The area of general distribution has gradually developed to its present extent by the spread of the beetle, largely by flight, from

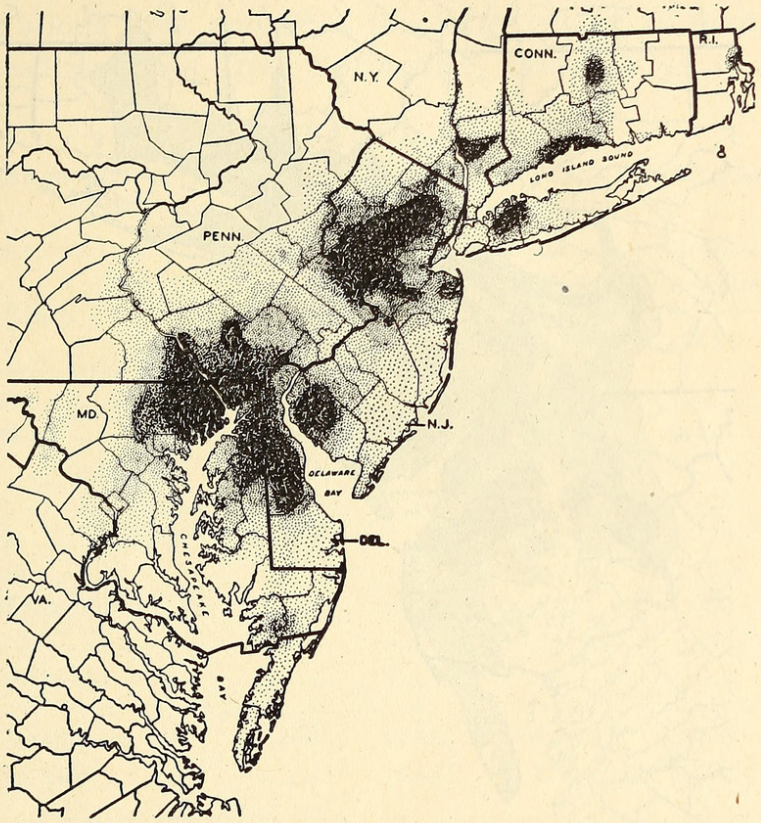

FIG. 2. The area of general distribution of the Japanese beetle in the summer of 1943.

NOTE. In figures 2, 4, 5, 6, and 7 the relative abundance of the beetle is shown by the closeness of the dots in stippled areas. The single dots beyond the limits of the area of general distribution in figures 5 and 6 mark the locations of isolated beetle infestations.

the original point of introduction in this country near Riverton, in west-central New Jersey. This dispersal has taken place in all directions over a period of more than 25 years, until at the close of the 1943 summer season the pest had covered an area of roughly 29,200 square miles and had invaded eight states and the District of Columbia (Fig. 2). The growth of the area of gen-

eral distribution is shown graphically in Figure 3, and the progressive increase in the size of the infested area is shown in table 1.

In recent years one of the most significant factors involved in the progressive increase of the area of general distribution has been the absorption by this area in its outward spread of a num-

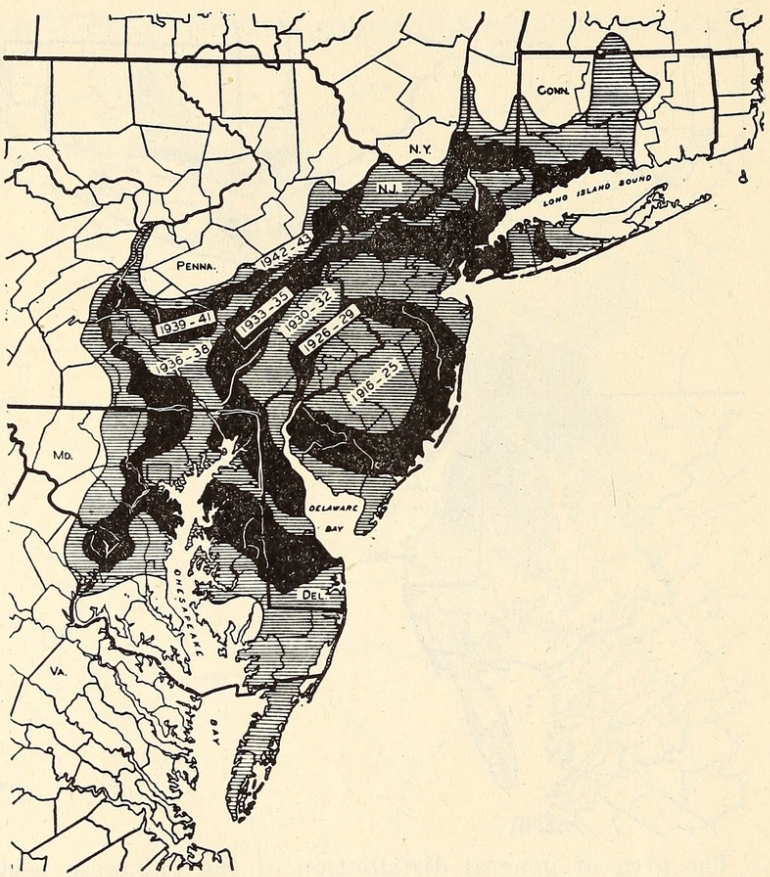

FIG. 3. Progressive changes in the outer limit of the area of general distribution of the Japanese beetle from 1925 through the summer of 1943.

ber of extensive secondary centers of dispersal, which have developed independently of the primary infestation. The largest of these secondary centers have evolved, not from single isolated infestations, but from numbers of such infestations which have united to form extensive tracts of generally infested territory.

The largest secondary center of dispersal has been that in the parts of Maryland and Virginia lying east of Chesapeake Bay (Figs. 2 and 4). The infestation there originally consisted of a

number of local colonies which had fused to such an extent that, when this area merged with the area of general distribution in 1942, all the Eastern Shore of Maryland and Virginia except one relatively small tract was involved. The same type of situation existed when the fringe of the generally infested area, which had been moving north in Connecticut above New Haven, met and united with a strong local colony that had existed around Hartford for a long time, and when this latter colony, in turn, joined one spreading south from Springfield, Mass. (Figs. 2 and 4).

TABLE 1

INCREASE IN SIZE OF AREA OF GENERAL DISTRIBUTION OF THE JAPANESE BEETLE, BY STATES, FROM 1935 THROUGH 1943

State	Estimated infested area (square miles)				
	1935	1937	1939	1941	1943
New Jersey	6,460	6,980	7,250	7,431	8,224
Pennsylvania	3,100	4,358	5,013	6,114	7,169
Delaware	670	946	1,064	1,550	1,965
Maryland	480	664	1,546	3,016	5,887
New York	690	858	1,141	1,722	2,418
Connecticut	.....	45	286	620	2,200
District of Columbia	.....	.....	.....	62	62
Virginia	.....	.....	.....	85	1,085
Massachusetts	.....	.....	.....	.....	190
Total infested area	11,400	13,851	16,300	20,600	29,200
Increase in area	.....	2,451	2,449	4,300	8,600

These large additions were largely responsible for the sizeable increase in the area of general distribution between 1941 and 1943, as shown in Table 1. There have been other instances of this kind in earlier years, when the area centering about Harrisburg, Pa., was added in 1937 (Fig. 5) and when the spread of the area of general distribution to the southwest below Baltimore reached and united with a local infestation about Washington, D. C., in 1941 (Fig. 4). In many instances, however, these isolated colonies were so small that their addition to the area of general distribution would not have been recognized had not the area involved been scouted just before the map was prepared.

Topography, or rather a complex of factors conditioned by topography, is becoming an increasingly important influence on the natural dispersal of the Japanese beetle. The rate of spread of the insect was fairly uniform in the earlier years, owing largely to the fact that the dispersal at that time was through fairly uni-

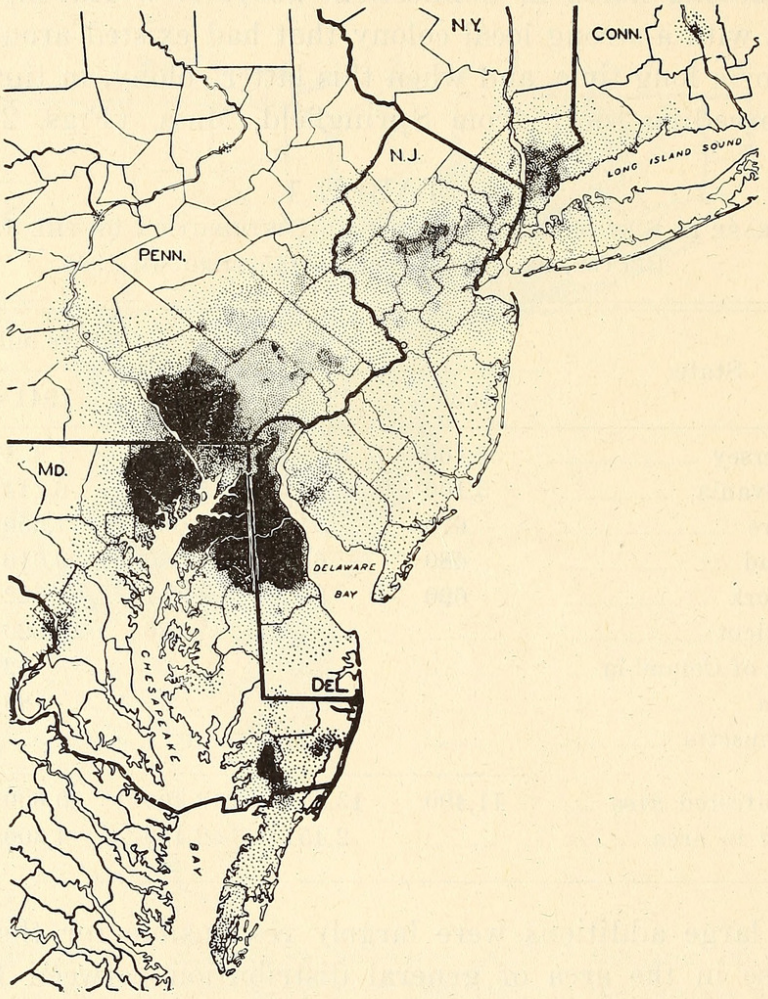

FIG. 4. The area of general distribution of the Japanese beetle in the summer of 1941. The extent of certain large isolated centers of beetle dispersal in the outer zone is shown by stippling.

form terrain. As the spread has progressed inland to the north and west, however, the beetle has reached the eastern rim of the Appalachian Mountains, which extend in a northeastern-southwestern direction across Pennsylvania, northern New Jersey, and southeastern New York. By 1943 the outer limit of dispersal had either reached or had begun to penetrate this mountain system in

all three states (Fig. 2). Observations here and at other points have shown that such physical barriers, although not permanent obstacles, do markedly retard the rate of beetle dispersal.

The physiography of the easternmost part of the Appalachian Mountains in Pennsylvania is characterized by a series of approximately parallel, heavily wooded ridges separated by narrow valleys, the ridges rarely rising more than 600 to 800 feet above

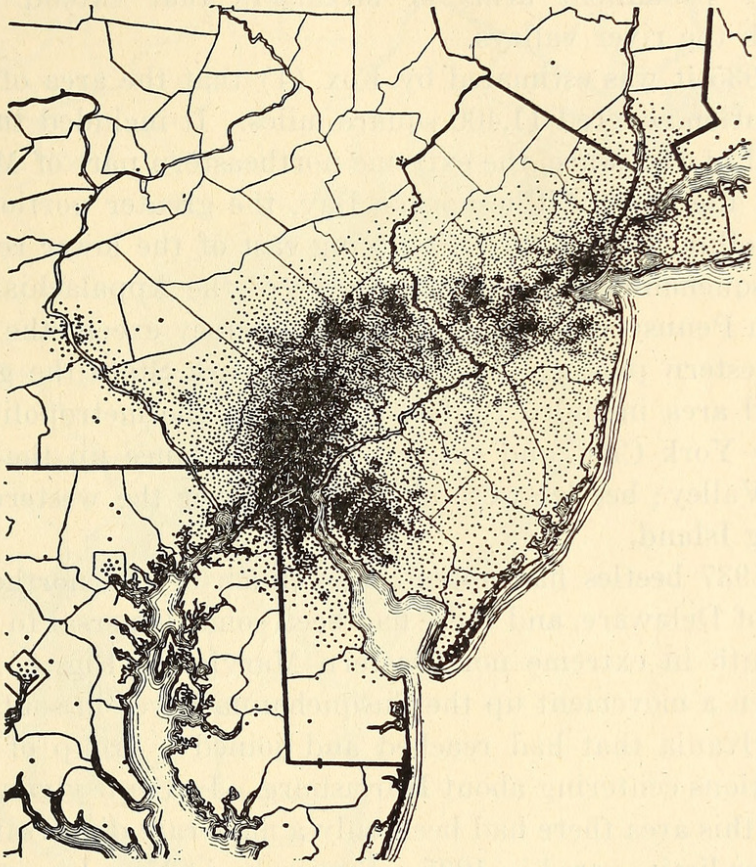

Fig. 5. The area of general distribution of the Japanese beetle in the summer of 1937.

the immediate lowlands. Occasionally these ridges are bisected by river valleys of various sizes and by natural breaks known as gaps. It is becoming increasingly evident that the dispersal of the Japanese beetle has been more rapid up these valleys and through the gaps than in the rougher, higher terrain. In 1943 the infestation extending up the Susquehanna River in Pennsylvania could be considered continuous as far as Sunbury, a penetration of roughly 50 miles into the Appalachian Mountain sys-

tem, while in the lower Hudson River Valley in New York the beetle had made its way through the bordering semimountainous country to a point some distance above Poughkeepsie (Fig. 2). The spread to the north through Connecticut has largely followed the Connecticut River Valley. Thus the outline of the area of general distribution, which in earlier years was roughly arcuate in shape, is becoming progressively irregular, being characterized by prominent arms or streamers that extend outward through the river valleys.

In 1935 it was estimated by Fox (4) that the area of general distribution covered 11,400 square miles. It included the northern half of Delaware, the extreme northeastern part of Maryland around the head of Chesapeake Bay, the greater portion of the open, rolling farming country lying east of the lower reaches of the Susquehanna River and southeast of the Appalachian Mountains in Pennsylvania, and all of New Jersey except the extreme northwestern part (Fig. 6). In New York State the generally infested area included Staten Island and the metropolitan area of New York City, and extended some distance up the Hudson River Valley; beetles were also present over the western fourth of Long Island.

By 1937 beetles had spread over much of the northern two-thirds of Delaware, and there had been some dispersal to the west and south in extreme northeastern Maryland (Fig. 5). There had been a movement up the Susquehanna River in southeastern Pennsylvania that had reached and joined a group of isolated infestations centering about Harrisburg. In Pennsylvania to the east of this area there had been only a moderate dispersal beyond the outer limits noted in 1935. Similarly, in New Jersey the dispersal had been rather slow in the semimountainous area in the northwestern part of the State. There had been a slight spread up the Hudson River Valley in New York and to the east on Long Island. The State of Connecticut had been invaded for the first time when the area of general distribution moved into the southwest corner.

On the maps for 1935 and 1937 (Figs. 6 and 5, respectively) the larger isolated colonies that lie in the outer zone just beyond the area of general distribution are designated by single dots; on

later maps only a few of the more important colonies are shown, and the extent of these is indicated by the limits of the stippled areas.

By 1939 there had been a moderate dispersal to the south in Delaware and eastern Maryland; to the west in Maryland the

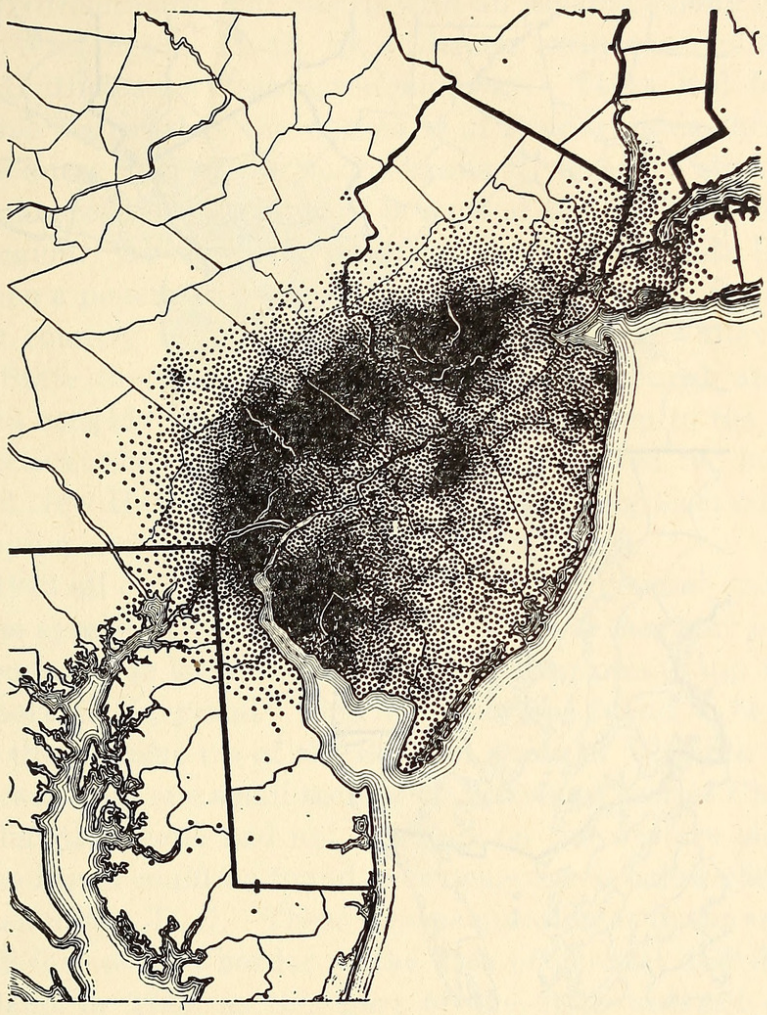

FIG. 6. The area of general distribution or the area generally infested by the Japanese beetle in the summer of 1935.

spread had carried the beetle beyond the city of Baltimore; and in Pennsylvania the Susquehanna River had been crossed from the Maryland State line to a point well above Harrisburg (Fig. 7). As in previous years, there had been only a slight movement to the northwest in the Appalachian Mountains in Pennsylvania and New Jersey, and only the normal spread had occurred up the

Hudson River Valley and to the east on Long Island, in New York State. There had been a pronounced eastward dispersal in Connecticut along Long Island Sound, resulting from the inclusion of several local infestations in the area of general distribution. The presence of a large isolated center of dispersal on the Eastern

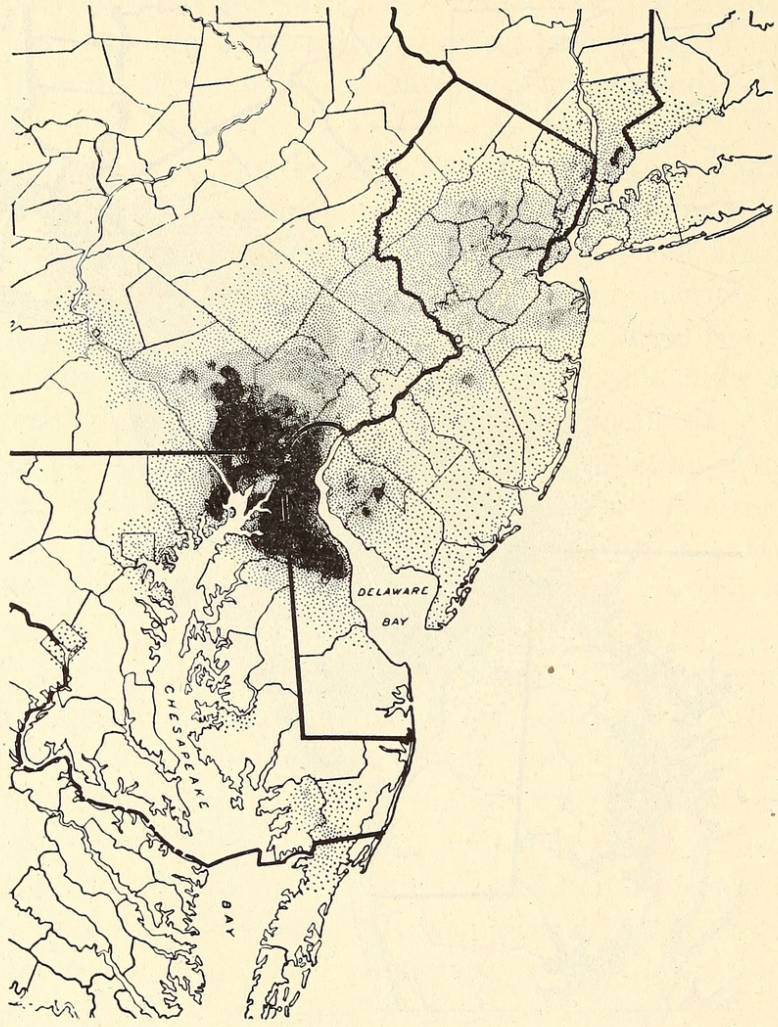

FIG. 7. The area of general distribution of the Japanese beetle in the summer of 1939.

Shore of Virginia and in southeastern Maryland is indicated on the map for 1939 (Fig. 7). There were other local colonies in this area, especially to the southward in Virginia, but, as only a partial survey of this area was made in 1939, their extent at that time was uncertain.

By 1941 all but the extreme southern part of Delaware had

become infested by the Japanese beetle, and the isolated center of dispersal on the Eastern Shore of Maryland and Virginia had increased in size until it had almost reached the lower fringe of the area of general distribution just to the north (Fig. 4). The main infested area in Maryland had spread southwestward beyond Baltimore and had united with an isolated colony centering about Washington, D. C., by a slender strip that followed the main Baltimore-to-Washington highway. There had been considerable dispersal to the westward in Pennsylvania through the open country west of the Susquehanna River and a slight though gradual spread northwestward in most of the Appalachian Mountain region. At one point near the New Jersey State line there had been a penetration through the Delaware Water Gap into the higher country beyond. Up the Hudson River Valley in New York State the beetle had spread beyond Newburgh and it had covered roughly half of Long Island in its sweep to the east. In Connecticut the dispersal to the east had carried the insect well beyond New Haven, and north of there a strong local colony was developing and spreading south from Hartford.

In 1943 all of Delaware was in the area of general distribution and the spread of the beetle to the south had met and joined the previously large isolated center of dispersal occupying the Eastern Shore of Maryland. This new area was found to be continuous to the extreme tip of the Eastern Shore of Virginia (Fig. 2). There was only one small section of Maryland east of Chesapeake Bay that the beetle had not reached; on the western side of the bay the insect could be found everywhere well below the latitude of Washington, D. C. There is some question as to the exact location of the western border of the area of general distribution in Maryland in 1943, as this part of the state was not carefully scouted, and, as may be seen from the map, there is a large isolated center of dispersal to the west that may possibly have become joined to the generally infested zone at some point. The spread to the west in southeastern Pennsylvania west of the Susquehanna River had continued and it will probably move rapidly in the future, as this open, fertile farming country is well fitted to support a heavy beetle population. Beetles were found along both banks of the Susquehanna River as far as Sunbury,

where a local colony has existed for some years. By 1943 all the open farming country in southeastern Pennsylvania south and east of the Appalachian Mountains was generally infested, and at several points the insect had begun to penetrate this mountain system. In 1943 all of New Jersey was placed in the area of general distribution for the first time. In New York State the Hudson River Valley became infested beyond Poughkeepsie and beetles may now be found in the hilly terrain near the Connecticut State line beyond Pawling. There had been a steady dispersal to the east on Long Island, slower in the central part than in the shore areas because this inland section is unfavorable for beetle spread and development. As already noted, there had been a marked increase in the infested area in Connecticut since 1941, for, in addition to a considerable dispersal to the east, there had been a spread up the Connecticut River Valley in which the area of general distribution moving north from New Haven had met and united with the strong isolated infestation that had been moving down from Hartford for several years. North of Hartford there had been fusion with a dispersal center that had been moving south from Springfield, Mass.

By the end of the 1943 beetle season the area of general distribution was estimated at 29,200 square miles. This is more than twice the size of the continuous area in 1937, when 13,851 square miles were infested. It required from 1916 to 1937, a period of 21 years, to cover a smaller area than has been covered in the 6 years from 1937 through 1943. As previously noted, this striking increase came about largely as a result of the inclusion in the area of general distribution of a number of large isolated centers of dispersal. It is of interest that the extreme outer limits of general dispersal to the south, Cape Charles, Va., and to the north, Springfield, Mass., are each approximately 200 miles from the seat of the original infestation in this country near Riverton, N. J., while some of the more remote points of dispersal to the northwestward into the mountainous section of Pennsylvania are only about 75 miles away.

It will be noted that the distribution maps which accompany this paper are not all on the same scale and that there are differences in their structural make-up. This is because these maps

have been drawn by different persons and because the size of each map had to be adjusted to cover the limits of the area of general distribution as found at the time.

BEETLE ABUNDANCE IN THE AREA OF GENERAL DISTRIBUTION AND CLIMATIC AND BIOTIC FACTORS THAT CAUSE CHANGES IN NUMBERS

The abundance of the Japanese beetle at any point is dependent on many factors, among the more important of which are the age of the infestation, the type of habitat, which includes the availability of favored food plants and suitable places for oviposition, the amount of summer rainfall, and the presence or absence of predaceous and parasitic insects and pathogenic microorganisms. It is not within the scope of this paper to go into all these subjects in detail, as they have been treated in other publications (4, 5, 8, 9), but influences known to have been especially active in the years 1935 through 1943 will be briefly discussed.

When the Japanese beetle first spreads into new territory, so few are to be found that it is necessary to search the more favored food plants carefully to locate them. This would be the condition along the outer fringe of the area of general distribution. From this small start the population will gradually increase for a number of years until, if conditions are favorable, beetles will be present in highly destructive numbers; eventually the population will decline until a more or less stable condition at a lower level is reached. The abundance of the insect at any place, therefore, will depend to some extent on the age of the infestation or the position of the given place in the above cycle.

The Japanese beetle has been found to thrive in suburban residential areas where there are plenty of garden and shade-tree hosts and an abundance of thrifty turf for oviposition; beetle colonies also flourish in agricultural areas having good loamy soil, an abundance of pasture land, and plenty of food plants in the form of fruit trees, cultivated crops, or favored weed hosts. Beetles do not usually develop to great numbers in densely wooded regions, in neglected land overgrown with plants that are unattractive as food, or in places with a very light type of soil. Beetle concentrations will depend to some extent, therefore, on the environmental conditions encountered as the insect moves

into new areas (5, 8). It should be noted, however, that strong beetle colonies have been found in some locations that would appear to be unfavorable for their development, showing that the beetle has great adaptability.

The amount of rainfall during the summer months, when eggs and newly hatched larvæ predominate in the soil, has an important bearing on the size of the beetle population the following year, because the eggs need an abundance of moisture to complete their embryological development (4, 6). The rainfall at any point varies greatly from year to year and, as precipitation in summer is often in the form of local showers, there may be plenty of moisture in the soil at one point and a deficiency at places nearby. In the Philadelphia area the critical period for eggs in the soil is roughly from July 1 to August 10, as soil surveys have shown that nearly 95 per cent of the eggs in an average season are found during this time; at points south of Philadelphia this period occurs earlier, and it is slightly later farther north. Variations in rainfall can therefore cause marked fluctuations in the beetle population.

Insect parasites of the different stadia have, at least locally, an influence on the size of the beetle populations. Under varying, limited environmental conditions parasitic nematodes, fungus diseases, and an undetermined number of bacterial diseases may also become highly important factors in reducing the soil population. In restricted areas predators, such as birds, skunks, mice, and moles, are often active in destroying various stages of the beetle (5).

Of the various factors effecting a measure of biotic control of the Japanese beetle, however, probably the most widespread and generally effective is a group of bacterial pathogens that produce the condition known as milky disease of beetle larvæ. The infective stage of this group in the soil is a bacterial spore which is well adapted to survive under a wide variety of environmental conditions, because it is highly resistant to desiccation and can maintain its viability and infectiousness over a period of several years and then be able to transmit the disease to other larvæ that ingest the spores along with soil particles in feeding. When diseased larvæ die, the infective spores that fill the body cavity are

left in the soil and, in places with high larval populations, the spore concentration increases so rapidly that milky diseases become an increasingly important factor in keeping the population of the insect at a low level.

Following several years with favorable climatic conditions and in the absence of a strong concentration of milky disease spores in the soil, the Japanese beetle by 1935 had become abundant over much of the infested area in New Jersey and eastern Pennsylvania, as is evident from the extent of the closely stippled and dark areas on the distribution map for that year (Fig. 6). In the more heavily stippled areas obvious foliage injury would be of general occurrence and locally there would be extremely severe damage. From this destructive condition there would be a gradation to one of only slight feeding in the lightly stippled areas along the lower Atlantic coast, where beetles have rarely been present in destructive numbers. The feeding habits and food plants of the beetle are treated in a circular by Hawley and Metzger (8).

In the interval between the summer of 1935 and that of 1937 climatic conditions had a marked reducing effect on beetle populations (Fig. 5). The summer of 1936 was warmer than usual and also deficient in rainfall during July in the section of New Jersey north of Trenton and the contiguous part of Pennsylvania to the west. Elsewhere in the area of general distribution precipitation was rather uneven in 1936, and, as a result, infestations in 1937 tended to vary greatly in intensity. In January and February, 1936, there was an extended period when low temperatures combined with abnormal soil moisture brought about the most widespread mortality of hibernating larvæ that has occurred since the beetle first became established in this country. As noted in a paper by Hawley and Dobbins (7), this winter-killing occurred largely in the southern half of New Jersey, in southeastern Pennsylvania, and at certain points in Delaware and Maryland. The combination of these unfavorable weather conditions resulted in a marked drop in the beetle population in much of the infested area by the summer of 1937.

Rainfall was far below normal in July and August, 1937, in the southern half of New Jersey, and the already depleted beetle

population was still further reduced. Elsewhere in 1937 and everywhere in 1938 rainfall was adequate for the favorable development of the insect, and by the summer of 1939 an increase in beetles at most points was clearly evident. The highest concentrations continued to exist in southeastern Pennsylvania, northeastern Maryland, and northern Delaware (Fig. 7).

In 1939 and 1940 summer rainfall was below normal in parts of northern New Jersey and in all of southern New Jersey, and by 1941 the infestation in the southwestern part of the State, where a few years before beetles had been more destructive than elsewhere in the country, had markedly decreased from that observed in former years. Numbers were also reduced in Pennsylvania, except in the densely infested zone in the southeastern corner of the State. This same high concentration of the insect was apparently also maintained in northern Delaware and northeastern Maryland. In the isolated infested area in southeastern Maryland beetles were also present in considerable numbers and there were increases at some points in southeastern New York (Fig. 4).

In both 1941 and 1942 there was a return to a condition of at least normal summer rainfall, and this was accompanied by increases in the beetle population throughout most of the enlarged area of general distribution. The infestation in southwestern New Jersey showed a remarkable increase in intensity, and there were larger areas of high beetle concentration in northern New Jersey, in parts of Connecticut, and in Pennsylvania, Delaware, and Maryland, as well as on Long Island (Fig. 2). The current trend appears to be toward the development of several large heavily infested tracts separated by more lightly infested zones. In any of the darker areas on the more recent maps severe foliage injury would be general.

In discussing changes in beetle abundance from 1935 through 1943 the influence of summer rainfall has been stressed, not because it is the only factor involved but because it is the one best understood. At the beginning of this period the organisms causing milky disease were present locally in the oldest infested area about Philadelphia, but diseased larvæ were found rarely, if at all, in the more remote parts of the area of general distribution. There has been some natural dispersal of milky disease infection

during the period from 1935 to date which has carried the organism into new areas, but this spread has not kept pace with the natural dispersion of the beetle. For this reason the bacterial pathogens that cause the most prevalent type A disease have been introduced at many points throughout the beetle-infested states in an extensive colonizing program carried out by the Moorestown, N. J., laboratory in cooperation with entomological agencies in the states involved (13, 14). As shown by soil surveys discussed in papers by White (10, 11) and by White and Dutky (12), the type A disease has become so well established at many points that it is now an important factor in reducing the soil population of the Japanese beetle. The widespread distribution of this disease was not started until 1939 and, as it is possible to treat only a relatively small percentage of the land in any given area with the limited spore material available, it is still too soon to expect large reductions in beetle populations at the more recent points of introduction. Soil surveys have shown, however, that there is such a high incidence of disease at certain points in Connecticut, New York, Delaware, and Maryland, where treatments were applied early in the distribution program, that recent reductions in beetles in these areas are undoubtedly due to this cause. As already noted, spore concentrations of milky disease in the soil increase rapidly in the presence of high larval populations; therefore this disease should become an even more effective agent as time goes on.

The situation in southwestern New Jersey deserves especial consideration. It has been possible to trace the yearly changes in the soil population in this area by surveys made by the personnel of the Moorestown laboratory. Several years ago, when beetles were plentiful in this area, spores of the milky disease built up to a high concentration; later, when a marked drop in the larval population occurred, the disease still persisted, although a smaller number of the infected larvæ were recovered. This was the condition in 1940, but, following two summers with favorable rainfall, the larval population had greatly increased by 1943 and the disease incidence had become so high that this factor alone undoubtedly would have brought the soil population down to a much lower level. However, the summer of 1943 was again ex-

tremely dry, and this will also tend to reduce the beetle concentration in this area in 1944. Apparently, therefore, there are two main agencies operating to bring about changes in the soil population, one of which, the milky disease, when once established, continues to build up and increase in effectiveness as a control measure; whereas the other, summer rainfall, is an uncertain, fluctuating factor that may bring about either an increase or a decrease in numbers. These two factors working together are probably responsible for most of the larger changes in population density. As already noted, other agencies that go to make up the biotic complex are operative, but the area in which they occur is usually more restricted. There is some evidence that at certain places, in the outer zone to the north, unrecognized factors are at work, therefore the picture of population changes, as we know it now, is still far from complete.

STATUS OF THE BEETLE IN THE ISOLATED COLONIES OF THE OUTER ZONE

In the outer zone, beyond the limits of the area of general distribution, the Japanese beetle occurs in isolated colonies of various sizes with uninfested areas in between. These colonies exist because at some time in the past beetles were carried to these points by automobile, train, airplane, or in the transportation of plants or other materials (5, 9). Every known point where beetles have been found in the outer zone is indicated by a dot on the map in Figure 1. In some places, as in Bratenahl, a section of Cleveland, Ohio, and at Providence, R. I., Richmond, Va., and Asheville, N. C., these colonies have increased in size and strength over a period of years until beetles are now present in destructive numbers. At many points shown on the map only a few beetles were originally found and in some places it was impossible to find any beetles when these locations were checked by trapping or scouting. For example, 1 beetle was found at Fort Madison, Iowa, the most western point, in the summer of 1937 and none has been taken since. At 3 locations in Florida that are shown on the map a total of 10 beetles have been taken in 2 trapping seasons and there is no evidence that permanent colonies now exist in this state. A combined scouting and suppression program is carried on in the outer zone each year by the Division of Japanese

Beetle Control of the Bureau of Entomology and Plant Quarantine, in cooperation with state regulatory agencies. As a part of this program traps are operated at key locations in many states and information is thus obtained as to the presence or absence of the insect at these remote points. The presence of beetles at most of the locations shown on the map (Fig. 1) was discovered in these trapping operations. Beetles have been taken at only a few of the many places that have been trapped. At many points in the outer zone an effort is being made to eradicate these local infestations by treating the soil with lead arsenate to destroy the larvæ as they feed. Trapping in these treated places has shown that a good control has been obtained and few beetles will now be found at most such places.

It is not within the scope of this paper to consider how far the Japanese beetle will eventually spread in this country or what its status as a pest will be in its future range. This subject has been ably treated in a paper by Fox (4) published in 1939, and most of the evidence obtained since this time indicates that the insect will be able to maintain itself in most of the Eastern States, as Fox predicted, and that in much of its new range it could build up to destructive numbers. It is pointed out by Hawley (6) that under the colder climatic conditions in the northern part of the outer zone the seasonal cycle of the insect is so modified that it will probably not become so numerous or destructive there as it has farther south. Some uncertainty still exists as to how the beetle will react in the coastal sections of the extreme Southern States with their lighter types of soil, the higher temperatures, the prolonged periods of scanty rainfall, and the differences in vegetation. Sufficient evidence is available, however, to show that the Japanese beetle can eventually disperse into the outer zone well beyond the present limits of the area of general distribution before encountering any effective barrier to its successful establishment.

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