BIONOMICS OF THE CODLING MOTH, CARPOCAPSA POMONELLA L., IN THE ANNAPOLIS VALLEY, NOVA SCOTIA.

Harold T. Stultz

Thesis
Presented to the

Faculty of Graduate Studies and Research of McGill University
In partial fulfilment of the requirements for the
Degree of Master of Science
1946

ACKNOWLEDGEMENTS

This study has been conducted under the general supervision of A.D. Pickett of the Dominion Entomological Laboratory, Annapolis Royal, N.S. He is immediately responsible for its inception and for the provision of departmental facilities wherever and whenever required. In addition he has given invaluable assistance through advice, and discussion, throughout the course of the study as well as by reading and criticising this paper during its preparation.

W.A. Ross, Chief Fruit Insect Investigations, Dominion Department of Agriculture, has taken on active interest in the project from the time it was initiated. Out of his experience with the codling moth in Ontario he has given advice and encouragement from time to time. He has also, shown a ready response to requests for departmental facilities.

N.A. Patterson has been responsible for the spraying and most of the records for drops and picked apples in experimental spray plots.

The bench insectary, cages, and other apparatus required for this study, have been constructed by S.H. Payne who also assisted in planning them. Mr. Payne photographed and printed all the graphs.

The originals of the graphs are the handwork of either the author or of Miss Mildred Clarke working under his supervision.

Assistance in record taking has been obtained from several temporary summer employees of the Division of Entomology, namely Gerald Hines in 1942, J.R. Harlow in 1944 and 1945, and Walter Chipman in 1945.

The headings throughout the paper have benefitted from the criticism and suggestions of Frank T. Lord and Albert McPhee.

TABLE OF CONTENTS

Page

Page

LIST OF ILLUSTRATIONS

BIONOMICS OF THE CODLING MOTH, CARPOCAPSA POMONELLA L., IN THE ANNAPOLIS VALLEY, NOVA SCOTIA

Harold T. Stultz.

1. INTRODUCTION.

When Charles Fletcher was appointed Dominion Entomologist in 1884, the codling moth was already recognized as a major pest of the apple in Eastern Canada.

While control of the insect by trapping the larvae in tree bands had been practiced since 1846 (Slingerland, 1898), it was only about the time of Fletcher's appointment that the use of poison sprays for the control of this insect had become well established. From the time of his earliest reports, he recommends both methods of control. The available records indicate that for awhile after the turn of the century the codling moth markedly decreased in importance as an apple pest, following the use of bordeaux-arsenical sprays in the Annapolis Valley. About 1924 it apparently started increasing in importance so that by 1930 it again became a major pest in a few restricted areas, particularly that around Berwick. In 1927 Brittain (1927) was still able to say that, "The control of the codling moth is not the problem in Nova Scotia that it is in many other apple growing sections and the ordinary sprays or dusts, applied immediately after blossom fall and again in two weeks time, are usually sufficient to keep it in control". By 1937, however, it threatened to make commercial apple growing impracticable in a few orchards in the Berwick area unless special methods of control were used against it.

Until the present project was started in 1939, no special biological study of this insect had been made in the Annapolis Valley, probably because it was felt that the numerous and detailed studies done elsewhere on the continent, more particularly that in Maine by Siegler and Simanton (1915), were sufficient for the needs of entomologists and growers in this area. In 1938 and 1939 both the Provincial and Dominion entomological staffs conducted codling moth spray experiments at Berwick. Every year since then, excepting 1940, the Dominion Entomological Division has conducted one or more codling moth experiments, in orchards in the same locality.

When it became necessary to initiate special codling moth spray programs it was realized that they should be based on accurate knowledge of the life history and habits of the insect in the Annapolis Valley. In 1939 some preliminary records and material were obtained by the writer who was assigned to this project by A.D. Pickett, Officer-in-Charge of the Dominion Entomological Laboratory, Annapolis Royal. During the years 1940 to 1943 inclusive the writer spent a major portion of his time on this project. Most of the life history data reported in this paper was gathered during this period. It is supplemented, however, by some additional data gathered in 1944 and 1945.

During 1940 and 1941 life history records were made on codling moth material at both Annapolis Royal and Berwick. Although these two stations are only about 45 miles apart, yet codling moth injuries are almost unknown as such in commercial orchards in Annapolis County, whereas at times between 90 and 100 per cent of the apples have been culls in a few orchards in the Berwick area of Kings County. Conditions were nearly as bad in a few orchards in several other localities, particularly near Falmouth and Gaspereaux Village.

Beginning in 1942 a summer headquarters was established at Berwick and the study of codling moth development was confined to Kings County, more particularly the Berwick area where most of the persistant infestations are located.

II. HISTORICAL BACKGROUND

A. Early history in America

According to Slingerland (1898) whose paper is a codling moth classic, the first American picture of the codling moth was that published by a Miss Morris (1846) just 100 years ago. The insect was first recognized as such in America by Tufts in 1819, although the insect had actually been introduced many years before. Previous to this time all wormy apples had been credited to the plum curculio. It was probably introduced into America from Europe in packages containing apples or pears. The time of its arrival is not known, although Slingerland suggests about the middle of the eighteenth century. The native home of the insect is considered to be that of its principal food, the apple, whether Europe or Central Asia.* At the present time it is a cosmopolitan pest, occurring wherever apples are grown. By 1898 it was recognized as a pest in nearly every section of the United States where apple orchards were established.

As already indicated it was well established in the apple growing areas of Ontario, Quebec and the Maritime Provinces when Fletcher took office in 1884. About this time (1885), at least one of Fletcher's correspondents in British Columbia reported that the codling moth together with other insects, threatened to make apple growing economically impractical in some orchards unless effective control measures were made available to the owners. It turned out

---

* Shelford (1927) suggests the Mediterranean region as the original habitat of the codling moth. This is postulated on the basis of hytherograph records for different apple growing regions of the world.

that this so-called codling moth damage in British Columbia was really due to the lesser apple worm, Grapholitha prunivora Walsh. It was not until 1905 that Fletcher (1906) was able to report that the codling moth had been definitely located in British Columbia. The lesser apple worm is also found in unsprayed orchards in Nova Scotia and sometimes accounts for a considerable proportion of codling-moth-like injuries in such orchards. Because the injury by G. prunivora is so readily confused with that by C. pomonella the earlier records of codling moth damage in Nova Scotia, even some of those in the 1920's are sometimes open to question and too much reliance should not be placed on them. The lesser apple worm does not long survive in orchards in which arsenical sprays are used. It is possible that the striking results following the use of the poisoned bordeaux mixture in the 1890's and early 1900's is partially due to the quick elimination of G. prunivora as well as to a definite reduction in the numbers of C. pomonella.

It may never be established where or when the codling moth was introduced into Nova Scotia. It is not at all improbable that, along with many other firsts, the Annapolis Royal area should be credited with that of being the location of the original introduction of the insect into this province, if not into North America. This statement is made on the basis of certain historical records assembled by Comeau (1934) concerning the early planting of the apple tree in Nova Scotia and elsewhere on this continent. There are definite records of apple trees growing at LaHave as early as 1635. Comeau believes that "circumstantial evidence strongly supports the suggestion that apple seeds and trees were planted at Port Royal in 1606 or 1610". The records do not indicate whether the first trees originated from seeds or apple trees originating in the Old Country. It is not at all unlikely that later French adventurers would sometimes start their voyages to the new world with a goodly supply of fresh apples for use on the trip. If these apples had originated in codling moth infested orchards in France it would be strange indeed if some of the containers did not harbour codling moth cocoons. If these infested containers were left ashore in the vicinity of orchards that had been planted earlier and had already come into bearing, these orchards would readily become infested. Thus if orchards were first established between 1606 and 1635 they might well have become infested before the end of the century.

B. Codling Moth Records for Nova Scotia, 1884-1945

James Fletcher issued his first report as Dominion Entomologist in December of 1884. His reports, covering the period up until his death in 1908 are based largely on information forwarded by correspondents living in different agricultural areas of the Dominion of Canada. On the basis of these reports, he often makes general statements regarding pests which refer to the country as a whole. The following notes regarding the prevalence of the codling moth have been copied from Dr. Fletcher's annual reports, where he actually or by inference refers to Nova Scotia conditions. Gaps in the record indicate years in which there was not even inferential reference to the status of the codling moth in Nova Scotia.

1884 - "The apple was attacked in some parts by the codling moth".

1885 - "This troublesome insect is so well known to fruit growers that any description of the insect as its mode of working is unnecessary. Throughout the Maritime Provinces .... it appears not to be quite as destructive as usual".

1896 - "........has, as usual, been mentioned frequently in correspondence, but on the whole, owing to the enormous apple crop and also to the more general adoption of spraying, has not done much harm". His correspondent, S.C. Parker, at Berwick, N.S. writes, 'Very few wormy apples'.

1901 - Mr. Parker (S.C.) secretary of the Fruit-Growers Association of Nova Scotia writes "in very much the same strain" as the secretary of the Ontario Association who writes that, "The codling moth is still the terror of the apple-growers. It is a most serious enemy, and, if you can give us any later information with regard to the best method of destroying it we should be very glad".

1902 - " A marked decrease in the injuries by some of our well known pests such as the codling moth,..........through most of our fruit-growing districts".

1903 - "The apple crop, in Nova Scotia was a remarkably good one, large in quantity and excellent in quality, being very free from insect attacks".

1904 - "The year 1904 may be said to have been remarkable for the absence of injury by the codling moth, Professor Sears at Wolfville, wrote, 'We have been singularly free from injurious insects this year'.

1905 - "The Codling Moth, which on the whole, perhaps, is the worst enemy of the fruit grower, has levied a heavy toll as usual in unsprayed orchards, but wherever thorough work has been done in spraying regularly with the poisoned bordeaux mixture, good results have almost invariably followed. In every part of Eastern Canada where apples are grown, reports speak of injury by this insect and,.........possibly the comparative scarcity of fruit this season makes the injury by the Codling moth seem more apparent. There is not the slightest doubt that in all parts of Canada east of Toronto spraying orchards regularly with poisoned bordeaux mixture, three or four times in spring, the first application to be made within a day or two after the blossoms fall and the subsequent sprayings, each ten days apart, is a satisfactory and well paying remedy for the Codling moth".

1906
1915 - The Dominion Entomologist's reports during the period 1906 - 1914 make no reference to codling moth conditions in Nova Scotia. In 1912 G.E. Sanders was put in charge of a Dominion Entomological Laboratory near the western end of the Annapolis valley. Apparently the codling moth had been a relatively unimportant pest in his early experience since he writes (1915) "Owing to its comparative scarcity the codling moth has received very little attention as yet in the province. It is very rare to find even an unsprayed orchard which gives over 5 per cent wormy apples......here in Nova Scotia we have never found any definite indications of a second brood".

1916 - In the following year Sanders (1916) wrote: "In spite of the great congestion of the orchards in the Annapolis Valley we are so far North that the codling moth is a pest of very minor importance, and we seldom find over 5 per cent of the apples in an orchard infested. I sometimes think that spraying helps to control it in the unsprayed as well as in the sprayed orchards, for as near as I can determine, the codling moth is decreasing in the unsprayed orchards as the proportion of sprayed orchards about them becomes greater and greater".

In an unpublished manuscript written the same year Sanders (1916) said, "In districts outside the Annapolis Valley occasionally 30, 40 or even 50 per cent of the apples may be found infested".

The following material pertaining to codling moth abundance in the Annapolis Valley since 1917 is taken from the annual reports of the Dominion Entomological Laboratory at Annapolis Royal (Anonymous 1922-23,1928-30, Sanders 1917-21, Spittall 1924-27, Gilliatt 1931-37, Pickett and Patterson 1938-39, Cameron and Patterson 1940, Patterson and Neary 1941-1945). Comparable data,not quoted here, will be found in the annual insect pest forecasts of the provincial entomologists during the period 1929-1945 (Pickett, Cameron and Neary in annual Reports N.S. Fruit Growers Association).

1917 - 1920 - Not reported in summaries of insect outbreaks

1921 - "Reports of injury received from numerous farmers. Wormy apples very common. It would appear that codling moth has had two broods in Nova Scotia this season".

1922 - Not reported.

1923 - "Not abundant in western end of Annapolis Valley but apparently a slight increase in Wolfville district. Our experimental records show that this pest has during recent years been of little importance in Nova Scotia".

1924 - "Work seen at Tupperville, Berwick and Annapolis Royal..... believed to be slowly increasing".

1925 - "Occurs in more places in Annapolis Valley than in 1924. Appears to be on the increase at Berwick. On the whole, however, it is not yet a pest of importance in our orchard areas".

1926 -"Fairly common in Bear River district and at Nictaux. Slowly increasing and becoming more widespread. Quite severe in neglected orchards in Western Hants County".

1927 - "Not changed from 1926. Up to 1926 believed to be slowly increasing. Not a pest of economic importance".

1928 - "Wormy apples more numerous than for many years".

1929 - "Less in evidence than in 1928. Stings noted in orchard at Canning".

1930 - "A decided increase over entire Annapolis Valley, the injury being more pronounced than for several years".

1931 - "Probably caused somewhat more wormy fruit than in average year".

1932 - "A further increase has apparently occured as wormy apples and stings quite pronounced in many districts of the Valley. The infestation was most general in the Berwick and Canning districts".

1933 - "Injury from 'late brood' somewhat more in evidence than formerly but not as severe as in a few orchards in 1932".

1934 - "Though not a major orchard pest it has been causing some injury in recent years. About same degree of infestation as in 1933".

1935 - "An apparent increase reported in Central and Eastern portions of Valley where much injury was done to crop".

1936 - Not reported. (A.D. Pickett states that this was definitely an off year for codling moth).

1937 - "The stings severe in areas around Berwick and Waterville. Also considerable sting injury in parts of Hants County. The increase of this insect in many parts of the Annapolis Valley is quite pronounced in comparison with 1936".

1938 - "An increase occurred throughout Valley but only in Berwick and Waterville districts did serious outbreaks occur. In these districts some orchards showed 40 to 60 per cent stung apples of some varieties".

1939 - "On the whole somewhat less injuries than in 1938. A few orchards fairly heavily infested".

1940 - "Some increase over 1939. In the Berwick district some orchards not receiving special treatments for their control had nearly the whole crop ruined".

1941 - "In many orchards in central and eastern Kings and Hants Counties generally more numerous than in 1940 being a pest of major importance. In the western end of the Valley it was of only minor importance and showed no apparent gain".

1942 - "In past years this insect has been a major pest in some areas in Kings County and in some orchards of Hants County. This year there has been a general increase throughout, and a pronounced increase all over Western Nova Scotia within and outside areas where spraying was done. The damage was more widespread than unual, with a heavy carry-over of 'Worms' in many orchards".

1943 - "The damage to fruit this year was not as great as expected a year ago, due in part to the fairly high mortality of the over-wintering caterpillars, and the backward spring. However, in moderately to heavily infested orchards in which the full spray programme was not carried out, much damage was done. In other blocks of orchards which previously had light infestations the amount of injury increased; but for the Valley as a whole there was a decrease in the amount of damage done".

1944 - "The injury caused by codling moth in 1944 was less for the fruit growing area as a whole than in 1943, even though the area of infestation increased. This reduction in injury may be explained in part by the fairly dry season which aided in the retention of poisonous residues on the foliage and fruit. There was, however considerable injury in some districts and in individual orchards where codling moth has been a pest for years. Many of these orchards received a special spray programme in 1944 for the control of codling moth, and in most cases the injury was reduced".

1945 - "The codling moth was somewhat more abundant than during the previous season. The light crop of fruit throughout the entire fruit growing area concentrated the larvae on fewer apples, making the infestation seem even heavier than it was. On account of the light crop, many orchards received less spray than usual and as a result a larger proportion of deep entries occurred in the fruit than usual. There was no evidence of second generation larvae in the fruit."

The above record in codling moth prevalence, during the past 60 years although rather extensive is recorded here not only to bring this information together in one place, but also as evidence that the status of the insect has been changing in respect to control measures that were formerly quite effective. This is in accord with the experience of entomologists and fruit growers in other areas of North America where intensive control measures by means of insecticides, particularly arsenicals,have been carried on over a period of years. (Hough 1943).

C. Brief History of Orchard Sprays in Nova Scotia

In view of the fact that it has been established (Pickett et al 1946) that spray practices have a profound effect upon the biotic complex of an apple orchard a brief history of orchard sprays is included in this paper. A more complete account will be found in Kelsall's(1937) paper on the subject.

Progressive apple growers were using a poisoned bordeaux spray for some time previous to 1900. By 1910 spraying was a routine procedure for nearly all growers. It was about this time that both lime-sulphur and lead-arsenate came into use. It was about this time also that power sprayers were introduced.

The extensive use of orchard dusts was commenced about 1918. In a short time large numbers of growers were relying on this method of control. It reached its height about 1924 and thereafter its use declined. The dusts used consisted of mixtures of sulphur and lead arsenate or af Bordeaux dust and calcium arsenate. Wettable and colloidal sulphurs came into increasing use after 1924 so that their use has been quite general since about 1929. A Bordeaux mixture containing excess lime has generally been used in the early pre-blossom sprays and very often for the last cover spray.

The use of mineral oil sprays in the dormant or delayed dormant period was commenced in the latter part of the 1920's. Because of their devastating effect on the natural control agents of the European red mite, Metatetranychus ulmi (Koch) = (Paratetranychus pilosus C & F) their use has been discouraged except under conditions of necessity. Nevertheless the increasing prevalence of the oyster shell scale (Lepidosaphes Ulmi L.) has resulted in the wide-spread use of dormant oils which in many cases include a dinitro (so called DN-phenol or DN-cresol) compound.

III. MATERIALS AND METHODS

A. Insectary studies

1. Rearing Apparatus and Methods

During the years 1940 - 1943, reared larvae formed their cocoons and pupated in cocooning sticks of the type generally employed in codling moth life history studies (Peterson's manual, (1937) Part two, plate 11, figure eleven). When the adults emerged, they were transferred to lantern globe cages, as illustrated (Fig. 1). The base of the cage consists of a petri dish cover. Moisture is supplied by means of a wet cotton plug in a vial inserted through the cotton top of the lantern globe. By filling the vial with water every day or so, the cotton plug is kept moist. One or two pear leaves were kept in the bottom of the cage. Female moths oviposited on the leaves, on the sides of the globe and on the petri dish base. The petri dish base and the pear leaves were removed and replaced daily except Sunday as long as oviposition was going on. A record was kept of the number of eggs laid daily, except Sunday, on the petri dish bases and on the leaves and subsequent records were kept of development to the black-spot stage and hatching on the petri dish bases. As a rule the number of eggs on the sides of a globe were not counted until oviposition was completed and the moths in a cage had died. Successive cumulative percentages of the total eggs laid by females in globes are based on daily counts of eggs on leaves and base. Dead moths were usually removed daily except for material kept at Berwick. The sex of each moth was determined and recorded.

A record of larval development was obtained by placing pear leaves carrying eggs, in a gum jar together with a number of clean apples collected from an unsprayed orchard in which the [illegible] known to be scarce or absent. The date on which eggs hatched was recorded as the date that larvae entered the fruit. The length of the larval stage was determined by recording the date larvae entered cocooning sticks placed in the gum jars with the wormy apples. These were examined almost daily and the date of entry into a cocooning site in the stick was marked in pencil on the wood opposite the site. The methods followed are somewhat similar to those described by Schoene, Hough, et al (1928) The cocooning sticks were kept in wire cages (Fig. 2) of the type described by Cutright (1936) and figured in Peterson's manual, (1937) Part two, plate 143. Moths were also obtained from short pieces of unsplit apple tree branches having rough bark, on which known numbers of over-wintering larvae had been caged the preceding fall so that they had spun cocoons under the rough bark. These were kept in cylindrical wire cages hung near the lower centre section of apple trees so that conditions would approximate those of larvae which had made their over-wintering quarters normally on tree trunks.

In addition to these methods, in 1943 and 1944 codling moth larvae in cocooning sticks or corrugated paper rolls were placed in two large flower pots to which wooden tops were fitted by means of felt strips and wire lugs so that neither larvae nor moths could escape around the edge. A hole fitted with a short glass tube was put in the centre of each for the emergence of moths. A lantern globe cage which had a cloth top was placed over this for the reception of moths as they emerged. One of these pots was kept moist by wrapping it around with absorbent paper and cheese cloth and then setting the pot in a pan of sphagnum moss which was kept constantly wet. The other pot was left dry. The drain holes on the bottom were plugged and both pots were set on the ground side by side under the bench insectary at Berwick. A wooden screen with louvres like a meteorological screen was set around the pots. This kept the pots constantly shaded but with a free flow of air around them. This experimental set-up was designed in order to find out whether constantly damp cocoon conditions induced the occasional appearance of the biennial habit in the codling moth. While no evidence was gained on this point, yet some interesting records were obtained regarding the effect of these conditions on moth emergence, mortality and oviposition.

2. Insectaries

At Annapolis Royal the lantern globe cages and rearing jars were kept in the laboratory insectory which is located about 10 feet beyond the east end of the main laboratory. This building has walls of wire cloth on all sides except the south-east corner in which a small boarded shelter is located. The codling moth material was under shaded conditions at all times.

At Berwick the lantern globe cages and rearing jars were kept inside a portable bench insectary which was designed for this project (Fig. 3 and 4). This insectary was first used in 1941. Material was kept under partially shaded conditions by means of extended eaves formed of cotton sheeting stretched on wooden frames as illustrated. This insectary was set up in an open space between two adjoining orchards at Berwick, namely the D.L.B. Chute "Captain Robbins" orchard and the Cyril Hiltz South orchard.

B. Field Studies

1. Spring Development in Hibernating Quarters

A record of pupation and moth emergence in the field was obtained by periodically completely removing and examining all loose bark from the trunk and limbs of apple trees carrying above-the-average populations of overwintering larvae. This method also made it possible to obtain a record of larval and pupal mortality resulting from the activity of parasites and predators as well as from other causes. The spring development of the parasite <u>Ascogaster carpocapsae</u> Viereck was followed in this way, as was also that of the important predator beetle <u>Tenebroides corticallis</u> Melsh. Each tree or group of trees examined on any one day was completely searched so that the record gave the status of the codling moth for the whole tree at that time, and thus might be expected to yield a record that was approximately true of the orchard at the time of examination. The record would be only a rough approximation due to the natural variation in types of cocooning sites available in different trees.

2. Bait Pan Method

(a.) Orchards

The bait pan method has been used to obtain a record of codling moth activity in the field. By this means a record has been obtained of approximate dates for the beginning, height, and completion, as well as the relative amounts of moth activity in different orchards and for different seasons. Such a record is now available for as long as seven years for two orchards and for shorter periods for several others. In this paper records will be given for the following orchards:

(1). D.L.B. Chute "Captain Robbins" orchard, Berwick. Two pans in the same two trees for five years 1941 - 1945. This has probably had the most persistent if not the worst codling moth infestation of any orchard in the valley. The infestation in this orchard aroused considerable concern on the part of the owner and others as early as 1930. The insect has been temporarily controlled in sections which the Provincial or Dominion Entomological staffs used it for experimental spray plots, but the sections sprayed by the owner have continued to be heavily infested although there has been some reduction of late years following better control measures including the use of summer oil with lead arsenate. The area in which the pans were located was sprayed by the owner every year.

(2). Hiltz orchard, Berwick. Bait pans have been hung in this orchard for seven seasons, 1939 - 1945. The number of single pan trees per season have varied as follows: 6 in 1939, 20 in 1940, 10 in 1941, 7 in 1942 and 5 during each of the past three seasons. In addition one tree has had four pans hung in it each season for three seasons, 1942 - 1944. This orchard has at times had as heavy infestations as orchard number 1 which is located adjacent to and just east of it. Starting in 1939 the Dominion Entomological staff has had a codling moth spray program in this orchard every year excepting 1941, when it was rather indifferently sprayed under the direction of the owner. The codling moth population has been kept low during the past three or four years. A sulphur-lead arsenate program has been used on the north end of this as well as the adjacent South Yarmouth orchard (Number 3 below) while a copper-lead arsenate program has been used on the South end of both orchards.

(3). South Yarmouth Orchard, Berwick. This orchard lies immediately west of orchard number 2. Bait pans have been hung in this orchard for six seasons. The record in this report is based on captures in 2 pans 1940 - 1943, 3 pans in 1944, and 5 in 1945. During 1939 - 1941, the codling moth infestation was fairly heavy but not quite as bad as in the Hiltz and D.L.B. Chute orchards. In 1942 most of it was not sprayed at all and as a result a very heavy population of codling larvae developed that season. During 1943 - 1945 good control has been obtained by means of a codling moth spray program put on by members of the Dominion Entomological staff. This consisted of a sulphur-lead arsenate program at the north end and a copper-lead arsenate program over the south end. Two trees with paired pans, one with and one without nicotine sulphate were hung 1942 - 1944. In 1944 one tree had six pans hung in it, all near the top level.

(4) Drew-Hall-Lyons orchard, Berwick. Two pans have been hung in the same two trees for the past three seasons, 1943 - 1945. This is a small area of about 2 acres containing about 64 trees. The area is broken by the presence of two small residences, several small outbuildings and by some open yard space. The trees had not been sprayed for about 10 years, until the Dominion Entomological staff used it for several fungicide (non-insecticide) plots in 1944 and 1945. Because of lack of proper care the apple crops have been scanty. Codling moth infestation has been as light or lighter than in some orchards, in the same general area, which have been regularly treated with sprays containing arsenicals. In 1943 the infestation averaged around 18 per cent deep entries and 7 per cent stings.

(5) F.M. Nash orchard, Rockland. Two pans have been hung in the same two trees for seven years, 1939 - 1945. They have been located in an orchard of mature trees, mostly Gravenstein and Ben Davis, lying just west of the main buildings. This orchard had a severe codling moth infestation in 1938. The owner has since used a modified codling moth program every year. Nevertheless, the number of moths captured in the bait pans has generally been higher than would be expected considering the light codling moth injury. More heavily infested orchards have been located within one half mile

on other properties lying at lower levels, during this whole period.

(b) Bait, Type of Pan, Method of Hanging

Originally the standard 10 per cent molasses bait was used. Starting quite early in the season of 1942, this formula was supplemented by the addition of nicotine sulphate at the rate of one per cent.

As will be shown later ("Codling Moth Behavior as Indicated by Bait Pan Captures") the addition of the nicotine sulphate made little or no significant difference in the number of codling moths captured.

There was a two-fold object in adding the nicotine sulphate: (1) To inhibit birds from removing captured moths from the surface of the bait. The bird responsible was apparently the pewee, a fly catcher. (2) It quickly immobilizes the captured moths and thus keeps them in better condition for identification. It is particularly valuable in this respect in that it prevents the larger moths from threshing about, and thus spoiling the smaller Tortricoidea.

The bait was exposed in enamelled pans measuring about seven inches in diameter and two and a half inches in depth.

Unless indicated otherwise, each pan was hung near the top of its tree by means of a rope passed over a limb.

3. Larval Entries

During the years 1940 - 1945 it was a regular practice to obtain a record of the beginning, rise, peak and decline of larval entries throughout each season. The method was as follows: One or more trees were selected each year and the fruit examined at intervals, generally two to five days apart, beginning shortly before the first entries were expected. Records were kept of both new entries and old entries. New entries were those extimated to have occurred within about 24 hours previous to examination. All others were recorded as old entries.

4. Completion of Larval Feeding

A record of larval emergence from fruit and migration to cocooning quarters was obtained by banding infested trees with folded strips of jute sacking (Fig. 5). During 1940, 1941 and 1942 the bands were examined at frequent intervals, when all larvae present were collected and counted. Separate records were kept for larvae parasitized by *A. carpocapsae*, and for normal looking larvae. A record was also kept of possible or known parasites and predators found with codling moth larvae in the bands.

C. Meteorological Records

Meteorological records were obtained by means of official maximum and minimum thermometers, rain guage and sunshine recorder located at Annapolis Royal. Thermographs were located at Annapolis Royal, at Berwick and during summers of 1940 and 1941 at Rockland, which is located on the slope of South Mountain, South-east of Berwick.

The maximum and minimum thermometer records at Annapolis Royal were taken at 5 P.M. either Atlantic Standard or Daylight Saving Time, according to which was in official use at the time.

The daily mean temperature records which have been obtained from the thermograph charts are bases on midnight to midnight readings. Hartzell (1919) shows that such readings result in less discrepancy than those obtained at any other time of day, particularly before 8 P.M. This finding has been checked and found to be correct. The long term temperature records for Annapolis Royal are based on thermometer readings, whereas temperature records to be correlated with codling moth development are based on midnight to midnight readings from thermograph charts.

IV. THE RELATION OF THE CODLING MOTH TO WEATHER AND CLIMATE

The establishment, development, reproduction and prevalence of a free-living organism in any given environment is directly dependent, among other things, upon prevailing weather and climatic conditions. Of these, temperature, precipitation and sunlight are of greatest importance. Of these three temperature probably has the most profound effect upon geographic distribution and upon the rate of development and reproduction within the limits of temperature in which the organism can exist.

In the case of the codling moth it is obvious that temperature directly influences the number of generations that may occur in any year in any area within its range. It also influences the proportion of each generation which will pupate and emerge as moths which may in turn give rise to another generation. The temperature ranges characteristic of the climate of the apple growing areas of the Southern United States makes possible the appearance of a partial fourth generation. On the other hand the temperature ranges of the climate of the Annapolis Valley usually permit development of only one significant generation in this area. Fluctuations in temperature conditions from one year to another during certain critical periods of development make possible yearly variations in the development and reproduction of the codling moth.

Temperature also affects the codling moth indirectly through the host plant and through natural control agents.

Precipitation affects the codling moth both directly, as will be indicated later in this paper, and indirectly through its host plant and its parasites and predators.

The published literature, concerning relations between the codling moth and weather and climate is extensive and no effort will be made to summarize it here except in so far as it has a bearing on records and results reported in this paper.

Glenn (1922) states that there is a fairly constant relation between temperature and the rate of development of different stages of the codling moth and outlined a method of forecasting dates when the different stages of the several generations may be expected to appear.

Townsend (1926) made a study of the effects of temperature and mositure upon the breaking up of hibernation in the codling moth. The break-up of hibernation is hastened by the addition of water to the tissues such as normally takes place during rains. The frequency of soaking is of much importance. An enzyme action is probably involved.

Shelford (1927) made an extensive investigation on the relation of the codling moth to weather and climate. He concluded that it is possible to calculate the time of the appearance of stages and to estimate progress to any date, with a fair degree of accuracy, from temperature and humidity alone, once the time of first spring pupation is known. He found that autumn and winter rainfall affects the rate of development of hibernated larvae and of pupae derived from them. When the rainfall is heavy the larvae are more abundant, more of them pupate and pupal stages are shorter than is the case following an autumn and winter of less precipitation. He claimed that the great influence of rainfall is illustrated by the fact that the temperature for some months of an abundant year was low or lower than for the corresponding months in the years in which the moths were scarce. In a year in which codling moth flourished in Southern Illinois the previous autumn was rainy and the spring only moderately so. In a year in which codling moth is scarce the previous autumn is very dry and the spring very wet.

Headlee (1928, 1931, 1936) developed and used the thermal constant as an indicator of the time to apply cover sprays for the codling moth.

Webster (1931, 1936a, 1936b) has correlated weather conditions with fluctuations in population of the codling moth from year to year in the State of Washington.

In Central Asia, Nevskii (1937) found that the abundance of codling moth fluctuates greatly from year to year. He stated that the percentage infestation was correlated with the number of days that were favourable for oviposition, that is, on which the temperature was above 61.7^{o}F and there was no wind or rain during the half hour at sunset(or sunrise) when the females lay their eggs. Temperature also affects the rate of development of eggs and larvae, the percentage of larvae able to enter apples and possibly the percentage of full-fed larvae able to go into diapause. In May and June a large number of young larvae are killed by rain before they enter fruit.

Gould and Geissler (1941),working in West Virginia, conclude that the seasonal fluctuation in moth population is determined almost entirely by weather condition.

A short history of the pest status of the codling moth in the Annapolis Valley from 1884 until the present time has been given in a previous section of this paper. In the light of the above citations particularly those from Shelford (1927) the reader may be interested in attempting to correlate the reported fluctuation of the codling moth since 1933 with records of mean monthly temperatures and monthly precipitation. Graphs have been drawn (Fig. 6 and 7) showing monthly temperature and precipitation date for the years 1933 to 1945 as recorded at Annapolis Royal. Daily mean temperatures are also given (Fig. 8 and 9) for the months April - October for the years 1940 - 1945.

May, June and July are probably the most critical months from the standpoint of actual development of the codling moth in the Annapolis Valley, since it is during these months that the over-wintering brood pupates, emerges and lays the eggs which give rise to the first generation larvae. Reference to Fig 7 will show the relatively small fluctuations in average monthly mean temperatures from year to year for these months. It will be noted that three of the years with the highest May temperatures (1937, 1940, 1942 and 1944) are years of codling moth abundance with 1942 showing a good correlation in this respect. There is little or no correspondence between June and July temperature and relative amounts of codling moth abundance.

There are striking fluctuations in the amounts of precipitation recorded for each month from year to year (Fig. 6 and 7) It is of interest to note whether or not there has been an occurence of the correlation which Shelford (1927) records as existing between autumn and spring rainfall and codling moth abundance.

The year 1942 was one of exceptional codling moth abundance. Total rainfall during the preceeding autumn and winter was about average. October rainfall however was considerably above average, precipitation in 1942 was below average for the months of April, May and June. This is the only year for the period 1933 - 1945 that precipitation was below average for all three months.

(Fig. 6).

A pronounced increase is recorded for 1937 in comparison with the previous year. Rainfall during the preceeding September was exceptionally heavy while that for April 1937 was considerably below average. The mean monthly temperatures for April, May, June, July and August were all above the averages for these months.

In 1943, a year of decreased abundance, the rainfall for May, June, July, and August was considerably above the average for these months (Fig. 6). The mean monthly temperature for April was considerably below average while that for May, June, July and August were either about average or slightly above average.

Although 1936 was evidently an "off year" for codling moth there is little evidence that this is correlated with rainfall conditions, unless it is significant that the rainfall for May and June was somewhat above average. Temperatures were about average for the station but little below average for the period 1933 - 1945.

1944 was reported as a year of decreased abundance. There is little evidence that Shelford's hypothesis applies in this particular instance. On the whole the rainfall for the previous autumn and winter is somewhat above the average, although that for September and January was rather low. April rainfall was a little below the average, that for May was exceptionally light, while that for June was high. Temperatures for May, June and July were above average.

The general impression gained after examining our records of codling moth abundance in relation to precipitation and temperature and then attempting to apply Shelford's (1927) hypothesis is that there is probably a basis for it, but that no conclusions should be drawn to this effect from the data presented in this paper.

In studying these records it should be kept in mind that whereas weather conditions directly influence codling moth development, their effect on seasonal prevalence may be both direct and indirect. Thus a heavy frost which caused a poor set of apples in a number of codling moth infested orchards in 1945 definitely affected the codling moth population in these orchards. It resulted in a high percentage of injured fruit among those that did set and also resulted in a low overwintering population where regular spraying was done. For this reason it was difficult to estimate the relative abundance of the insect in 1945.

Shelford (1927) did not offer an explanation as to how heavy autumn and winter rainfall followed by comparatively light spring rainfall, or how the opposite conditions, influenced codling moth abundance. Possibly a clue as to how these conditions could operate is to be found in the results obtained by putting overwintering larvae in "wet and dry" pots and keeping them there until the moths had emerged. Moths emerging from conditions of constant high humidity died within a few days after emergence and laid few eggs (Fig. 29 and Table 10). Applying this information to Shelford's findings the following is offered as at least a partial explanation of the way in which autumn and spring precipitation would be likely to influence codling moth abundance. It is based on field observations as well as the results of the "wet" and "dry" pot experiment. Codling moth larvae tend to avoid wet situations when choosing hibernation quarters. In fact a small percentage will leave such situations in the spring, just previous to pupation, and build new cocoons in drier situations. During a dry autumn many larvae will accept overwintering quarters in situations which are later constantly wet under conditions of excess precipitation. In a wet spring many of these situations never dry out until after completion of the emergence of moths of the overwintering brood. Most of the larvae become moths but are short lived and lay few eggs. During a wet autumn larvae seek the driest situations which are otherwise suitable for hibernation quarters. In the spring, particularly in a dry spring, such situations are favourable for the production of normal moths. The evidence at hand indicates that overwintering larvae which leave constantly wet situations just previous to pupation and form cocoons under drier conditions, give rise to short lived moths which lay fewer eggs than moths which during the larval stage had been under more favourable conditions.

It may be of interest to compare the average mean monthly temperatures of two stations in the Annapolis Valley with those of stations in or near apple growing areas in New Brunswick, Maine, Quebec, Ontario and England. This is done in table 1. When this record is studied in conjunction with records concerning the intensity of the codling moth problem and the prevalence of a second generation in these areas, it is evident that there is a quantitative correlation between the appearance of a second generation in an area and mean spring and summer temperatures. It is not so certain however that the intensity of the codling moth problem can be directly correlated with the mean temperature conditions in a region. For the convenience of the reader the following brief notes are given concerning the relative intensities of the codling moth problem and of the appearance of a second generation in the localities listed. The source of information is given for each.

Annapolis Royal, N.S. : Codling moth not a problem in commercial orchards in this area. Sporadic outbreaks sometimes quite serious for a few years in unsprayed orchards at Lequille and Graywood just South of Annapolis Royal. Second generation insignificant. (Author's observations).

Kentville, N.S.: Codling moth problem persistent and serious in some commercial orchards at or near this station, particularly at Berwick and Gaspereaux. Second generation generally insignificant but occasionally of importance as in 1942. The percentage of first generation transforming to adults in the same season is small even in a year like 1942, when it was apparently less than 1 per cent (Author's observations).

Fredericton, N.B.: Codling moth not a serious problem in commercial orchards (Verbal statements of C.W.B. Maxwell and F.T. Lord). Wormy apples are found quite often in unsprayed blocks of trees. In 1942 they were quite abundant on unsprayed trees at Shediac Cape. No record of a second generation. (Author's observations).

Portland, Maine: Codling moth not a serious problem in commercial orchards (Verbal statement Dr. F.H. Lathrop 1941). Status in unsprayed orchards not known. Small second generation; approximately 1 to 2 per cent in 1913 & 1914 (Sieglar and Simanton 1915).

Montreal (Southwestern Quebec): Codling moth " a most important pest in some of the orchard districts". Apparently a small second generation generally occurs every year in the Southwestern districts. "From our records of emergence of moths in the insectary, 48.987 per cent in 1937, and 16.89 per cent in 1938, of larvae of the first generation transferred to form a partial second generation. (Beaulieu 1938) "It would seem......that the second generation would be important only in certain years". (Beaulieu 1940).

TABLE I: A comparison of the average mean monthly temperatures at a number of meteorological stations in or near apple growing areas in Eastern Canada, the State of Maine, and Southern England.

	Annapolis N.S.	Kentville N.S.	Fredericton N.B.	Portland Maine	Montreal Que	Vineland Ont	Rothamsted England
January	23.0	19.5	12.8	22.2	13.0	24.0	37.7
February	23.4	18.6	14.9	23.5	14.5	22.5	38.1
March	30.4	29.4	26.2	32.4	25.6	31.0	41.1
April	40.2	40.0	38.9	43.0	41.4	43.5	45.5
May	50.0	49.0	49.8	53.3	55.2	55.0	52.5
June	58.6	58.8	60.1	62.5	64.9	65.5	57.2
July	63.9	65.5	67.0	68.1	69.6	70.0	60.7
August	63.0	64.4	63.7	66.4	67.0	68.5	59.9
September	57.9	57.1	56.2	59.6	58.8	62.0	55.8
October	49.2	49.3	45.6	49.5	46.7	50.0	48.9
November	37.9	35.9	33.2	38.4	33.1	40.0	42.3
December	28.1	24.4	19.1	27.2	19.6	30.5	38.3

Vineland, Ont: Codling moth problem persistent and serious in many commercial orchards. "The most destructive apple and pear insect pest in Ontario". (Caesar 1911). An average of about 12 per cent of the first generation larvae pupate and give rise to adults and a second generation. The percentage during the period 1923 - 1928 varied between 4.5 and 44.0 per cent (Hall 1929).

Rothamsted, (Southeastern England): Although generally present the codling moth apparently is not as serious a pest as in parts of Eastern Canada; at least not in the vicinity of East Malling. It is however of sufficient importance to warrant some experimental work on the development of control methods. A small second generation occurs, which is evidently quite similar to that in the Berwick area of Nova Scotia. (Steer 1936, Montgomery et al 1940).

At Berwick, the centre of the worst codling moth infestations in the Annapolis Valley, the mean daily temperatures on hot days, during the summer are considerably higher than at Annapolis Royal (Fig. 8,9,10,11) or at Kentville (Fig. 10). The maximum temperatures at Berwick on hot days are generally considerably higher than those at Annapolis Royal (Fig. 11).

The difference in temperature conditions between Berwick and Annapolis Royal in 1941 resulted in a considerable difference in the time and rate of codling moth pupation and emergence in the insectary at those two points. This is shown graphically in Fig. 12. Although there were small daily and weekly differences in the mean temperatures obtained for these two points it seemed doubtful whether the differences as recorded were sufficient to account for the difference in the rates of codling moth pupation and emergence. For this reason a record has also been included in Fig. 12 showing the weekly variations in the number of hour-degrees for each of seven different temperature ranges of 10 degrees each lying between 30° and 100° Fahrenheit, for Berwick as compared with Annapolis Royal. Note that, whereas at Annapolis Royal there was an excess of hour-degrees of low temperature (30°-50°F), at Berwick there was considerable excess of hour-degrees of the higher temperature ranges (50°-90°F). The period, May 20 to July 28, during which this excess of hour-degrees of high temperature prevailed at Berwick, was also the most critical from the standpoint of codling moth development since pupation, emergence and oviposition by the over-wintering brood and hatching largely took place during this time. It is quite likely that this difference in temperature conditions at those two points is sufficient to account for the fact that second generation entries are of economic importance in heavily infested orchards at Berwick and vicinity whereas no second generation entries were observed in a quite heavily infested but unsprayed orchard at Lequille. There is the possibility of course that natural control agents were responsible for the lack of late entries near Annapolis Royal.

The rate of pupation and moth emergence is accelerated as the mean temperatures become increasingly higher during the late spring and early summer (tables 3 - 7).

The period of pupation and moth emergence was shorter in seasons when mean temperatures were relatively high than when the mean temperatures were lower. This is evident if pupation and moth emergence records in 1942 are compared with those in 1940, 1941 and 1943 (Fig. 20).

As the mean temperatures gradually increase during the early summer they bring about a decrease in the incubation period.

f mean temperatures gradually go down during the latter part of uly and early August as they did in 1940 and 1943, the incubation eriod lengthens (tables 12-14). In table 2 data is summarized from ables 12-14 showing that each incubation period is correlated with characteristic range of mean temperatures for that period. Discrepancies in the record are largely due to the fact that the time of oviposition and hatching was generally recorded not oftener than nce a day so that an error of as much as 24 hours or even more, is quite possible. It is of interest to note that these correlations gree quite well with those obtained by Glenn (1922) in Illinois.

ABLE 2: Comparison of the mean temperature ranges determined for the approximate incubation periods recorded for codling moth eggs reared in insectaries at Annapolis Royal and Berwick, 1940, 1941 and 1943.

	Ranges of Mean Temperatures for Incubation Periods		
ncubation period	Annapolis Royal N.S., 1940	Berwick, N.S., 1942	Berwick, N.S. 1943
[illegible] days			73.3-74.5
[illegible] days	70	70 -71	
[illegible] days	69 - 70	66.4 -70	69.6-70.8
[illegible] days	67.5 - 69.5	64.6 -69.3	67.9-69.4
[illegible] days	65.8 - 66.9	63.0 -66.4	65.3-67.9
[illegible] days	63.9 - 66.7	64.2 -64.9	61.0-65.7
[illegible] days	63.1 - 64.7		61.0-64.1
[illegible] days	61.7 - 62.4	60.1 -60.7	
[illegible] days		53.8	

The longevity of moths is in general decreased by an increase in mean temperatures. This is indicated in Fig. 13 giving the results of records obtained in 1940 and 1942.

The evidence for a correlation between mean temperature and length of the larval feeding is not particularly clear. However, the record for 1940 (table 15) does indicate that, in general, larvae which started feeding at the beginning of a warm period, completed their feeding in a somewhat shorter time than those which fed during cooler periods. The record for larvae reared in 1942, at Berwick, indicates little significant difference in the larval feeding periods of the groups of larvae hatching over the period June 25 to August 22. Reference to mean temperatures for 1942 (Fig 9) shows that the general temperature level kept up fairly well until past the middle of September. No attempt has been made here, as was done by Glenn (1922), to determine a mean temperature characteristic of different average larval feeding periods. It was found (tables 15 and 16) that the larval feeding periods of the individual members of a group of larvae hatched at the same time and reared in the same jars may vary from as much as 15 to 63 days. Glenn (1922) also reports great variation in feeding periods of larvae reared under identical temperature conditions. It is evident that factors other than temperature influence the length of the larval period.

The influence of weather conditions upon codling moth activity in respect to egg-laying is of great economic importance and is often referred to in articles concerning the timing of sprays against this insect. "It is generally agreed that the moths require calm evenings and a temperature above 60° F for egg-laying" (Steer 1936). Newcomer and Whitcomb (1924) and others have shown that few eggs are laid at temperatures below 60°F. Observations made in the Annapolis Valley fully substantiate this. Isely (1938) states that the largest number of eggs were laid when the mean daily temperature was 80.6°F. He found that too high a temperature for only a few days will prevent newly emerged moths from ever laying eggs. He also states that moths that had been exposed to excessive temperatures as larvae or pupae tended to be sterile. During the course of the present studies there was never any evidence that temperatures became sufficiently high to prevent egg laying or to cause sterility of reared moths. The few batches of sterile eggs that did turn up could be accounted for by non-fertilization due to lack of males in the cages. Newcomer and Whitcomb's (1924) records show that a large proportion of the daily oviposition may be done during the afternoon. This has been observed repeatedly in the insectary at Annapolis Royal and Berwick. Heavy oviposition in lantern globes in the insectary is particularly noticeable on warm, overcast afternoons. There is the possibility that the same thing occurs in shaded situations in apple orchards on such days.

Bait pan records suggest that evening temperatures have a differential effect on the flight activity of the two sexes in that there tends to be a larger proportion of males captured at minimum flight temperatures than at higher temperatures. This is represented graphically (Fig. 14,15,16,17) for moth captures made during the seasons of 1940, 1941, 1942, and 1943. This temperature effect is superimposed upon a gradual increase in the percentage of females captured as the season advances.

This latter phenomenon arises out of the fact that the moths of the over-wintering brood which first emerge are mostly males. As more and more moths emerge the proportion changes until a majority of the last to emerge are females.

Data represented in Fig. 14-17 also indicate that heavy or prolonged rainfall tends to depress the percentage of females in bait pans, even though evening temperatures are favourable for moth activity.

Data represented in the same figures also indicate how evening temperatures below 60°F and how rainfall reduces the total numbers of moths taken in bait pans.

V. LIFE HISTORY OF THE CODLING MOTH IN NOVA SCOTIA

A. Introduction

Twelve years ago Brittain and Pickett (1933), in an account of the codling moth in Nova Scotia, stated that "Ordinarily there is only one generation a year under our conditions, but in cases where the season is exceptionally long with an abundance of warm weather, there may be a partial second generation". The results of the present study indicate that this statement is essentially true. During the period since this study was started there has been only one year, that of 1942, in which there were sufficient numbers of second generation larvae to cause a serious amount of injury. In that year certain well sprayed orchards in the codling moth area suffered more loss from second generation entries than they did from the first. This was due to the fact that large numbers of second generation larvae hatched and entered fruit in late August and early September (Fig 30) after the protecting spray coating had become much weakened by weathering and the expansion of the fruit. These late larvae succeeded in forming a large proportion of deep entries whereas a very high percentage of the first generation entries in these orchards consisted of stings. This was the only year in which we succeeded in rearing second generation larvae, (eleven in all) in the insectary. In 1941 two first generation moths, a male and a female, were obtained from caged material but no eggs were obtained even though the moths emerged only two days apart (Aug 18 and 20) and were caged together. Small numbers of late bait pan captures and fruit entries provide circumstantial evidence that there was a slight second generation in certain heavily infested orchards in 1940, 1941, 1944 and possibly 1945 as well as the economically important one in 1942 (Fig 23 and 30).

Because, so few first generation moths turned up in the course of the rearing work it has not been possible to gather much life history data on a second generation in Nova Scotia. The life history study here reported largely refers then to the single annual brood, which is characteristic of the insect in the Annapolis Valley. This is followed by the limited amount of data available regarding the occasional appearance of first generation moths and of second generation eggs and larvae in the area.

B. Overwintering Brood

1. The Pupal Period

Records of the time and rate of pupation of caged larvae were obtained in 1940, 1941 and 1942. During these years pupation started between May 12 and May 22. However pupation starts somewhat earlier than this in favourable situations on tree trunks, as is indicated in the records of tree trunk examinations (Fig. 18 and 19). The pupation period shortens as the season advances, requiring around 30 to 35 days at the beginning and 12 to 20 days for larvae pupating toward the end of June (Tables 3 -7). Although the pupation period starts somewhat earlier on tree trunks than in cages it also extends somewhat longer. This is due to the greater variety of cocoon sites present on the tree, varying from dry situations exposed to direct sunlight to damp situations which are always shaded.

2. Moth Emergence

Records of moth emergence come from three sources: caged material, tree trunk examinations, and bait pan captures. These are represented graphically in Fig. 18 - 22 in which comparisons are made of records obtained from various sources, and in different years. An attempt is also made to correlate graphically the time relation between pupation, moth emergence, larval entries into fruit, larval feeding periods, temperature conditions and, for 1941, the development of the apple variety McIntosh (Fig. 25 and 26).

Codling moths may start emerging as early as the last week in May as is shown by tree trunk examinations for 1942 (Fig.19) and bait pan captures in 1944 (Fig.23). The over-wintering brood completes emergence in late July or early August (Fig. 20). Moth emergence starts earlier and extends later in the orchard than it does from cocooning sticks or rolls of corrugated paper kept in wire cages or boxes (Fig. 18 and 19). The earliest emergence in the orchard is from dry, unshaded situations on the sunny side of tree trunks. The latest

TABLE 3: Record of pupation of larvae gathered from sprayed orchards and kept in cocooning sticks in Cutright cages at Annapolis Royal, 1940.

Date of Observation	Number of Larvae	Cumulative % Pupated	Pupal Period in Days: Extremes	Pupal Period in Days: For the majority
May 12	186	0		
18	109	41.4	28 - 40	30 - 35
20	91	51.0	28 - 38	33 - 35
23	88	52.7	33 - 36	33 - 36
25	58	68.8	22 - 34	31 - 34
28	31	83.3	23.- 38	30 - 33
June 7	8	95.7	23 - 48	26 - 33
10	7	98.2	30	30
16	5	97.3	25 - 29	25 - 29
20	2	98.9	23 - 28	23 - 28
25	1	99.4	22	22
July 1	0	100.0	22	22

TABLE 4: Record of pupation of larvae gathered from unsprayed and otherwise neglected orchards and kept in cocooning sticks in Cutright cages at Annapolis Royal, 1940.

Date of Observation	Number of Larvae	Cumulative % Pupated	Pupal Period in Days: Extremes	Pupal Period in Days: For the majority
May 12	175	0		
18	83	52.6	23 - 47	27 - 30
20	71	59.4	27 - 32	28
23	71	59.4		
25	40	77.0	22 - 35	23 - 26
28	37	78.8	28 - 29	28
June 7	4	97.7	15 - 49	22 - 26
10	1	99.4	27 - 51	27
16	1			
20	1			
25	1			
July 1	0	100.0	22	22

TABLE 5: Record of pupation in cocooning sticks in a Cutright cage at Berwick, N.S., 1941.

Date of Observation	Number of Larvae	Cumulative % Pupated	Pupal Period in Days	
			Extremes	For the majority
May 21	284	0	0	0
22	247	13.0	25 - 32	29
23	244	14.0	28 - 31	
26	239	15.8	26 - 28	28
28	124	56.3	23 - 38	23 - 26
June 2	94	66.8	18 - 26	21 - 25
3	93	67.2	20	
6	69	75.7	17 - 25	22 - 24
8	68	76.0	19	
10	67	76.4	35	
12	45	84.1	12 - 27	18 - 20
14	40	85.9	16 - 20	18 - 19
16	30	89.4	16 - 23	
18	29	89.8	14	
20	19	93.3	15 - 18	16 - 18
21	15	94.7	17 - 20	
23	3	98.9	14 - 26	14 - 18
27	1	99.6	13	13
July 1	0	100.0	16	

TABLE 6: Record of pupation in cocooning sticks in a Cutright cage at Annapolis Royal, 1941.

Date of Observation	Number of Larvae	Cumulative % Pupated	Pupal Period in Days	
			Extreme	For the majority
May 16	555	0		
17	553	0.3	24 - 42	
22	552	0.5	40	40
23	520	6.3	30 - 57	34 - 36
24	519	6.4		36
26	485	12.6	26 - 42	32 - 35
27	467	15.8	31 - 34	32 - 34
28	462	16.7	24 - 34	33 - 34
29	434	21.8	30 - 34	32 - 33
30	433	21.9		33
June 1	429	22.7	29 - 33	
2	415	25.2	29 - 33	30
3	391	29.5	28.- 31	28 - 29
5	370	33.3	26 - 30	26 - 30
7	351	36.7	24 - 33	27 - 29
9	349	37.1	26 - 27	
10	326	41.2	25 - 27	26 - 27

Table 6 continued

Date of Observation	*Number of Larvae	Cumulative % Pupated	Pupal Period in Days Extreme	For the majority
June 13	314	43.4	23 - 25	24
16	287	48.2	21 - 25	22 - 24
17	282	49.1	20 - 25	23
18	278	49.9	20 - 25	
19	254	54.2	20 - 29	21 - 24
20	237	57.3	22 - 27	23 - 24
21	197	64.5	21 - 32	22 - 26
22	190	65.7	23 - 27	24
24	149	73.1	18 - 28	23 - 24
25	148	73.3	24	
26	130	76.5	19 - 24	22
27	127	77.1	21 - 23	
28	111	88.0	20 - 28	20 - 21
29	109	80.3	19 - 21	
30	87	84.3	19 - 23	19 - 22
July 1	72	87.0	18 - 26	18 - 23
2	52	90.6	20 - 25	21 - 22
3	49	91.1	21 - 22	21
4	43	92.9	20 - 23	21 - 23
5	29	94.7	19 - 23	20 - 22
6	25	95.5	21 - 22	
7	19	96.5	18 - 23	21 - 22
8	9	98.3	17 - 30	20 - 22
10	8	98.5	13	
11	6	98.9	20	20
13	5	99.1	19	19
14	4	99.2	18	18
15	3	99.4	29	
16	1	99.8	22 - 23	
20	0	100.0	20	20

TABLE 7: Record of pupation in cocooning sticks in a Cutright cage at Berwick, 1942.

Date of Observation	Number of Larvae	Cumulative % Pupated	Pupal Period in Days: Extremes	Pupal Period in Days: Average
May 16	168	0		
18	167	0.6		
21	162	3.6	31 - 33	32
23	155	7.7	31 - 34	33
24	153	9.0	33 - 31	31
25	152	9.5	32 - 32	32
27	149	11.3	31 - 31	31
30	147	12.5	29 - 29	29
June 3	145	13.7	26 - 26	26
6	144	14.2	32 - 32	32
12	127	24.4	16 - 25	20
13	124	26.2	19 - 20	19.5
16	123	26.7	18 - 18	18
18	69	59.0	14 - 25	16.5
20	67	60.0	16 - 16	16
23	27	84.0	13 - 19	15
24	19	88.6	12 - 18	16
25	18	89.9	17 - 17	17
26	13	92.0	15 - 18	16
28	7	95.8	12 - 18	15
29	3	98.2	15 - 15	15
30	1	99.3		
July 1	0	100.0	17 - 17	17
			Average	17.2

emergence is from damp, heavily shaded situations such as wounds, or heavily mossed bark near the ground and on the north side of large tree trunks. Emergence of caged material occurs over a considerably shorter period because the environmental conditions have less variation. Thus the emergence from cocooning sticks or paper rolls kept in a constantly wet clay pot starts later than from a dry clay pot under conditions of constant shade. Moth emergence under these conditions is, in turn, later than from wire cages or boxes under conditions of semi-shade where hung in trees or set on insectary shelves (Fig 21).

The bait pan captures reflect moth emergence in the orchard, as determined by periodical trunk examinations, better than do records of moth emergence from caged material (Fig. 18 -22). Unfortunately, because of lack of personnel and other practical considerations, it was not possible to obtain extensive enough records to give really accurate percentage figures for pupation and moth emergence in the orchard as a whole. The records from week to week were sometimes quite inconsistent due to the fact that only one large tree or two or three small ones were done on any one day and the difference in hibernating conditions between different trees is too great for such a record to reflect accurately the average of codling moth development of all the trees in an orchard. However, since bait pan captures arise out of moth emergence in the orchard it is only reasonable to expect that there should be considerable correlation between the two.

An examination of the records for the years 1940 - 1943 (Fig 22) indicates that there is a delay of several days between comparative percentages of moth emergence from tree trunks and bait pan captures. This is quite pronounced at the beginning of the emergence period but tends to disappear toward the end. To some extent this record appears to be in accordance with the findings of Nel (1940) working in South Africa, who, on the basis of the dissection of 236 female codling moths captured in bait pans during the peaks of catches showed that the majority of moths had laid a large part of or all their eggs. In contrast to this Bobb (1938) reports that in Virginia a high percentage of females caught had deposited but few eggs before flying into traps, and that less than 5 per cent had deposited their full quota of eggs. Spuler (1927) and Yothers (1927) also report that a very high percentage had laid but few eggs before flying into the traps. It was the general opinion of all three that most females are captured soon after emergence.

No records have been kept of the number of eggs present in female moths captured in bait pans during the course of the present study. Such a record should be based on samples examined throughout the season as it was obvious that the percentage of spent females varied during the season. Most of those taken early in the season contained a large proportion of their eggs whereas a majority of those taken after the peak were partially or wholly spent. This general conclusion is based on the observation, made in the course of sexing the moths, that the female that is full of eggs has a full spongy abdomen, whereas a spent female is conspicuous because of the prominence of a firm cartilaginous-like structure, probably the bursa copulatrix, located inside the posterior third of the abdomen.

Nel (1940) says that the peaks of egg-laying apparently occur before the peaks of bait trap catches and therefore advises that critical ovicidal sprays should be applied before or immediately after peaks of catch, not 5 - 10 days afterwards. A study of the graphs accompanying this report does not lend support to the above advice (Fig 18, 25, 26 and 31) inasmuch as the relations indicate that a period of ten days or more elapses between corresponding percentage figures or peaks for these two phenomena. In Washington State Moore, Webster et al (1939) have found that a period of as much as 25 to 30 days may elapse between the peak of bait pan captures and peak of larval entries. This is quite similar to the relation found in the Annapolis Valley.

(a) Time of Day for Moth Emergence

In cages most moths emerged between 9 a.m. and 1 p.m. A.S.T., with the heaviest emergence occuring between 10 a.m. and 12 noon. Very few emerged before 9 a.m. or after 3 p.m.

3. The Sex Ratio of Reared Moths:-

This was obtained for four different years (Table 8). A slight preponderance of females is indicated.

TABLE 8: Sex ratio of reared moths.

Years	Total Moths	% Males	% Females
1940	667	45.3	54.7
1942	781	44.2	55.8
1943	1068	51.0	49.0
1944	209	48.4	51.6

These figures correspond quite well with those of Hall (1927). Workers generally record a slight preponderance of females. In Washington State, Newcomer and Whitcomb (1924) report 59 to 64 percent females, which is relatively high.

4. Oviposition

The record for caged moths is represented graphically together with curves for mortality of male and female moths (Fig 27 - 29). In 1940 the average pre-oviposition period was between 3 and 4 days. It is only rarely that a moth oviposits within 24 hours after emergence and occasionally the pre-oviposition period may be as much as 8 to 10 days. At Annapolis Royal, in 1940, 80 percent of the eggs were laid by the twelth day after emergence. At Berwick in 1942 and 1943,

TABLE 9: A comparison of the average number of eggs laid per female per lantern-globe cage for 1940, 1942 and 1943 (a) For the Ten highest averages per season (b) The average number per female for the season.

1940(Annapolis Royal)			1942(Berwick)			1943(Berwick)		
No of Females	Average no. of Eggs per Female	Dates Moths Emerged	No of Females	Average no. of Eggs per Female	Dates Moths Emerged	No of Females	Average no. of Eggs per Female	Dates Moths Emerged
(a) Ten highest oviposition averages:								
3	115.0	July 12	1	158.0	Aug. 6	7	51.3	July 8
16	110.0	July 5	5	109.2	Aug. 9	10	35.2	July 16
13	105.0	June 24	8	85.7	Jun.29	15	31.3	July 14
3	105.0	July 15	3	83.0	Aug.12	15	30.8	July 7
12	99.0	July 10	1	80.0	Aug.18	9	30.7	July 4
13	96.7	July 2	7	76.4	July19	12	27.3	July 11
15	92.0	July 19	9	73.0	July15	9	26.5	July 12
9	89.0	June 27	7	69.0	July14	23	24.2	June 25
6	85.0	July 18	7	59.0	July 1	8	19.6	July 10
15	75.6	June 30	24	57.0	June28	5	19.0	June 20
(b) Average number of eggs per female for all cages:								
295	62.8	Jun.17-Jul.24	436	36.3	Jun.2-Aug.18	279	17.6	Jun.11-Jul.26

80 percent of the eggs were laid within eight days after emergence. At Berwick egg laying was completed by the eighteenth day.

5. Number of Eggs per Moth

Very few records were made of the number of eggs laid by individual moths. A record of the average number of eggs laid by different groups of females, and the seasonal averages for 1940, 1942 and 1943 is presented in table 9.

It will be noted that there has been a decline in the number of eggs per female during the period 1940 to 1943. In 1944 there was a further decline to an average of 12.1 eggs per female for 216 females.

Moths emerging from the wet clay pot (Fig 29) laid very few eggs compared to those laid by moths emerging from the dry clay pot or from other types of dry cages. The numbers are compared in table 10 below:-

TABLE 10: A comparison of oviposition records for females emerging from wet and dry quarters at Berwick, 1943 and 1944.

Year	Wire Cages		Dry Clay Pot		Wet Clay Pot	
	No of Females	Eggs per Female	No of Females	Eggs per Female	No of Females	Eggs per Female
1943	279	17.6	118	27.7	215	3.0
1944	-	-	216	12.1	61	8.0

The larger number of eggs per female for the wet clay pot in 1944 may be partially due to the fact that the pot and its contents became dry, or nearly dry, on several occasions.

6. Length of Life of Moths

Records for the years 1940, 1942 and 1943 are represented graphically together with records for oviposition (Fig. 27-29). Note that the moths emerging in 1940 at Annapolis Royal lived longer than those emerging in 1942 and 1943 at Berwick. This is probably due to the higher temperatures prevailing at Berwick. Every year it has been observed that moth longevity is in inverse proportion to prevailing temperatures. That is, as temperatures become higher the length of life is shortened (Fig 13) as is also the period of oviposition. Females tend to live somewhat longer than males. A few moths lived for as much as 30 to 39 days, at Annapolis Royal, but this was exceptional. At Berwick 80 per cent or more of the moths died within 16 days after emergence. Most of the moths which emerged from cocoons which had been kept under constantly moist conditions died within a week (Fig 29). The average length of life of males at Annapolis Royal in 1940 was 17.2 days, while that for females was 17.7 days. The average length of life of males from day cages at Berwick in 1942 was 8.8 days, while that for females was 10.5 days. That for males at Berwick in 1943 was 8.6 days while that for females was 11.5 days.

7. Time and Place of Egg Deposition

While no records were obtained directly regarding the time that eggs are first deposited in the orchard, yet this date can be estimated fairly accurately on the basis of the record for first larval entries into fruit together with the estimated or known incubation period of eggs for that part of the season immediately preceding the first entries. Reference to oviposition periods in tables 12 - 14, together with data of first entries (fig 30) indicates that the first eggs were laid shortly before closure of the calyces of the variety McIntosh.

During the early part of the season most of the eggs are laid on leaves with a very few being laid on the fruit. However, as the apples grow larger more and more eggs are found on them. Numerous records show that the moths tend to concentrate their eggs in the vicinity of fruit. For instance, if practically all the apples of a tree are on one branch, a count of codling eggs on leaves will disclose a much higher number on the leaves on this branch than on those branches with few or no apples. The following are some records of codling moth eggs counted on leaves picked near apples as compared with leaves from twigs growing at a distance from apples (Table 11).

These records were obtained from four trees enclosed in large cheese cloth covered cages (16' x 16' x 16'). A known number of codling moths emerged in these cages, and since they could not escape, a concentration of eggs and larvae was obtained on the enclosed trees.

TABLE II: A record of the number of codling moth eggs laid on leaves taken near apples as compared with leaves from twigs without apples. Berwick 1944.

Tree	Orchard	Date	Leaves Examined	Leaves Close to apples Number Eggs	Leaves Distant from Apples Number Eggs
1	Drew	July 26	100	32	6
2	Drew	July 26	100	31	2
2	Drew	Aug. 24	250	8	2
3	S. Yarmouth	July 15	200	35	0
3	S. Yarmouth	July 24	200	25	17
4	S. Yarmouth	July 17	200	31	17
4	S. Yarmouth	July 27	100	29	2

The time of day that eggs are laid is of practical importance in estimating the probable amounts of oviposition going on from day to day. Students of the codling moth seem generally agreed that in the orchard most eggs are laid in the early evening, starting shortly before sundown. Bait pan captures indicate that this is the period of moth activity. Some special records of captures in pans at Berwick indicate that most moths are caught between shortly before sundown until about two hours after sundown. If the temperature goes below 60° F at or shortly before sundown very few moths are taken. It has been observed that if temperatures go below 60° F by sundown nearly every evening for a period following the emergence of the first moths, this is followed by a corresponding delay in the appearance of early entries in apples. This was particularly evident in 1940 (Fig. 14 and 25). Observation of caged moths in the insectary indicates that under certain conditions large numbers of eggs may be laid during the afternoon and early evening. This is particularly noticeable on warm overcast days. Newcomber and Whitcomb (1924) record that caged moths lay over 50 percent of their eggs before 6 p.m. Since the shaded conditions in the insectary are sufficient to induce considerable egg laying during the daytime it is not improbable that considerable egg laying may also be done during the daylight hours in the orchard under conditions of heavy shade, particularly on warm cloudy days, such as often occur during July.

TABLE 12: Record of incubation periods during the season of 1940 in the insectary at Annapolis Royal. Also, the correlation between incubation periods and average mean temperatures for these periods.

Date Eggs Laid		Number of Eggs Hatched for the indicated Incubation Periods. 6	7	8	9	10	11	12	13 Days	0° F. Mean Temperature
June	26								32	61.7
	27								20	62.4
	28							78		63.1
	29							34		63.7
	30							18		63.9
July	2						19	42		64.7
	3						48			64.8
	4						28			64.8
	5						230			64.6
	6						83			64.5
	8						59			64.7
	9						74			64.7
	10						102			64.7
	11						22			64.7
	12						69			64.9
	13						72			65.0
	15					46				65.8
	16					119				66.9
	17				61					67.5
	18				66					68.4
	19				58					69.0
	21				88					69.5
	22				12					69.4
	23			23	29					69.4
	24		31	102						70.0
	25				55					68.9
	26					130				67.7
	27					14	26			66.7
	29						50			65.7
	31					4	44			66.5
Aug.	2						17			64.4
	6						46			64.3
	7						18			63.9
	8						11			64.1
	9						6			64.5

Average incubation period = 10.8 days

TABLE 13: Record of incubation periods during the season of 1942 in insectary at Berwick. Also, the correlation between incubation periods and average mean temperatures for these periods.

Date Eggs Laid		Number of Eggs Hatched for the indicated Incubation Periods. 6	7	8	9	10	11	12	13	14 Days	0° F. Mean Temperature
June	10									9	53.8
	12									3	
	13								20		60.1
	14										59.1
	16							4	3		60.7
	18					2					62.9
	19					17	4				63.8
	22					7					65.8
	23				36	23					69.3
	24				32						66.8
	25		33	8							71.1
	26			14	3						68.0
	28			65							69.5
	30		36	21							70.0
July	1		82	32							70.0
	2			35	109	9					68.0
	3					14					66.3
	4					9					64.6
	5					8					63.0
	6				11	27					64.7
	7					72					64.0
	8										64.9
	10				11	9					67.1
	12				45						67.3
	13				40						65.2
	15				26	8					68.1
	18				77						65.9
	20				4	16					66.1
	22				22	26					66.4
	23			48		11					65.1
	24					41					64.9
	27					1	6				64.2
	29					2	4				64.2
	30						2				64.8
Aug.	4					12	12				69.2
	13				31						69.4
	14				34						66.7
	16				165	38					60.9
	18					26					61.3
	19					28					59.9
	21					23	87				
	22						6	5			

Average incubation period = 8.84 days.

TABLE 14: Record of incubation periods during the season of 1943 in the insectary at Berwick, also, the correlation between incubation periods and average mean temperatures for these periods.

Date Eggs Laid	Number of Eggs Hatched for the indicated Incubation Periods. 6	7	8	9	10	11	12	13 Days	0° F. Mean Temperature
June 23							33		62.7
24							13		62.3
25							56		61.4
26 - 27						29	140		61.0
28							19		63.8
July 2					46				66.6
3 - 5				20					69.4
6			14						70.8
9	32	31							73.3
10	38								74.5
10 - 12		15							72.2
13			26						69.6
14				103					68.4
15				35					67.9
16					30				67.8
18				54					69.2
19				49					68.8
20				7					69.2
21				157					68.4
22					58				67.9
23				94					68.2
25				54					68.7
26				39					68.4
27					27				66.7
28					32				65.3
30						29			65.7
Aug. 1						159			64.4
2							17		63.7
5							3		64.1

Average incubation period = 9.87 days

C. First Generation

1. Incubation Period of Eggs

Temperature conditions influence the incubation period of eggs. In the course of this study codling moth eggs were recorded as hatching in from as few as 6 days to as many as 14 days after oviposition. The average incubation period at Annapolis Royal in 1940 for 2086 eggs was 10.8 days. That at Berwick in 1942 for 1599 eggs was 8.8 days and in 1943, for 1459 eggs it was 9.8 days. In the detailed records (Tables 12 - 14) note the range of mean temperatures characteristic of each incubation period. Although these are only approximations yet they are close enough to be of value in estimating the probable incubation periods of eggs at different times during the season if daily mean temperatures are available.

2. Time of Hatching

In the orchard this is indicated by entries into apples. A comparative record of the occurrence of new entries and increase of total entries at Berwick for the seasons 1940 to 1945 is given in Fig.30. The relation of entries to fruit development of the McIntosh is included in table 19. June 22, 1942, is the earliest date that entries are known to have occurred in the Annapolis Valley. The latest date recorded for the observance of a first entry was July 10, 1943. The record for first entries is fairly accurate, since a close watch has been kept for them every year, starting in 1940. The numbers of entries generally increase quite rapidly after the appearance of the first ones (Fig 30). The time when the peak of entries occurs varies from year to year (Fig 30), starting as early as July 2 in 1942 and as late as July 26 in 1945. The relation between time of hatching and moth emergence records and bait pan records has already been discusses under the heading "Moth Emergence".

3. Length of Larval Feeding Period

At Annapolis Royal in 1940, the average length of the feeding period for larvae reared in jars was 37.8 days, with a maximum of 74 days and a minimum of 23 days (Fig. 32, Table 15). At Berwick in 1942 the average was 30.8 days, with a maximum of 63 days and a minimum of 14 days (Fig 33, Table 16). Some indication of the larval feeding period in the orchard may be had by counting the number of days elapsed between corresponding percentage figures for cumulative entries into fruit and capture of larvae in tree bands. In 1940 there was a fairly good correspondence between the feeding periods of larvae reared at Annapolis Royal and the number of days elapsed between corresponding percentage points of curves for larval entries and band collections at Berwick (Fig 25). No larvae were reared in the insectary in 1941 but the number of days between the entry curve and the band collection curve for that year is probably too great to reflect reality (Fig 26). A comparison of the number of days elapsed between corresponding percentages of the entry and band collection curves drawn for 1942 shows a good correspondence with the average feeding period of reared larvae; each being close to 30 days (Fig 34). In this case both field records are for unsprayed Gravenstein trees in the South Yarmouth Block. The series of entry counts was confined to the one tree. The mature larvae were collected from bands on eight Gravensteins in the same orchard. Entries stopped early in this unsprayed orchard in 1942 due to natural control by Trichogramma and possibly other agencies. The cumulative percent curve for entries for 1941 (Fig. 26) is based

TABLE 15: A record of the dates of hatching, number of larvae, and of the feeding period of each group of larvae reared in the insectary at Annapolis Royal in 1940.

Hatching Date	No of Larvae	Feeding Period		
		Average	Minimum	Maximum
July 5	12	31.2	29	33
8 - 9	30	36.1	26	55
9 - 10	24	39.5	32	54
10 - 11	30	37.8	29	56
11 - 12	12	36.5	32	48
13 - 14	13	41.2	23	62
15 - 16	16	30.0	23	45
16 - 17	13	32.3	27	36
17 - 18	14	30.9	28	35
18 - 19	9	29.4	26	39
19 - 20	46	34.5	26	63
21 - 22	17	35.3	25	41
22 - 23	29	40.9	30	58
24 - 25	19	42.0	30	59
25 - 26	32	40.6	29	59
26 - 27	21	36.0	30	50
28 - 29	16	46.1	31	74
29 - 30	5	43.0	33	54
30 - 31	10	38.2	29	47
July 31-Aug 1	10	36.3	31	49
Aug 1 - 2	9	38.0	29	52
3 - 4	15	38.9	28	53
4 - 5	11	42.0	32	51
6 - 7	14	40.1	33	67
9 - 10	10	41.8	34	59
10 - 11	14	45.5	32	64
12 - 13	6	41.6	36	48
17 - 18	11	40.0	30	52
18 - 19	6	38.5	33	47
Total	474	37.87 average		

TABLE 16: A record of the date of hatching, number of larvae, and of the feeding periods of each group of larvae reared in the insectary at Berwick in 1942.

Hatching Date	No of Larvae	Feeding Period Average	Minimum	Maximum
June 25 - 26	24	33.5	32	40
July 1 - 3	12	29.2	25	36
2 - 3	21	28.2	24	35
6 - 7	16	28.2	20	43
7 - 8	10	27.3	20	37
8 - 9	43	31.6	18	63
9 - 10	24	38.0	17	59
10 - 11	45	31.0	22	45
11 - 13	57	31.5	15	63
13 - 15	79	30.9	16	55
15 - 17	19	31.6	14	53
17 - 18	50	29.7	22	47
18 - 20	37	31.3	16	50
20 - 22	34	28.4	16	48
22 - 24	20	30.0	21	52
25 - 27	11	26.3	21	43
27 - 29	19	33.0	16	44
30 - 31	22	30.6	19	54
Aug 21 - 22	7	30.1	23	32
Total	550	30.8 average		

on counts on a McIntosh in a sprayed orchard (D.L.B. Chute). One of the curves for tree band collections is based on records from 5 McIntosh trees in the same row of the same orchard. The other is based on collections from 2 Baldwin trees in the adjacent Hiltz orchard.

The results of captures of codling moth larvae in tree bands on four different varieties of apple in 1940 (Fig 35) suggested that possibly the larval feeding period was shorter in the fruit of Northern Spy than in McIntosh, Golden Russet and Baldwin. The results of captures in bands in 1941, however, (Fig 36) do not support this. An examination of the record for the two years indicates that there is probably little significant difference in the rates of larval development in these four varieties.

The difference between the two curves for Northern Spy in the two orchards used in 1941 may possibly be significant, since the larvae from the D.L.B. Chute orchard came from trees which had the regular pre-blossom and post-blossom arsenical sprays whereas the larvae from the check plot in the Hiltz orchard came from trees which received no arsenical sprays after the bloom. The owner, however, had used an arsenical in the pink spray.

D. Second Generation

1. Results from Caged Material

In 1942 a few caged first generation larvae pupated and emerged as moths from which in turn second generation eggs and larvae were reared.

(a) The following is a synoptic life history of three moths obtained from first generation larvae which had been reared in jars:-

(1) Overwintering brood of moths emerged June 9
(2) Eggs laid............................ June 11 to 13
(3) Eggs hatched......................... June 25 to 27
(4) Larval development and pupation in jar................................. June 25 - ?
(5) From which three moths emerged...... Aug. 4,10,17.

These moths were caged with moths from other sources, each in a separate lot so that their progenies are merged with those of first generation moths from other sources.

Of 556 larvae collected from tree bands between July 24 and July 31 only 2 pupated and became moths. Both were from larvae collected on July 24. The moths emerged on August 16 and 19.

Another source of first generation moths was the collections of larvae and pupae taken from tree trunks. The following is a record of the collections of unparasitized material made on and after July 10 in the Coulter Block at Berwick (Table 17):

TABLE 17:

Collection Date	Codling Moth Larvae	Codling Moth Pupae	Empty Cocoons
July 10	1	14	147
15	3	11	97
24	10	5	126
31	60	17	-
Aug. 8	81	13	-
13	221	11	-
20	106	4	-
25	83	0	-

Empty cocoons were not counted after July 24. From the above record it appears that larvae of the overwintering brood had practically completed pupation by the middle of July. Probably the 5 pupae collected on July 24 were of this brood whereas most if not all of those collected after this date were probably first generation pupae. Apparently there was no increase in numbers of pupae after July 31.

The evidence at hand indicates that whatever pupation of first generation larvae occurred in 1942 was completed by the end of July. This means that only a small fraction of one per cent of the first generation larvae pupated during the same season in which they hatched. Moreover what ever pupation did occur took place between about July 21 and 31. The cause of this early cessation of pupation is obscure, involving as it does the problem of diapause in insects (Wigglesworth 1942). If it is due to a temperature relation, such as a temporary drop in temperature in

July, it is evident that some sort of irreversible action is involved, since high and apparently favourable temperatures occurred in August. Headlee (1931) reports data which indicate that when the summer average weekly minimum temperatures reach the immediate neighborhood of 60° F, pupation ceases. In New Jersey, if this temperature condition comes before there is a second brood there is no second brood. If it comes during the second brood there is only a partial second brood. Isely (1939) on the other hand, says that, "The time when larvae no longer pupate does not appear abruptly during a season as a response to some climatic condition".

There is obviously a considerably variation in larvae in respect to their ability to pupate or enter diapause during the latter part of July in the Annapolis Valley. This is evident, from the record for reared larvae and for larvae collected from tree bands in 1942. The few that did pupate were not the earliest to enter hibernation quarters. Isely (1937) evidently considers that there are one, two, three and four-generation strains of the codling moth in Arkansas of which the three-generation is the dominant strain. He states that, "The factor that probably determines whether or not larvae enter hibernation is the elapse of enough time, at a favourable temperature, after the beginning of the season for them to have completed their inherent number of generations". Shelford (1927) concluded that the falling of mean temperatures or at least minimum temperatures has no apparent effect on the initiation of hibernation. He also added that, "The explanation of hibernation phenomena is probably to be sought in the activity of enzymes".

If it is true that the pupae collected on the tree trunks after August 1, 1942, (Table 17) are first generation pupae rather than late members of the overwintering brood, then we must conclude that a larger percentage of first generation pupation occurred on the tree trunks than among larvae reared in jars or among larvae from tree bands. It is doubtful whether moisture conditions are a significant factor. The larvae reared on apples in gum jars formed their cocoons in corrugated paper rolls which were continuously under conditions of high humidity, due to the fact that the jars were nearly filled with apples. The larvae collected from tree trunks were placed in similar jars where they also formed cocoons in rolls of corrugated paper. In this case however the larvae were held under conditions of comparatively low humidity.

The following is a record of the emergence of first generation moths from material collected from tree trunks in the Coulter Block, Berwick, on and after July 24 (Table 18):-

TABLE 18:

Collection Date	July 24	31	Aug. 8	13	20
No of larvae collected -	8	60	81	221	106
No of pupae collected -	1	17	13	11	4
Date Moths emerged	**Number of Moths Emerged**				
August 3		1			
5		1			
7	1				
8		1			
10	1	1	2		
11		3			
12	1		1		
17	2		4		
18					
19				4	
21				1	1
Totals -	5	7	7	5	1

A total of 30 first generation moths were obtained for caging; of these 9 were males and 21 were females. They laid a total of 1021 eggs or an average of 49 eggs per female. One individual female laid 80 eggs and another 62 eggs. Most of the eggs required an incubation period of 10 - 11 days.

Approximately 11 larvae were reared through and entered cocooning sticks, of these 7 hatched on August 21 - 23. One completed feeding on September 14, one on September 17 and five on September 23, making feeding periods of 23 to 32 days.

The majority of the 50 or more larvae that entered fruit never completed their development. They remained small or simply disappeared.

2. Results of Field Studies

Circumstantial field evidence of a second generation of codling moth is indicated by late entries in the fruit (Fig 30) and late captures in bait pans (Fig.23). Most moths taken after the middle of August are likely to be first generation moths rather than those of the overwintering brood. On the basis of this evidence it seems likely that besides the substantial second generation in 1942 there was also a slight second generation in 1941 and possibly also in 1940 and 1945. The loss of fruit from late entries was negligible in all but 1942.

K. Correlation of Codling Moth Development with that of the Apple and other Plants

From the standpoint of instituting control measures against this insect it is important that there be a convenient standard of reference by which to judge the approximate status of the codling moth at any particular time in any particular season. Fig 26 provides such a standard for the year 1941. Table 19 correlates the development of the variety McIntosh with the development of the codling moth in the orchard at Berwick for the years 1940 to 1945.

On the basis of the data available the following chart has been constructed as a means of estimating the approximate status of the codling moth in relation to the development of buds, flowers, and fruit of the variety McIntosh as well as the bloom of the Nanny-berry Bush (Viburnum lentago L) and the Spreading Dogbane (Apocynum androsoemifolium):-

Chart correlating codling moth development with that of the apple variety McIntosh, the bloom of the Nannyberry Bush and the Spreading Dogbane.

Plant Stage Apple (McIntosh) unless indicated otherwise	Approximate Stage of Codling Moth Development
1. Early pre-pink	Larvae starting to pupate
2. Full bloom - end of bloom	Moths beginning to emerge
3. Calyx closures almost completed	First eggs been laid several days.
4. Spreading dogbane bloom just starting. Nannyberry bush in full bloom.	First entries in apples.
About a week after #4	Heavy entry period begins, lasting about a month.
About 3 weeks after #4	Main peak of entries.
About 3-4 weeks after #4	First larvae complete feeding and leave fruit
About 4-5 weeks after #4	Larvae probably leaving apples in large numbers to seek cocooning sites.

If large numbers of larvae complete feeding and form cocoons before the end of July there is apt to be sufficient second mary record correlating the development of the codling moth in the orchard with easonal development of the apple variety McIntosh at Berwick 1940-1945.

	1940	1941	1942	1943	1944	1945
	May 5	-	April 30	May 14	May 4	April 16
	-	May 10	-	May 18	May 9	April 20
'RUNKS	May 16(10%)	May 12(10%)	May 12(13%)	May 17(9%)	-	May 10 (
	May 17	May 19	May 11	May 19	May 17	April 30
	May 27	May 28	May 18	May 28	May 22	May 10
	June 2	June 6	May 24	June 4	May 27	May 21-3
I TRUNKS	-	June 10	May 26	June 9	May 28	-
	June 10	June 12	May 28	June 14	May 30	June 7
[T PANS	June 9	June 15	June 7	June 16	May 30	June 12
closing	-	June 16	-	June 23	June 7	June 13
loses	June 20	June 20	June 15	June 29	June 16	June 22
arting	July 3	June 28	June 24	-	-	June 29
[RIES	July 3	June 29	June 22	June 9	June 23	July 5
LST GEN.)	Jul 10-Aug 9	Jul 4-Aug 8	Jun 30-Aug 9	Jul 20-Aug 23	Jul 4-30	Jul 13-Aug
	Jul 21-Aug 1	Jul18-25	Jul 2-Jul16	Jul 20-27	Jul 18-26	Jul 26-Aug
ANDS	Aug 4	Aug 1	July 19	Aug 10	-	Aug 4
	-	Aug 18-20	Aug 3-21	-	-	-
S	-	Aug 25-Sep 5	Aug 21-Sep 20	-	Sep. 6	-
to pick	Oct. 1	Sept 28	Sept 20	Oct 1	Sept 22	Oct 2

generation entries to be of economic importance in varieties such as Spy, Golden Russet, and Wagener. In such a case these are likely to appear by the last week in August.

VI CODLING MOTH BEHAVIOR AS INDICATED BY BAIT PAN CAPTURES

A. Period of Moth Activity

This has already been shown graphically in various figures, particularly in Fig. 23 and 24. It was thought that there might possibly be some difference in the initial rise of captures in different orchards according to whether or not most of the moths originated in these orchards. Thus it might be expected that the rise of moths in the Hiltz orchard would be behind that in the D.L.B. Chute orchard in 1943, 1944 and 1945 as a result of more effective codling moth control in the Hiltz orchard after 1941. Such difference might be expected between the Hiltz and South Yarmouth orchards in 1943 and 1944 following the uncontrolled outbreak in the latter orchard in 1942. It was thought that captures in the Nash orchard might be retarded, thus indicating a substantial influx of moths from outside the baited areas. Such has not been the case (Fig. 24).

B. Comparison of Total Captures 1939-1945

A record of total bait pan captures in the same orchards, generally in the same trees, gives some indication of population levels and trends from year to year. Such a record has been accumulated for a number of orchards in the Berwick area (Table 20).

TABLE 20: A comparison of the numbers of Codling Moth captured per bait pan per season during the years 1939 - 1945 in several orchards in the Berwick area.

Orchard	1939	1940	1941	1942	1943	1944	1945
D.L.B. Chute	-	-	713	435	306	171	130
Hiltz	37	164	378	193	155	169	168
South Yarmouth	-	188	617	371	211	116	88
Drew	-	-	-	-	144	122	184
F.M. Nash	26	80	242	74	102	136	217

The numbers of moths taken per pan in the different orchards in different years is not a reliable guide with which to estimate the probable amounts of codling moth injury in each of these orchards for the years in which the above records were taken. The D.L.B. Chute orchard has consistently suffered considerably greater loss than the other orchards, particularly since 1942. Since 1938 there has been comparatively little codling moth injury in the F.M. Nash orchard.

A comparison of the amounts of fruit injuries and bait pan captures in the Hiltz-South Yarmouth orchards (table 21) shows that bait pan captures only partially reflect the amount of codling moth populations originating in the orchards in which the pans are located.

It is probably true, as evidence obtained by Steiner (1940) with liberated marked moths suggests, that there is a normal levelling off of the populations between areas of heavy and low density with movement occurring in both directions proportional to the populations.

The evidence in Table 21 also suggests that moths tend to lay the majority of their eggs in the orchard in which they originate.

TABLE 21: A comparison of records of the numbers of larval entries per 100 apples (picked fruit) as well as of total numbers of moths taken in bait pans, for two adjoining orchards (Hiltz and South Yarmouth) at Berwick, for the years 1943, 1944 and 1945.

	1943		1944		1945	
	Hiltz	S. Yarmouth	Hiltz	S.Yarmouth	Hiltz	S.Yarmouth
Moths captured:						
Bait pan #1	241	398	258	136	305	124
Bait pan #2	357	344	320	130	260	80
Entries per 100 apples - variety Gravenstein:						
Stings	8.8	76.5	8.3	9.5	-	-
Deep Entries	0.4	4.7	0.0	0.1	-	-
Entries per 100 apples - variety Golden Russet:						
Stings	43.8	206.6	36.9	15.9	131.1	152.2
Deep Entries	4.7	19.5	5.1	1.5	6.4	10.5
Entries per 100 apples - variety Baldwin:						
Stings	35.4	165.4	22.1	22.5	157.6	155.0
Deep Entries	1.4	6.1	0.8	1.4	4.3	3.7

NOTE: During the period 1943-1945 the same spray program was used on the two blocks of orchard from which these records were obtained. Just previous to this (in 1942) the codling moth had been controlled by spraying in the Hiltz orchard whereas a large population of overwintering larvae developed in the South Yarmouth orchard due to it being left unsprayed.

C. Effect of Location of Pans in Trees

During the summer of 1942, 1943 and 1944 a large Baldwin tree in the Hiltz orchard had four bait pans hung in it. This tree was about 20 feet in height. In 1942 the pans were located as follows: (1) Low (4 feet from ground) and at the end of a long branch. (2) Mid-height, centre (almost directly above the trunk and about 9 feet above ground). (3) Top centre, (almost directly above trunk and about 17 feet above ground). (4) Mid-height, outside, (about 9 feet above ground and just beyond the tip of a long branch). Pans (3) and (4) were hung from the ends of long poles which had been tied to the limbs of the tree. Pans (1), (3), and (4) were each near the leafy periphery of the tree while (2) was near the centre and remote from the periphery. A record of the total numbers of moths taken in each pan during the period, June 8 to September 6, is given in table 22:-

TABLE 22: Moths captured in four different locations on one tree compared with a similar single-pan tree nearby.

	Low Outside	Mid-height Centre	Top Centre	Mid-height Outside	Total for tree	Tree Nearby
Male........	16	25	206	42	289	75
Female......	27	32	113	29	201	60
Total.......						
% Females...	63.0 %	56.0%	35.0%	24.5%	41.0%	44.4%
% of tree total.......	8.8 %	11.8%	65.1%	14.5%		

Bobb, Woodside, and Jefferson (1939) as well as others have reported that the top of a tree is the most favourable location for a bait pan. The object of this experiment was to find out whether this was because the pan was near the top of the tree or near the leafy periphery. The results of the experiment indicate that the former is the case.

The average number of moths per tree for the seven single-pan trees in the orchard was 192.6 moths with an average of 40 per cent females.

In 1943 and 1944 the four pans were hung at about equal heights and nearly at a level with the top of the tree. Exactly the same locations were used for hanging the pans in these two years. The record is given in table 23:-

TABLE 23: Total Codling moths taken in individual pans in the 4-pan tree in 1943 and 1944.

	1943		1944	
	Total Moths	Per cent Females	Total Moths	Per cent Females
North	58	51.7	80	30.0
Centre	65	35.3	66	30.3
South-east	74	35.1	77	33.7
West	91	45.0	34	55.8
Total for tree	288	41.6%	257	34.6%
Single-pan tree nearby	110	55.4%	88	33.7%

D. Effect of Adding Nicotine Sulphate to Bait

Bel'skiĭ (1936) reported that the addition of nicotine sulphate tended to increase the effectiveness of a molasses bait. For three years (1942, 1943, 1944) twin pans of molasses bait, one with the addition of nicotine sulphate at the rate of one per cent and the other without, have been hung at equal heights near the tops of each of two trees in the South Yarmouth orchard at Berwick. The results (table 24) indicate that the addition of nicotine sulphate makes little significant difference in the numbers of moths taken. There was a small but consistent decrease in the percentage of females taken in the molasses-nicotine bait. The addition of nicotine sulphate proved to be a useful practice in that it prevented poaching by birds and because it resulted in quick immobilization of captured moths, thus keeping them in better condition for identification.

TABLE 24: A comparison of the numbers of codling moths captured in fermenting molasses-water baits with and without the addition of nicotine sulphate, South Yarmouth orchard, Berwick, 1942 - 1944.

	1942	1943	1944
No nicotine			
Tree #3	108	212	54
Tree #4	100	198	69
Average per pan	104.0	205.0	61.5
Percent Females	59.6%	33.2%	45.5%
Nicotine Added			
Tree #3	105	166	73
Tree #4	138	218	69
Average per pan	128.5	192	71.0
Percent Females	52.5%	28.6%	34.5%
Single-pan trees			
Tree #1	78	184	81
Tree #2	133	239	136
Average per pan	105.5	211.5	108.5
Percent Females	60.2%	36.4%	41.0%

In 1942 a molasses-water bait without nicotine was used in single-pan trees #1 and #2. In 1943 and 1944 nicotine sulphate was added to the bait hung in these trees.

E. Effect of Varying the Number of Pans per Tree

From the results obtained in 1942 it was evident that when more than one bait pan was hung in a tree this resulted in a substantial increase in the number of moths taken in that tree as compared with the number taken in single-pan trees of similar size in the same area. It was evident that a concentration of bait pans resulted in an increased concentration of moths in a tree. Most of these moths must have been attracted from quite a large area since the trees used, particularly those in the Hiltz orchard, would have overwintered only a small proportion of the moths taken in them. Table 25 summarizes the results of captures in single-pan, twin-pan, 4-pan and 6-pan trees in the adjoining Hiltz and South Yarmouth orchards at Berwick:-

TABLE 25: A comparison of the numbers of codling moths captured per bait pan and per tree where one or more were hung per tree. South Yarmouth and Hiltz orchards, Berwick, 1942 - 1944.

	1942	1943	1944
Hiltz single-pan trees			
Tree #1	119	110	93
#2	163	63	86
#3	135	110	88
#4	241	240	258
#5	357	252	320
Average per pan and per tree	203	155	169
Hiltz 4-pan tree	490	288	257
Average per pan	122.5	72	64.2
So. Yarmouth 1-pan trees			
Tree #1	344	184	81
#2	398	239	136
Average per tree and per pan	371	211.5	108.5
So. Yarmouth 2-pan trees			
Tree #3	213 *	378	127
#4	238 *	416	138
Average per tree	225.5 *	397	132.5
Average per pan	112.7 *	198.5	66.2
So. Yarmouth 6-pan tree			330
Average per pan			55

* This record was not started until July 10 and is therefore not comparable with the others. The average number of moths per tree and per pan for trees #1 and #2, South Yarmouth, starting July 10 is 105.5, which is comparable with the figure 112.7, the average given for 2-pan trees #3 and #4.

F. Comparison of Codling Moth Injuries on Trees with and Without Bait Pans

In the course of taking records of codling moth injuries on picked fruit in the Hiltz-South Yarmouth orchards in 1944, records for some of the bait pan trees and for some neighboring trees of each were kept separately. The object was to determine if the presence of the bait pans had a modifying effect on the amount of injury by codling moth larvae. The results are as follows (table 26):-

TABLE 26: Number of codling moth larval stings and deep entries per 100 apples from neighboring trees with and without bait pans. Berwick, 1944.

	Bait Pan Trees		Neighboring Trees	
	Stings	Deep Entries	Stings	Deep Entries
Hiltz, single-pan tree #1	3	0	9	0.1
" " " " #2	13	0	7	0.3
Hiltz, four-pan tree	5	0.5	10	0.1
So. Yarmouth single pan				
Tree #1	0	2	3	1.5
#2	15	1.5	20.2	1.1
2-pan tree #1	9	0.5	5	0
2-pan tree #2	10	0.5	8	0
6-pan tree	15	0.4	11	0.2

It would appear from the above results that the presence of one to six bait pans in a tree makes little significant difference in the amount of codling moth injury as compared with that on neighboring trees without bait pans. Any reduction in injury has been general over the area.

VII. SOME NOTES ON LARVAL BEHAVIOR

A. Calyx Entries

It is rare to find successful calyx entries in orchards which have been regularly sprayed with arsenicals. If several hundred apples from a heavily infested orchard are cut across the calyx end and examined it is evident that many codling moth larvae have started into the fruit at this point and then disappeared. The evidence is in the form of a small healed wound often accompanied by a pale encrustation, located in the calyx cup. It would appear that the spray residue left around the calyx, particularly that on the sepals, remains more effective than that on the face of the apple. This is to be expected since the sepals shrink in size rather than grow. The results of experiments with arsenical sprays on a few trees in the South Yarmouth orchard in 1942 at Berwick as well as on some neglected trees at Lequille, showed that lead arsenate at the rate of 4 pounds per 100 gallons of water applied during the pink stage was sufficient to control a large proportion of the calyx entries (table 27). The spraying at Berwick was done with a power sprayer. That at Lequille was done with a good hand sprayer.

TABLE 27: Control of calyx entries by means of an arsenical spray applied in the pink stage. Counts on drops and picked fruit for three varieties used.

Orchard	Treatment	Apples Examn'd	Total Entries	Entries per 100 Apples: Total	Entries per 100 Apples: Calyx	% Calyx Entries
Berwick	Sprayed	2645	2622	99.0	6	6.1
Berwick	Unsprayed	3380	4090	121.0	50	41.7
Lequille	Sprayed	1000	161	16.1	8.9	55.0
Lequille	Unsprayed	1000	575	57.5	44.2	77.0

This evidence brings into question the validity of the explanation given by Melander (1906, 1908) and Ball (1907) for the effectiveness of the calyx spray. They were the originators of what has become one of the first rules in codling moth control, namely, that regarding the importance of applying a calyx spray containing an arsenical. They laid emphasis on the importance of thorough spraying at this time in order to ensure that the necessary poison was placed in the inner calyx cup. Melander (1909) stated that a single thorough spraying just after petal fall resulted in practically 100 per cent control in Washington, Utah, and Colorado. Ball (1907) advised a second one just before calyx closure. As a result of experimental work done under his direction in Arkansas, Virginia, and Michigan, Quaintance (Quaintance et al 1911) was convinced of the "great importance of thorough spraying to fill the calyx cups with poison". Over 30 years ago however Sanders (1915) reported that a spray applied immediately before the bloom resulted in almost as good control as a spray applied immediately after petal fall, and somewhat better than one applied two weeks after petal fall. As a result of laboratory experiments with larvae on sprayed apples Waddell and Marshall (1942) decided that the function of the calyx spray was to deposit poison on the inner surface of the sepals and thus insure increased protection against entries into the calyx of the apple. They considered that, in British Columbia, it is not essential to force spray into the inner calyx cup. Golfari (1939) found that in only 15 per cent of cases does the calyx spray reach the calyx cup. He therefore decided that its chief value lay in the fact that poison was deposited on the sepals. The results given in table 24 support the views of Waddell and Marshall (1942) and of Golfari (1939). These views are reasonable when considered in conjunction with the relation that has been found to exist between the development of the apple and the codling moth. It has already been shown (Table 19) that in the Annapolis Valley the calyx cup is closed at the time larval entries begin to appear. Therefore, in order to enter the calyx, larvae must either go between the closed sepals or bite their way through the sepals themselves. In either case, if the sepals are covered inside and out with poison, the larvae can hardly avoid coming in contact with it in the process of entering the calyx cup.

The data given in Table 27 for unsprayed trees might be interpreted to mean that codling moth larvae in long-neglected orchards have a greater tendency to enter through the calyx than do larvae in a commercial orchard which has been left unsprayed for only one season. There is the possibility, however, that the smaller percentage of calyx entries in the South Yarmouth orchard as compared with the Lequille orchard is correlated with the much heavier infestation in the former orchard. Note that there is actually a few more calyx entries per 100 apples in the commercial orchard. Only a very small percentage of the apples in the Lequille orchard contained more than one entry whereas quite a large percentage in the Berwick orchard contained two or more entries. Garlick (1938) has cited figures to show that there may be "grounds for the belief, held by many (in Ontario), that there has been an increase in the proportion of side entries in recent years". Possibly such figures should be correlated with the comparative amounts of infestation in the orchards at the time these figures were obtained. It is possible that the percentage of calyx entries may have a quantitative basis.

The following additional data are offered as evidence that it is doubtful whether there has been a real change in the calyx entry habit of larvae in regularly sprayed orchards as compared with neglected orchards.in the Annapolis Valley.

Some records of calyx entries are available for the long neglected Wolfe orchard near Waterville for the years 1939, 1941, and 1942 (Table 28):-

TABLE 28:

Year	Apples Exam'd	Total Entries	Entries per 100 Apples Total	Calyx	% Calyx Entries
1939	300	83	27.6	14.6	53.0
1941	1600	422	26.3	17.2	65.1
1942	362	233	64.3	40.3	62.6

The following is a record of calyx entries in 1945 in the Herbert Margeson orchard at South Berwick. This orchard was sprayed quite regularly up until 1945 when, because of a threatened crop failure through frost, no spraying was done. Codling moth had been pretty well cleaned up by thorough spraying during the two previous years. 509 apples of the variety Wagener were examined. Out of a total of 486 entries, 281 or 57.8 per cent were calyx entries. This orchard is in the heavily infested codling moth area.

The following is a 1942 record from a commercial orchard in the Berwick area which was not sprayed that year and which had a comparatively light infestation: 1000 apples

(Wagener and Grevenstein) were examined. Only 80 entries were found and of these 60 per cent were calyx entries.

B. Larval Entries at Top Versus Bottom of Tree

Since bait pans located in the top of a tree capture many more moths than those located lower down (see section on bait pan records) it seemed possible that the numbers of larval entries might be larger per unit of fruit growing at the top of a tree as compared to those on the lower half of a tree. The following records (table 29) are for the lower and upper halves of the trees of three different varieties, all of about the same height, namely 16 to 18 feet. This record was made at picking time in 1943:-

TABLE 29:

Variety	Orchard	No of Apples	Section of Tree	Entries per 100 apples Sting	Deep
Gravenstein	Hiltz	220	Top centre	8.0	0.1
"	"	300	Bottom	6 .0	0.3
"	"	506	Drops	10.0	7.5
"	"	2065	Total crop	8.0	0.1
G. Russet	S. Yarmouth	620	Top	83.0	6.4
"	"	620	Bottom	76.1	3.1
"	"	60	Drops	61.6	58.3
"	"	1300	Total crop		
McIntosh	D.B.L. Chute	482	Top	71.6	9.7
"	"	650	Bottom	82.3	6.0
"	"	200	Drops	70.0	43.0
		1332	Total crop		

The difference in amount of injury in fruit picked from the tops and bottoms of these trees is about what would be expected due to differences in spray coverage likely to be attained in these two parts of the tree. The problem is not entirely solved however due to lack of knowledge regarding the source of the drop apples containing deep entries.

Woodside (1944) has reported the results of records for the relative amounts of codling moth injuries at four different heights in apple trees. In contrast to the record in table 29 these show very striking differences in the relative amounts of fruit injuries, particularly deep entries at the top as compared with the bottom of the trees. There was an average of 2.1 times as many stings and 27.8 times as many wormy apples at the 24 foot level as compared with the 6 foot level on sprayed trees. There was the same number of stings but 2.7 times as many wormy apples at the 24 foot level as compared with the six foot level of unsprayed trees. In other words Woodside found that while the relatively greater number of entries at the top of the tree was partly due to poorer spray coverage, part was also due to the behavior or habits of the insect.

C. Captures of Larvae in Codling Moth Bands on Apple Stubs Placed at Various Distances From the Trunk of a Heavily Infested Apple Tree

A heavily infested unsprayed Gravenstein tree in the South Yarmouth orchard was chosen for this experiment in 1942. The tree had a crop of 1570 apples all of which were allowed to drop to the ground where they lay undisturbed throughout the summer and autumn. A neighbouring tree of the same variety carrying a crop totaling 1435 apples had a total of 1227 deep entries or 85.5 per 100 apples. The apples of this tree also were not picked but were allowed to drop. Every week or so the accumulated drops were counted and a record made of the worm holes and larvae present.

Four short sections of apple tree limbs, each with a

3-ply band of jute sacking around it, were set upright on the ground at distances of 3,10,20, and 30 feet respectively from the trunk of the tree (Fig.37 and 38). The furthest stub would be just beyond the limits of the limbs. The trunk and main limbs of the tree itself were thoroughly scraped and a large band placed around the butt. The following is a record of the total numbers of larvae collected in each band (table 30). The A.carpocapsae - parasitized larvae are distinguished from the normal ones.

TABLE 30:

Distance from Main Trunk	Number of Larvae in Bands Normal	Parasitized	Total	% of Total for Tree	% Parasitized
Main Trunk	292	223	515	86.1	43.3
3 feet	59	17	76	12.7	22.4
10 feet	6	0	6	1.0	0
20 feet	1	0	1	0.2	0
30 feet	0	0	0	0	0
TOTALS	358	240	598		40.1

The following items of interest in connection with the above experiment are drawn to the reader's attention: (1) The very large percentage of larvae which were collected on the band on the tree butt despite the fact that the ground became covered with drop apples some of which fell as far from the trunk as the furthest banded stub. Many of these drop apples still contained larvae in various stages of maturity after they fell. This statement is made on the basis of successive examinations of the drop apples under the neighboring Gravenstein tree mentioned above. The results were as follows (table 31):-

TABLE 31: Record of the results of the examination of deep entries in the drop apples collected at successive intervals under Gravenstein #1. South Yarmouth Orchard, 1942.

Date	No of Apples	Empty Cavities	Mature Larvae	¾ Grown	½ Grown	¼ Grown	Less than ¼	Total Larvae	Larvae per 100 Apples
Aug 6	300	273	22	10	14	21	3	70	23.3
12	199	201	23	13	9	10	2	57	28.6
19	274	243	11	8	2	4	0	25	9.1
25	150	93	3	4	1	3	0	11	7.3
Sep 1	165	90	5	3	2	8	1	19	11.5
9	83	33	2	1	1	1	1	6	7.2
17	135	56	0	5	4	2	3	14	10.3
23	84	21	0	1	0	0	0	1	1.2
Oct 2	45	9	0	0	0	0	0	0	0
TOTAL	1435	1024						203	85.5

On the basis of this record (table 31) 200 or more larvae should have fallen to the ground together with the apples from the banded Gravenstein. (2) Also on the basis of this record approximately 1300 larvae are likely to have developed in the apples on the banded tree; yet only 598 or approximately 46 per cent are accounted for in the bands. (3) A much larger proportion of the larvae collected in the band on the tree trunk were parasitized than on any of the stub bands. The only stub band that had parasitized larvae was that closest to the tree trunk.

D. Captures of Larvae in Bands Placed Above and Below Tanglefoot Bands

The object of this experiment was to determine the proportion of overwintering larvae that travelled from the ground to the tree trunk and from the apples down the limbs to the tree trunk. The method used was to put a 4-5 inch band of tanglefoot about half-way up the butt of an infested apple tree and then place a jute band a foot or so above it and another below it, near the base of the tree.

Two trees were used in 1941, a McIntosh in the D.L.B. Chute orchard and an unsprayed Northern Spy in the Hiltz Orchard. In 1942 the experiment was repeated on the same McIntosh tree. There was a considerably heavier crop on the McIntosh tree in 1942 (1000-1200 apples) than there was in 1941.

The following table 32 gives a record of the results. In 1941 separate counts were kept of normal looking larvae and those parasitized by A. carpocapsae.

TABLE 32: Record of codling moth larvae found on jute bands placed above and below Tangle foot bands on trees in the D.L.B. Chute and Hiltz orchard, Berwick, 1941 and 1942.

	McIntosh Tree				Northern Spy Tree			
	Upper Band		Lower Band		Upper Band		Lower Band	
	Norm	Par	Norm	Par	Norm	Par	Norm	Par
1941								
Number	30	2	38	5	116	20	81	7
Per cent	42.6%		57.4%		61%		39%	
1942								
Number	76		260					
Per cent	27.4%		72.6%					

The proportions of larvae that go into upper or lower bands seem to be correlated with the readiness with which wormy apples drop before the larvae have left them. That is, wormy apples drop more readily from the McIntosh than from the Spy. The drop from the McIntosh was heavier in 1942 than in 1941. It is quite possible that some larvae reached the lower band by swinging by silk from the upper part of the tree. Marshall (1940) records this habit.

E. Development of Larvae in Early Drop Apples

Attention should be drawn to the fact that the so-called "June drops," or undeveloped fruit which fell to the ground in early July, are sometimes the source of a large percentage of the larvae able to mature in a sprayed orchard. This was noted particularly in the case of the variety Baldwin in the Hiltz orchard in 1941 and to a lesser extent in 1942. There was a heavy early drop of undeveloped fruit in both years, particularly in 1942. As a rule the percentage of apples with deep entries is not nearly as high as for the later and larger drops, but there have been instances where it has been nearly as high. For instance, on September 9th, 1941, a sprayed Baldwin tree in the Hiltz orchard at Berwick, had 720 early drops under it, none of them measuring more than 7/8 of an inch in diameter. Of these 163 had been completely excavated by codling moth larvae, some of which were still present. In addition 86 large drops were also collected from under this tree on the same day. Of these, 23 had deep entries There was an average of 2.3 deep entries per 100 apples on the tree, which bore about a barrel of apples at picking time. It is evident that in this particular instance the early drops were the source of more mature larvae than were the later drops or the picked fruit. On the basis of the above record from picked fruit, it might have been concluded that few codling moth larvae had matured on this tree. Even if the deep entries in late drops were also taken into account the outlook for codling moth for the next year did not look too bad.

In 1942 there was not nearly as large a percentage of deep entries in early drops, even for the variety Baldwin. On

August 20, for instance, 1500 were collected from under one tree. Of these 46 had been hollowed out by larvae of which 24 were still present. At the same time 200 large drops contained a total of 14 deep entries.

Larvae from these early drop apples were of normal size and readily formed cocoons in cocooning sticks.

F. Behavior of Larvae Under Conditions of Constant High Humidity

One of the interesting bits of information that turned up in connection with the wet and dry pot experiment was that concerning the behavior of overwintering codling moth larvae when caged under conditions of constant high humidity. The larvae used in the 1943 and 1944 experiments had been induced to spin their cocoons in rolls of corrugated paper the previous year. They were kept in open jars in the insectary all winter until about April 1 when the rolls were divided between the wet and the dry pots.

During the pupation period it was found that larvae were attempting to leave the wet pot by way of the hole left in the cover for the emergence of moths. This was true both in 1943 and 1944. They also left wet cocoons in the case of a preliminary experiment conducted in 1942 which will be described later.

When the covers were removed from the wet pots, both in 1943 and 1944, it was found that some of the larvae had built new cocoons in the felt which formed a gasket between the wooden cover and the rim of the pot.

The following is a record of results obtained in 1943 and 1944:-

1. Record for 1943:-

(a) Of 588 larvae in the wet pot:-

(1) 11.3% migrated from winter cocoons
(2) 81.5% emerged as moths
(3) 18.5% died as larvae or pupae

(b) Of 432 larvae in the dry pot:-
(1) 0 migrated from winter cocoons
(2) 74.4% emerged as moths
(3) 25.6% died as larvae or pupae

2. Record for 1944:-

(a) Of 167 larvae in the wet pot:-
(1) 25.5% migrated from winter cocoons
(2) 62.5% emerged as moths
(3) 37.5% died as larvae or pupae

(b) Of 311 larvae in the dry pot:-
(1) 0 migrated from winter cocoons
(2) 83.0% emerged as moths
(3) 17.0% died as larvae or pupae

In 1942 a different technique was used whereby cocooning sticks containing overwintering larvae were kept in wet sphagnum moss held in clay pots. Some were kept under this condition all winter, spring and early summer and others only after various dates between April 6 to May 21. In all cases most of the larvae refused to stay in their overwintering cocoons under such excessively wet condition. They migrated elsewhere and since no provision had been made for keeping them from leaving the pots many of them were lost. Others attempted to pupate in the drier parts of the moss where most of them died. As a result few moths were obtained.

It is not known just how general this migration of spring larvae is in the field. It has been observed on tree trunks on a number of occasions when overwintering larvae have been found either crawling on the bark or else building new cocoons. These were on trees that had wet cocooning sites either around the base of the tree or in deep wounds.

VIII. NATURAL ENEMIES

In the course of studying the life history of the codling moth a considerable body of information has been accumulated regarding some of its entomophagous enemies. The object of the following notes is to list all those which have been observed and where possible to indicate their relative or possible importance as codling moth control agents in the Annapolis Valley.

A. Birds

It has been repeatedly observed that birds sometimes destroy considerable numbers of overwintering larvae in their cocoons. Their work is indicated by prominent holes made in the bark at points where larvae have been located in cocoons underneath. No birds have ever been seen actually feeding but the holes are of the type made by woodpeckers. The amount of feeding done in this way varies greatly according to circumstance. Proximity to woodland favors their feeding on overwintering codling moth larvae. This was shown quite clearly in the case of the Wagener orchard of John Buchanan at Waterville in 1943. The observations were made in connection with a fairly extensive series of bark examinations following trunk treatments against overwintering larvae. Trunk examinations were made in early June. The following is a record of the relative percentages of cocoons emptied by birds according to whether or not the trees were near or at a distance from woodland (table 33).

The south end of the orchard was surrounded by woodland whereas the north end had orchards on two sides. Two series of counts were made one across the untreated north end of the orchard and the other across the treated south end. Both series of counts started on the side wholly bordered by woodland and ended about midway across the orchard. The treated end of the orchard was almost entirely surrounded by the woodland. The orchard was 33 trees wide including fillers. In length it varied from 31 trees on one side to 54 trees on the other. The uneven end being the treated south end.

TABLE 33: Percentages of codling moth cocoons emptied by birds. Counts started on west side next to woodland and continued across to about the centre of orchard, which was 33 rows wide. John Buchanan orchard, Waterville. June, 1943.

	Cocoons Emptied by Birds.		Number of Cocoons Examined	
Tree Number	Untreated End	Treated End	Untreated End	Treated End
1	83.5%	78.7%	97	75
2	73.1	73.1	51	41
3	24.0	75.0	21	36
4	63.0	64.0	43	50
5	8.7	54.1	23	24
6	0.0	47.0	23	32
7	18.1	19.0	11	21
8		2.1		48
		18.1		33

Note how in each series of counts the percentage of emptied cocoons becomes less the further the trees are from the wooded west side. It is possible of course that this is partly due to the decrease in numbers of larvae per tree trunk.

A replicate of the same experiment was conducted on some large heavily infested trunks in a large orchard at Berwick located at a distance of nearly a quarter of a mile from woodland. Although a total of 1844 cocoons was examined from 6 trees yet hardly any were found emptied by birds.

As a general rule birds tend to hunt more thoroughly on those apple tree trunks carrying the most larvae providing however that the apple trees are located close to suitable wooded areas.

It is appropriate to mention here the fact that birds, probably pewees, started cleaning out the bait pan captures in the early part of several seasons before the nicotine sulphate was added to the bait. After the birds once discovered this source of food they cleaned out most of the pans in an area pretty regularly, starting early in the morning. The evidence of their feeding was in the form of pieces of wings, antennae, scales, etc., left floating on top of the bait. After the nicotine sulphate was added to the bait, there was no further evidence of moths being taken from the pans. The pewees also disappeared from the orchards at this time. If fly-catchers and possibly other birds will take moths so readily and in such numbers from bait pans it is not unlikely that they will also take free-living ones in the orchard.

It should be mentioned here also that each summer during the period of this study one or more night hawks frequented the Hiltz-South Yarmouth orchards during the period of moth activity. They not only flew about over the orchard but on a number of occasions were found resting on the trees during the day time.

B. Spiders

A small dark crab-like, as yet unidentified, spider has often been found associated with codling moth larvae in burlap tree bands. In a few cases this spider has been found carrying a limp larva or has been in close proximity to one under a band The color of this spider is very similar to that of the bark of an apple tree trunk. It is frequently found on tree trunks when hunting for codling moth cocoons in the spring. Apparently it cannot enter an intact cocoon but it is a likely predator on larvae moving over the bark in search of cocooning quarters. Several specimens were enclosed in glass vials together with codling larvae but they refused to feed on them under such conditions. It seems likely to be of importance only at the time when larvae are searching for hibernation quarters.

Certain hunting spiders will feed on newly hatched larvae in captivity and it is to be expected that they might be of considerable importance in the field.

C. Mites

An active predator mite, Anystis sp. will feed on eggs and young larvae in captivity and may be an important control agent in the orchard, since it becomes quite abundant under favourable conditions.

D. Hemiptera

Two predacious Miridae have been found associated with larvae in codling moth bands. The relative numbers vary from year to year. They are Deraeocoris nebulosus (Uhler) and Phytocoris conspurcatus Knight. Both are bark inhabiting species. Knight (1941) lists them both as predacious forms. The first named has occasionally been observed feeding on larvae in bands. Both have been found in association with flabby, freshly killed larvae.

E. Coleoptera

Tenebroides corticalis Melsh. is probably one of the most widespread and best known of the enemies of the codling moth. Slingerland (1898) says that; "With the exception of the birds, it seems to be the most efficient enemy of the codling moth in New York". It is generally present in the Annapolis Valley wherever the codling moth is found in numbers. One good feature it possesses as a predator is the fact that both the larva and the adult feed on the codling moth larvae and pupae and this feeding goes on during the spring, summer and autumn. There is only one generation a year. The most active feeding is that done by maturing larvae and by adults during the pupation period of the codling moth in the spring and early summer. Codling moth pupae are especially subject to attack, possibly because T. corticalis is better able to enter cocoons after the exit tunnel is formed than before. They congregate in codling moth bands quite readily and do considerable feeding there. It is difficult to say how important this predator is in the Annapolis Valley. The degree of its effectiveness seems to be correlated with the amount of codling moth present, the period of time over which it has been prevalent and with its own reproductive potential. It has been noted that in proportion to the number of codling moth cocoons found it is relatively more abundant in neglected orchards carrying long standing codling moth infestations than it is in commercial orchards with new or fluctuating infestations. It seems to be a fairly effective searcher. Apparently either its reproductive potential is low or else the environmental resistance is high. This statement is based on the fact that the numbers of larvae are low in proportion to the numbers of adults fround on tree trunks. It shows a high degree of constancy of activity from year to year, particularly in unsprayed orchards.

F. Hymenoptera

The egg parasite Trichogramma evanescens Westw. (minutum Riley) is a fluctuating and unpredictable control agent. It has a high reproductive potential but is quickly and decisively affected by adverse conditions. A succession of suitable host material must develop and be in sufficient numbers right through the season to carry the parasite along in effective numbers. Physical conditions including weather and spray treatments must not become sufficiently detrimental at any time, even for a brief period, to break the chain of successive generations.

In a report of their studies on Trichogramma in Connecticut Schread and Garman (1933) point out the importance of temperature and humidity in relation to reproductivity. They also show that sulphur has a detrimental effect on egg parasitism. Prevailing temperatures in turn affect the degree to which sulphur may be detrimental.

Some particularly interesting records on egg parasitism were obtained in 1942. In that year the outbreak of first generation codling moth was cut off a month earlier in the unsprayed South Yarmouth orchard than it was in the nearby D.L.B. Chute orchard which was moderately well sprayed (Fig 30). A count of 200 eggs on leaves in the South Yarmouth orchard on July 16 showed that 193 were parasitized. Of the other six, one was in the "red ring" stage and six were only recently laid. In the D.L.B. Chute orchard on the same date 61 eggs out of 77 were parasitized.

Although egg parasitism has been observed every year, 1942 was the only year in which Trichogramma appeared early enough and in sufficient numbers to exert a really substantial degree of control; and that was on unsprayed trees.

Ascogaster carpocapsae Viereck is another well known and widespread parasite of the codling moth. Cox (1932) describes it and gives an account of its life history. In the Annapolis Valley this has proven to be quite an important parasite of the codling moth; perhaps the most important over a period of years. Table 34 contains a record of percentage parasitism by A. carpocapsae based on trunk examinations and collections from tree bands. This record probably minimizes the proportion of parasitized larvae, since a larger proportion of the small parasitized larvae are likely to find suitable cocooning sites in the upper parts of a tree than will the large normal sized larvae which require more space for cocooning.

The record in Table 34 indicates that, in general, spraying reduces the effectiveness of this parasite.

The development of A. carpocapsae closely parallels that of its host C. pomonella. In 1942 when there was a pronounced second generation of the host insect there was also a small second generation of A. carpocapsae. The emergence of codling moths and adult parasites closely paralled one another (Fig 39) as does also the appearance of parasitized and non-parasitized larvae in codling moth bands (Fig 40).

There has been no evidence of hyperparasitism of A.

TABLE 34: Record of amounts of A. carpocapsae parasitized codling moth larvae taken in a number of unsprayed and sprayed orchards in the Annapolis Valley. 1939-1944.

Year	Orchard	Larvae examn'd	Per cent Parasitized	Treatment
1939	Wolfe Waterville	333	33	Unsprayed
	Graywood, Anna. Co.	171	42.7	Unsprayed
	So. Yarmouth Berwick	358	5.0	Sprayed
	Hiltz, Berwick	284	0.3	Sprayed
1940	Wolfe	59	54.0	Unsprayed
	Graywood	67	74.6	Unsprayed
	Hiltz	1818	7.6	Sprayed
1941	Wolfe	160	58.8	Unsprayed
	D.L.B. Chute, Berwick	555	20.9	Sprayed
	So. Yarmouth	37	24.3	Sprayed
	Hiltz	722	13.8	Sprayed
1942	Wolfe	54	68.5	Unsprayed
	D.L.B. Chute	687	29.8	Sprayed
	So. Yarmouth	5878	44.1	Sprayed
	Hiltz	92	8.7	Sprayed
1943	Wolfe	93	34.4	Unsprayed
	D.L.B. Chute	191	23.0	Sprayed
	Hiltz	138	9.0	Sprayed
	So. Yarmouth	35	3.0	Sprayed
	Coulter	53	35.0	Sprayed
1944	Wolfe	79	24.0	Unsprayed
	D.L.B. Chute	152	27.0	Sprayed
	So. Yarmouth	409	50.3	Sprayed

carpocapsae during the course of these studies, despite the fact that hundreds of parasitized larvae have been kept under observation after being collected both in the spring and autumn months.

In addition to the two hymenopterous parasites already mentioned, a number of hymenopterous pupal parasites were obtained from about 2000 codling moth larvae and pupae collected from tree trunks during the spring of 1942 at Berwick. Similar collections of larvae and pupae were gathered and caged in 1943, and 1944 but no parasites were obtained. No parasites except A. carpocapsae have ever been obtained from codling moth larvae which had been collected in the autumn.

The following is a list of the pupal parasites obtained in 1942. The identifications are by G.S. Walley.

Name of Parasite	Emergence Dates	No. taken
Pimpla inflata Prov.	July 2,3, Aug 4	4
Pimpla aequalis Prov	July 21	1
Pimpla sp. (probably aequalis)	June 13, 19	2 (both males)
Dibrachys cavus (Walk)	Aug 10	6 (from one pupa
Phaeogenes sp. (Probably)	1 adult male dissected from pupa.	

IX. TOPOGRAPHIC AND EDAPHIC CONSIDERATIONS

From time to time statements have appeared in publications concerning cultural practices, soil management, etc., to the effect that soil conditions exert an influence on plant resistence to insect attack. Two recent books that have had a wide circulation contain examples of this viewpoint (Faulkner 1943, Howard 1944). Quite recently Wittwer and Haseman (1946) have published experimental results which show that injury by the thrip (Heliothrips haemorrhoidalis) to spinach can be controlled in the green house by controlling the nitrogen and calcium levels in the soil. These authors then go on to suggest that, "the explanation as to why some crop pests, such as codling moth, become more serious as fruit trees are grown continuously on the same soil without a complete renewal of the nutrients removed may be found, in part at least, in soil deficiency". The erratic occurrence of the heavily infested orchards in the Annapolis Valley may justify some investigations based on the general viewpoint expressed above.

Some records were taken in adjoining orchards at Berwick in 1943 which indicated that striking variations in the amount of codling moth injury might be associated with topographic or edaphic conditions in these orchards. The orchards concerned, namely the Coulter and South Yarmouth Blocks, are located in the southwest side of Berwick on a low ridge which has a long gradual slope on the south side and a shorter somewhat steeper one on the north side. The soil on the crest and upper slopes has been classified as Cornwallis sandy loam, while the lower slopes including most of the southern slop is classified as Berwick sandy loam (Harlow and Whiteside 1943). The paved highway runs along the crest of this ridge. It so happens that the apples grown on those sections which are located on the crest and upper slopes of this ridge were characterized by more entries than those grown on the lower slopes. The counts in table 35 were made on two varieties of apples in the Coulter Block. They were taken on rows running north and south starting with tree #1 at the top of the slope and next the paved road.

The south end of the South Yarmouth Block lies across the road from the Coulter block. The first 13 trees, counting sout to north from the road, stand on land which forms part of the crest of the ridge and is about on a level with the road. From there the rows slope down to a bog at the north end. Records of entries on Ribstons, Baldwins and Gravensteins were taken on rows running south to north (Table 36). Only the Gravensteins run the full length of the orchard.

TABLE 35: Numbers of codling moth entries per 100 apples for two rows of trees, taken from north to south in the Coulter Block, Berwick. Counts on apple trees, September 23, 1943.

No of tree in row	York Imperial Row			Northern Spy Row		
	Stings	Deep Entries	Clean Apples	Stings	Deep Entries	Clean Apples
# 1	207	16	8	348	70	2
10	173	14	11	484	110	2
20	63	12	55	145	42	20
30	60	8	53	57	12	52
40	25	4	76	67	6	50
50	22	6	80	28	6	79
60	4	0	96	41	9	65
70	12	0	91	9	2	90

TABLE 36: Numbers of codling entries per 100 apples for two rows of apples taken from south to north in the South Yarmouth Block, Berwick. Counts on picked apples from records of N.A. Patterson 1943.

No of tree in row	Ribston		Baldwin		Gravenstein	
	Stings	Deep Entries	Stings	Deep Entries	Stings	Deep Entries
# 1	185	14			119	12
2	186	15			134	6
5	183	19				
7	187	31				
8	155	15			113	7
10	179	16				
13	173	15	266	13	120	3
16			175	2	65	5
19			166	8	75	5
20			162	9	57	4
22			91	2	49	2
24			73	2	36	1
25			60	1	40	1
28			35	2		
30			53	1	18	4
32			31	0		

The record presented above is admittedly too meagre to allow the drawing of conclusions regarding the causal relations involved. It does, however, support the view that there should be some investigations regarding the effect of topographic and edaphic conditions on natural control of the codling moth.

Such an investigation might possibly help clear up some puzzling questions regarding the irregular distribution of heavily infested orchards in the Annapolis Valley. Why, for instance, is the codling moth outbreak in the Gaspereaux Valley largely restricted to two adjoining blocks of trees belonging to two different growers? Why is there not a heavier codling moth infestation in the F.M. Nash orchard at Rockland. It has never seemed to the writer that the spray program used in the Nash orchard was sufficient to keep the codling moth injuries as light as they have been since 1938 considering the numbers of moths taken in bait pans (Table 20).

Another puzzling type of natural control which may have an edaphic basis has been observed several times, notably so in 1942 in the case of the South Mountain Orchard of the former Sam Chute properties near Berwick. There was a comparatively light infestation of codling moth in this orchard which was not sprayed that year. Because it was unsprayed most of the entries were deep entries. An examination of infested apples on August 7 disclosed that a large percentage of the codling moth larvae were dead in their tunnels. They had apparently drowned since the tunnels were largely filled with a somewhat sticky fluid. Because it may have a bearing on the case it should be mentioned that this orchard was not suffering from drought at the time the observations were made, whereas the heavily infested orchards at Berwick were suffering quite seriously from drought.

X. SUMMARY AND CONCLUSIONS

The codling moth, Carpocapsae pomonella L., was one of the serious pests which first induced apple growers to develop and use control measures in Nova Scotia orchards. During the period 1884 - 1901, Dr. Fletcher and others repeatedly mention the grower's concern and serious loss resulting from the work of this insect. From shortly after the turn of the century, following the use of bordeaux-arsenical sprays, until about 1924 the insect was evidently considered a minor pest all over the Annapolis Valley.

From 1918 until about 1924 increasing use was made of both sulphur and copper - lime dusts containing either lead or calcium arsenate. From about 1925 to 1930 there are repeated references to the apparent increase of codling moth damage in certain locations. It was about this time that sulphur sprays came into general use with calcium and lead arsenates being used as the general insecticides.

Between about 1930 and 1939 the insect was increasingly recognized as a major pest in several restricted areas. Since 1939 the area of serious infestation has been gradually increasing, while at the same time a substantial reduction in codling moth damage has been brought about in some of the worst infested orchards as the result of the thorough and timely use of the recommended codling moth spray programs.

The present areas of persistant and serious codling moth infestations are located in the Berwick - Waterville area, in a few orchards east of Gaspereau village, and in a few orchards in the South Falmouth area. There are a few minor outbreaks in the Kentville - Wolfville - Port Williams area.

In the Annapolis Valley it is only in the presence of exceptionally favourable weather conditions occurring in conjunction with a high level of population that a second generation of codling moth larvae develops in sufficient numbers to be of economic importance. Such a development occurred in 1942. In that year serious loss from second generation entries occurred in a few commercial orchards in which there were large populations of first generation larvae which had been either poorly or not at all controlled by spraying.

Ordinarily then, an apple grower in this area need only concern himself with a single brood of codling moth.

In the Berwick area pupation begins toward the end of the delayed dormant period of the variety McIntosh. About 90 per cent will have completed pupation within 10 days after calyx closure.

The first moths emerge shortly after full bloom is reached. Approximately 50 per cent will have emerged a month later. In general, emergence of first generation moths is pretty well completed between July 20 and 30.

The first entries in fruit appear shortly after calyx closure, i.e. about the time the Spreading Dogbane, Apocynum androsoemifolium, starts to bloom. They generally accumulate quite rapidly after the first are found, with the peak occurring about three weeks later. The occurrance of new entries is about over by the end of the first ten days or two weeks in August, except for an exceptionally late season such as 1943 or when there is a substantial second generation.

The first larvae are likely to complete their feeding in a little less than a month after the appearance of the first entries. There is apt to be a certain amount of second generation entries if large numbers of larvae complete their feeding before the end of July.

Life history data for the codling moth at both Annapolis Royal and Berwick is correlated with temperature and precipitation records for these two stations.

A striking difference in the time and rate of pupation and moth emergence at Berwick as compared with Annapolis Royal in 1941 is correlated with the considerably greater number of hour-degrees of higher temperatures prevailing at Berwick during the critical period of pupation and moth emergence.

If daily mean temperature records are available, the time required for the incubation of eggs may be roughly estimated by the use of data showing the ranges of mean temperature that are characteristic of incubation periods in terms of days.

While the length of the larval feeding period is influenced by temperature it is evident that it is also greatly influenced by other factors, since there is often considerable variation in the feeding periods of larvae hatched at the same time and reared in the same cage.

Bait pan records indicate that evening temperatures have a differential effect on the flight activity of the sexes. The nearer evening temperatures drop toward 60°F the lower the percentage of females taken. Rainfall during the evening also tends to decrease the proportion of females taken in bait pans.

Apparently climatic conditions are not responsible for the great variation in prevalence of the codling moth in one part of the Annapolis Valley as compared with another.

It is probably true, as stated by Shelford (1927), that codling moth prevalence from one year to another is greatly influenced by autumn, winter and spring precipitation as well as by temperature. However, no consistent correlations in this respect are shown for this area on the basis of records compiled for the period 1933 - 1945. Experimental evidence is offered to show how heavy precipitation during late summer and autumn followed by a dry spring could be followed by increased codling moth abundance, and how the opposite set of conditions would be likely to result in decreased abundance.

The use of bait pans in various orchards has given valuable data regarding the activity and behavior of the codling moth. Besides indicating the period and intensity of moth activity and their relative abundance in different years in different orchards the results also indicate that: (1) There is a levelling off of populations between areas of heavy and low density. (2) Codling moths lay the majority of their eggs in the orchard in which they originate. (3) The larger number of moths captured near the top of a tree is apparently due to this being a more favourable location in itself rather than because such a location is near the leafy periphery of the tree. (4) Increasing the number of pans per tree considerably increases the number of moths taken per tree. As the numbers of pans per tree is increased the average number of moths per pan is decreased. (5) The presence or absence of bait pans in trees results in no significant difference in the percentage injury to fruit as between trees. If there is a reduction in the amount of codling moth injury due to the presence of bait pans, the reduction is general over the whole orchard area in which the pans are located.

Some records are given which have a bearing upon larval behavior in relation to control practices: (1) Evidence is cited corroborating the statements of others to the effect that the chief value of the calyx spray lies in the fact that poison is deposited on the inside and outside of the sepals rather than in the calyx cup. Since the first entries into fruit are not made until shortly after calyx closure it is probable that larvae are poisoned by coming into contact with it in the process of going through the sepals after the calyces are closed. (2) It is doubtful whether spraying in commercial orchards in Nova Scotia has, as yet, resulted in any substantial decrease in the innate tendency of codling moth larvae to enter apples by way of the calyx. (3) A comparison of the amounts of codling moth injuries on apples from the top and bottom portions of apple trees emphasizes the importance of taking particular care that the tops of bearing trees are thoroughly covered with spray. (4) In evaluating the results of control measures some attention must be given to the proportion of early drop apples in which larvae are likely to have completed development.

Among the natural control agents, birds, particularly woodpeckers, are quite effective where infested trees are located close to woodland."

The predator beetle Tenebroides corticalis Melsh. is quite generally distributed and both the adults and larvae are consistant feeders on larvae and pupae in orchards where the codling moth is well established.

The egg parasite Trichogramma evanescens Riley can be an important parasite but the degree of its effectiveness is quite unpredictable. It's effectiveness is greatly reduced by certain spray practices.

The larval parasite Ascogaster carpocapsae Viereck is an important parasite of the codling moth in the Annapolis Valley, since it is a fairly dependable one unless it is itself reduced in numbers through the use of detrimental sprays. One of its shortcomings is the fact that parasitized larvae are not destroyed until after they have completed feeding in the fruit and have formed their cocoons.

Several hymenopterous pupal parasites have been reared in very small numbers from codling moth larvae and pupae collected from tree trunks during the spring and early summer. They include Pimpla inflata Prov., Pimpla aequalis Prov., Dibrachys carus (Walk), and a Phaeogenes sp.

Two Mirid predators, Deraeocoris nebulosus Uhler and Phytocoris conspurcatus Knight, have been taken repeatedly in codling moth bands together with dead codling moth larvae. They may feed on larvae which are searching for cocooning quarters. It is doubtful if they are responsible for much control of the codling moth.

Spiders may be quite important predators of codling moth larvae, both when the larvae are newly hatched and when they are seeking cocooning quarters.

The mite *Anystis sp.*, under favourable conditions, may be an important predator on eggs and newly hatched larvae of the codling moth. This statement is based on the fact that they will feed on them in captivity.

Evidence is cited to show that edaphic and possibly topographic conditions should not be ignored in investigating the factors responsible for codling moth abundance.

XI. BIBLIOGRAPHY

This list includes all the literature referred to in the text as well as a number of other papers which have been selected because of the relevancy of their content.

Anonymous. Insects of the season. Annual report of investigations of the Dominion Entomological Laboratory at Annapolis Royal, 1922, 1923, 1928, 1929, 1930.

Ball, E.D. The control of the codling moth in the arid regions. U.S.D.A. Bur. Ent. Bull. 67: 55-77. 1907.

Beaulieu, A.A. On the biology of the codling moth in Quebec. 69th Ann. Rept. Ent. Soc. Ont. 1938: 61-65. 1938.

Beaulieu, A.A. Studies on the life history of the codling moth in Southwestern Quebec. Sci. Agric. 20: 624-631.1940.

Bel'skii, B.I. On the technique of catching injurious Noctuids with molasses (in Russian). Nauch. Zap Sakharn. Prom. 12: 99-107. 1936 (Abstract in R.A.E. 24 (A): 643-644. 1936)

Bobb, M.L. The use of bait traps in codling moth control. Virginia Fruit 26 (4): 20-24. 1938.

Bobb, M.L., A.M. Woodside, and R.N. Jefferson. Bait and bait traps in codling moth control. Va. Agric. Expt. Sta. Bull. 320: 1-19. 1939.

Brittain, W.H. Injurious insects in Nova Scotia. N.S. Dept. Nat. Resources Bull. 12, p. 37. 1927.

Brittain, W.H. and A.D. Pickett. Fruit insects Part I. Injurious insects of Nova Scotia. N.S. Dept. Nat. Resources Bull. 12 (Revised). p. 65. 1933.

Cameron, J. MacBain, and N.A. Patterson. Insects of the season. Annual report of investigations of the Dominion Entomological Laboratory at Annapolis Royal, 1940.

Cameron, J. MacBain, and A.D. Pickett. The insect outlook for 1940. Rept. N.S. Fruit Growers' Assoc. 1939. p.20. 1940.

Cameron, J. MacBain. Insect outlook for 1941. Rept. N.S. Fruit Growers Assoc. 1940. p.24. 1940.

Carlson, F.W. Refrigeration test of transforming codling moth larvae. J. Econ. Ent. 35 : 787. 1942.

Caesar, L. The codling moth. Ont. Dept. Agric. Ont. Agric. College Bull. 187: 1-40. 1911.

Callenbach, John A. Influence of road dust upon codling moth control. J. Econ. Ent. 38: 803-807. 1940.

Comeau, F.G. Origin and history of the apple industry in Europe and America with particular reference to Old Acadia. Pub. by author at Halifax, N.S. pp. 1-40. 1934.

Cox, James A. Ascogaster carpocapsae Viereck, an important larval parasite of the codling moth and oriental fruit moth. N.Y. State Agric. Expt. Sta. Tech. Bull. 188: 1-26. 1932.

Cutright, C.R. Some laboratory reactions of young codling moth larvae. J. Econ. Ent. 24: 81-83. 1931.

Cutright, C.R. and H.E. Morrison. Varietal susceptibility to codling moth injury. J. Econ. Ent. 28: 107-109. 1935.

Cutright, C.R. An emergence cage for codling moths, Carpocapsa pomonella L. Ohio Agric Expt. Sta. Bull. 1936.

Faulkner, Edward H. Plowman's folly. Univ. Oklahoma Press. 1943.

Felt, E.P. Recent experiments with the codling moth. J. Econ. Ent. 3: 474-477.

Fletcher, James. The report of the Entomologist and Botanist 1905, p. 183. 1906.

Fletcher, James. Annual reports of the Dominion Entomologist and Botonist 1884-1908.

Garlick, W.A. Miscellaneous notes on the codling moth. 69th Ann. Rept. Ent. Soc. Ont. 1938: 58-61. 1938.

Gilliatt, F.C. Insects of the season. Annual report of investigations of the Dominion Entomological Laboratory at Annapolis Royal. 1931-1937.

Glenn, Pressley A. Codling moth investigations of the State Entomologist's Office, 1915, 1916, 1917. Nat. Hist. Survey Bull.14 (Art 7): 219-289. 1922.

Golfari, L. Investigations on the habits of Carpocapsa pomonella in relation to the means used for its control (in Italian). Boll. Inst. Ent. Univ. Bologna 11: 41-63. 1939. (Abstract in R.A.E. 28 (A): 212-213. 1940).

Gould, E. and G.H. Geissler. Codling moth emergence - activity studies. J. Econ. Ent. 34: 576-579. 1941.

Hall, J. Allan. Observations on the behavior of newly hatched codling moth larvae. Can. Ent. 66: 100-102. 1934.

Hall, J. Allan. Six years study of the life history and habits of the codling moth (Carpocapsa pomonella L.) 59th Ann. Rept. Ent. Soc. Ontario 1928: 96-105. 1929.

Harlow, L.C. and G.B. Whiteside. Soil survey of the Annapolis Valley fruit growing area. Dom. Canada Dept. Agric. Tech. Bull. 47, Publ. 752: 1-92. 1943.

Hartzell, F.Z. Comparison of methods for computing daily mean temperatures: Effect of discrepancies upon investigations of climatologists and biologists. N.Y. Agric. Expt. Sta. Tech. Bull. 68: 1-35. 1919.

Haseman, L. Killing codling moth larvae with low temperatures. J. Econ. Ent. 35: 449-450. 1942.

Hattingh, C.C. A study of codling moth oviposition in a mixed pear orchard. J. Ent. Soc. S. Africa 5: 137-146. 1942.

Hattingh, C.C. The distribution of codling moth eggs on pear trees. J. Ent. Soc. S. Africa 6: 124-130. 1943.

Headlee, T.J. Some data relative to the relationship of temperature to codling moth activity. J. N.Y. Ent. Soc. 36: 147-163. 1928.

Headlee, T.J. Performance of the thermal constant as an indicator of the time to apply cover sprays for codling moth. J. Econ. Ent. 24: 291-296. 1931.

Headlee, T.J. Brood study of the codling moth for one decade. J. Econ. Ent. 29: 639-646. 1936.

Hough, Walter S. Colorado and Virginia strains of codling moth in relation to their ability to enter sprayed and unsprayed apples. J. Agric. Res. 48: 533-552. 1934.

Hough, Walter S. Development and characteristics of vigorous or resistent strains of codling moth. Va. Agric. Expt. Sta. Tech. Bull 91: 1-32. 1943.

Howard, Sir, Albert. An agricultural testament. Oxford Univ. Press. pp. 157-170. 1944.

Isely, D. and A.J. Ackerman. Life history of codling moth in Arkansas with special reference to factors limiting abundance. Ark. Agric. Expt. Sta. Bull. 189. 1923.

Isely, D. Codling moth oviposition and temperature. J. Econ. Ent. 31: 356-359. 1938.

Isely, D. Timing seasonal occurrence and abundance of the codling moth. Bull. Ark. Agric. Expt. Sta. 382: 1-26. 1939.

Isely, D. Early maturing varieties in codling moth control. J. Econ. Ent. 36: 757-759. 1943.

Kelsall, Arthur. Thirty years experience with orchard aprays in Nova Scotia. Sci. Agric. 19: 405-410. 1939.

Knight, Harry H. The plant bags, or Miridae, of Illinois. Bull. Ill. Nat. Hist. Survey 22 (Art. 1): 1-234. 1941.

Lathrop, F.H. Verbal statement regarding status of codling moth in Maine. Made to author at an entomological conference held at Fredericton, N.B. in January, 1941.

Melander, A.L. and E.L. Jenne. The codling moth in the Yakima Valley. Wash. State Agric. Expt. Sta. Bull. 77: 1-96. 1906.

Melander, A.L. Filling the calyx cup. J. Econ. Ent. 1: 217-220. 1908.

Melander, A.L. J. Econ. Ent. 2: 67. 1909.

Marshall, G. Edw. Some newly discovered habits of the codling moth J. Econ. Ent. 33: 200. 1940.

Montgomery, H.B.S., M.H. Moore, H. Shaw, and W. Steer. Insecticides and fungicides. Rept. East Malling. Res. Sta. 1939: 32-34. 1940.

Moore, Joseph B., R.L. Webster, Kermit Groves and Herman Fallscheer. Investigations on codling moth and mite control. Proc. Wash. State Hort. Assoc. 35: 103-104. 1939.

Morris, Miss. An article on codling moth. American Agriculturist 5: 65-66. 1846.

Neary, M.E. Insect outlook for the seasons of 1942 to 1946. Reports N.S. Fruit Growers' Assoc. 1941-1945.

Nel, R.I. The validity of the bait-trap method of spray timing in codling moth control. Union S. Africa Dept. Agric. Ent. Mem. 2 (5): 55-76. 1940.

Nel, R.I. Varietal interplanting in relation to control of codling moth. J. Ent. Soc. S. Africa 4: 111-134. 1941.

Nevskii, V. On the causes of fluctuations in population density of the codling moth Carpocapsa pomonella L. (In Russian). Acta Univ. Asiae med (8, Zool.) fasc. 37: 1-14 1937. (Abstract in R.A.E. 27 (A): 587-588. 1939).

Newcomer, E.J. and W.D. Whitcomb. Life history of the codling moth in the Yakima Valley of Washington. U.S.D.A. Dept. Bull. 1235: 1-76. 1924.

Petersen, Alvah. A manual of entomological equipment and methods. Edwards Brothers. Inc. Ann. Arbor, Michigan. 1937.

Patterson, N.A. and M.E. Neary. Insects of the season. Annual report of investigations of the Dominion Entomological Laboratory at Annapolis Royal. 1941-1945.

Pickett, A.D. Insect outlook for the seasons of 1930 to 1939. Reports N.S. Fruit Growers' Assoc. 1929-1938,

Pickett, A.D. and N.A. Patterson. Insects of the season. Annual report of investigations of the Dominion Entomological Laboratory at Annapolis Royal 1938-1939.

Pickett, A.D. Remarks on the control of some of the more important apple insects. Rept. N.S. Fruit Growers' Assoc. p. 29. 1940.

Pickett, A.D., N.A. Patterson, H.T. Stultz and F.T. Lord. The influence of spray programs on the fauna of apple orchards in Nova Scotia. 1. An appraisal of the problem and a method of approach. To appear in Sci. Agric. 1946.

Quaintance, A.L., E.L. Jenne, E.W. Scott and R.W. Braucher. The one-spray method in the control of the codling moth and the plum circulio. U.S.D.A.Bur. Ent. Bull. 80, Part VII revised. 1911.

Sanders, G.E. The codling moth in Nova Scotia. Proc. Ent. Soc. of Nova Scotia 1: 90. 1915.

Sanders, G.E. The biting insects of the apple in Nova Scotia. Unpublished manuscript on file in Dominion Entomological Laboratory at Annapolis Royal, 1946.

Sanders, G.E. Biting insects injuring the fruit of the apple in Nova Scotia. Proc. Ent. Soc. of Nova Scotia 2: 33. 1917.

Sanders, G.E. Insects of the season. Annual report of investigations of the Dominion Entomological Laboratory at Annapolis Royal, 1917-21.

Schoene, W.J., W.S. Hough, L.A. Stearns, L.R. Cagle, C.R. Willey and A.M. Woodside. Life history of the codling moth in Virginia. Va. Agric. Expt. Sta. Bull. 261: 1-56. 1928.

Shelford, Victor. An experimental study of the relations of the codling moth to weather and climate. Bull. 111. Nat. Hist. Survey 16 (Art V): 311-440. 1927.

Siegler, E.H. and F.L. Simanton. Life history of the codling moth in Maine. U.S.D.A. Bull. 252. 1915.

Slingerland, M.V. The codling moth. Cornell Univ. Agric. Expt. Sta. Bull. 142: 3-69. 1898.

Spittall, J.P. Insects of the season. Annual report of investigations of the Dominion Entomological Laboratory at Annapolis Royal. 1924-1927.

Spuler, Anthony. Codling moth traps. State College Washington Agric. Expt. Sta. Bull. 214: 1-12. 1927.

Steer, W. Observations on codling moth (Cydia pomonella L.) in 1936. Anna. Rept. East. Malling Res. Sta. 1936.

Steiner, L.F. Distances travelled by newly hatched codling moth larvae. J. Econ. Ent. 32: 470. 1939.

Steiner, L.F. Codling moth flight habits and their influence on the results of experiments. J. Econ. Ent. 33: 436-440. 1940.

Theron, P.P.A. Experiments on terminating the diapause in larvae of codling moth. J. Ent. Soc. S. Africa 6: 114-123. 1943.

Townsend, M.T. The breaking-up of hibernation in the codling moth larva. Ann. Ent. Soc. America 19: 429-439. 1926.

Tufts, Joseph. Massachusetts Agricultural Repository and Journal 5: 364-367. 1819.

Van, Leeuwen, E.R. The activity of adult codling moths as indicated by captures of marked moths. J. Econ. Ent. 33: 162-166. 1940.

Waddell, D.B. and J. Marshall. The calyx spray in codling moth control. Sci. Agric. 22: 413-418. 1942.

Webster, R.L. Codling moth and the weather. J. Econ. Ent. 28: 956-960. 1935.

Webster, R.L. The relation of the codling moth to temperature and rainfall. Proc. 32 Ann. Meet Wash. State Hort. Assoc.: 133-141. 1936.

Webster, R.L. A ten year study of codling moth activity. State College Washington. Agric. Expt. Sta. Bull. 340. 1936.

Wigglesworth, V.B. The principles of insect physiology. E.P. Dutton and Company Inc. New York. pp. 67-70. 1942.

Wittwer, S.H. and Leonard Haseman. Soil nitrogen and thrips injury to spinach. Science 103: 331-332. 1946.

Woodside, A.M. Codling moth infestation at different heights in apple trees. Va. Polytechnic Institute. Va. Agric. Expt. Sta. Bull. 360: 1-10. 1944.

Yothers, M.A. Summary of three years tests of trap baits for capturing the codling moth. J. Econ. Ent. 20: 567-575. 1927.

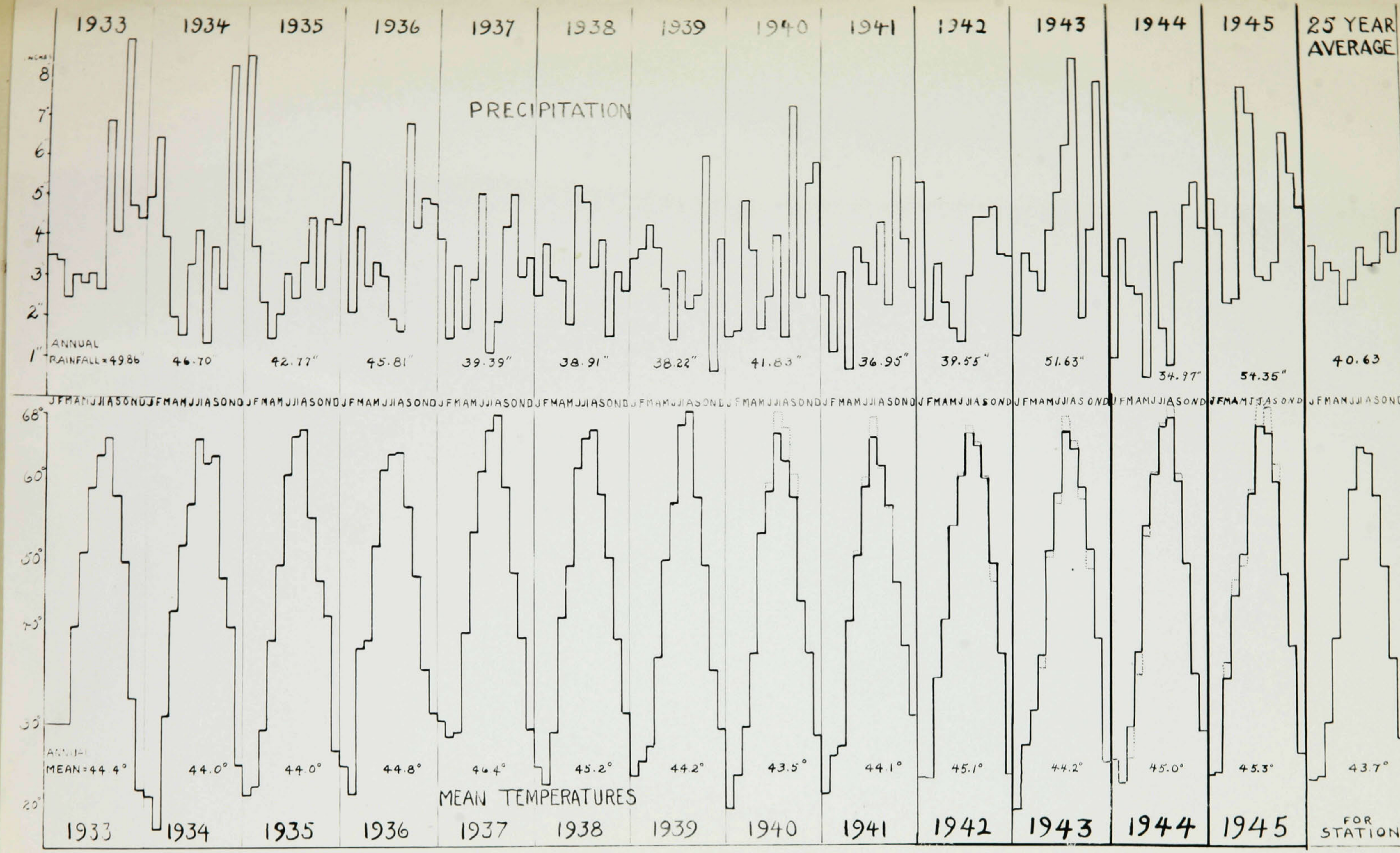
practices. Consideration is given to evidence of possible correlations between topographic and edaphic conditions and codling moth prevalence. Predators and parasites are listed together with some records of their habits and relative effectiveness as control agents.

Fig.I -Lantern-globe Cage .

Fig. 2. - Cutright Cage and Cocooning Sticks

Fig. 3. - Thermograph Screen and Bench Insectary at Berwick
Fig. 4. - Bench Insectary, End View

Fig. 5. - Codling Moth Band on McIntosh Trunk



MONTHLY PRECIPITATION AND MEAN TEMPERATURES FOR THE YEARS 1933-1945 AT ANNAPOLIS ROYAL. RECORD FOR BERWICK ALSO DRAWN IN FOR PERIODS AVAILABLE (DOTTED LINES).

Fig. 6.

A COMPARISON OF MEAN MONTHLY TEMPERATURES AND MONTHLY PRECIPITATION FOR APRIL – OCTOBER AT ANNAPOLIS ROYAL FOR THE PERIOD 1933 – 45 AS WELL AS WITH THE AVERAGE MEAN MONTHLY TEMPERATURE AND PRECIPITATION AT THIS STATION FOR THE PERIOD 1912–1938

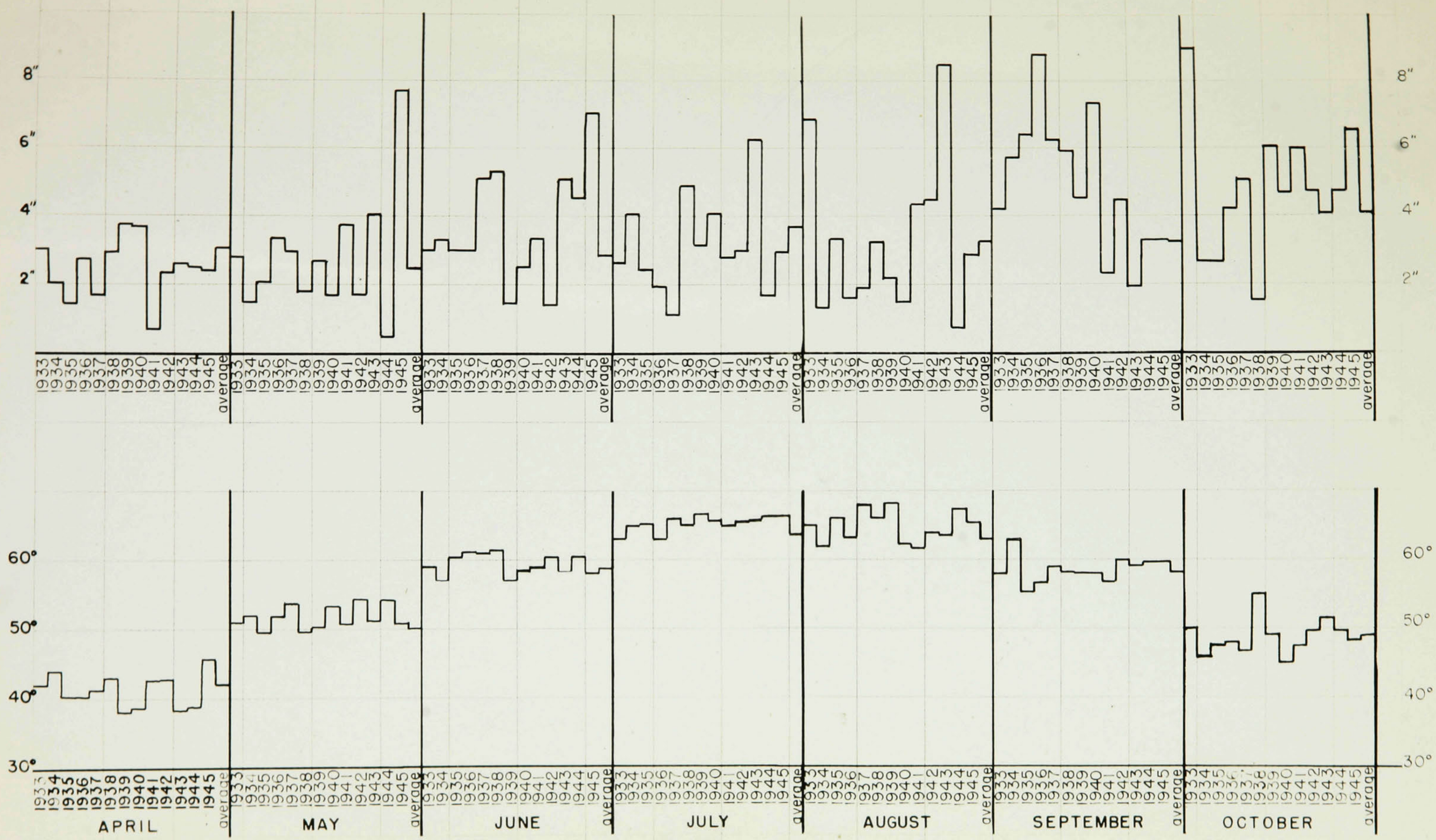


Fig. 7.

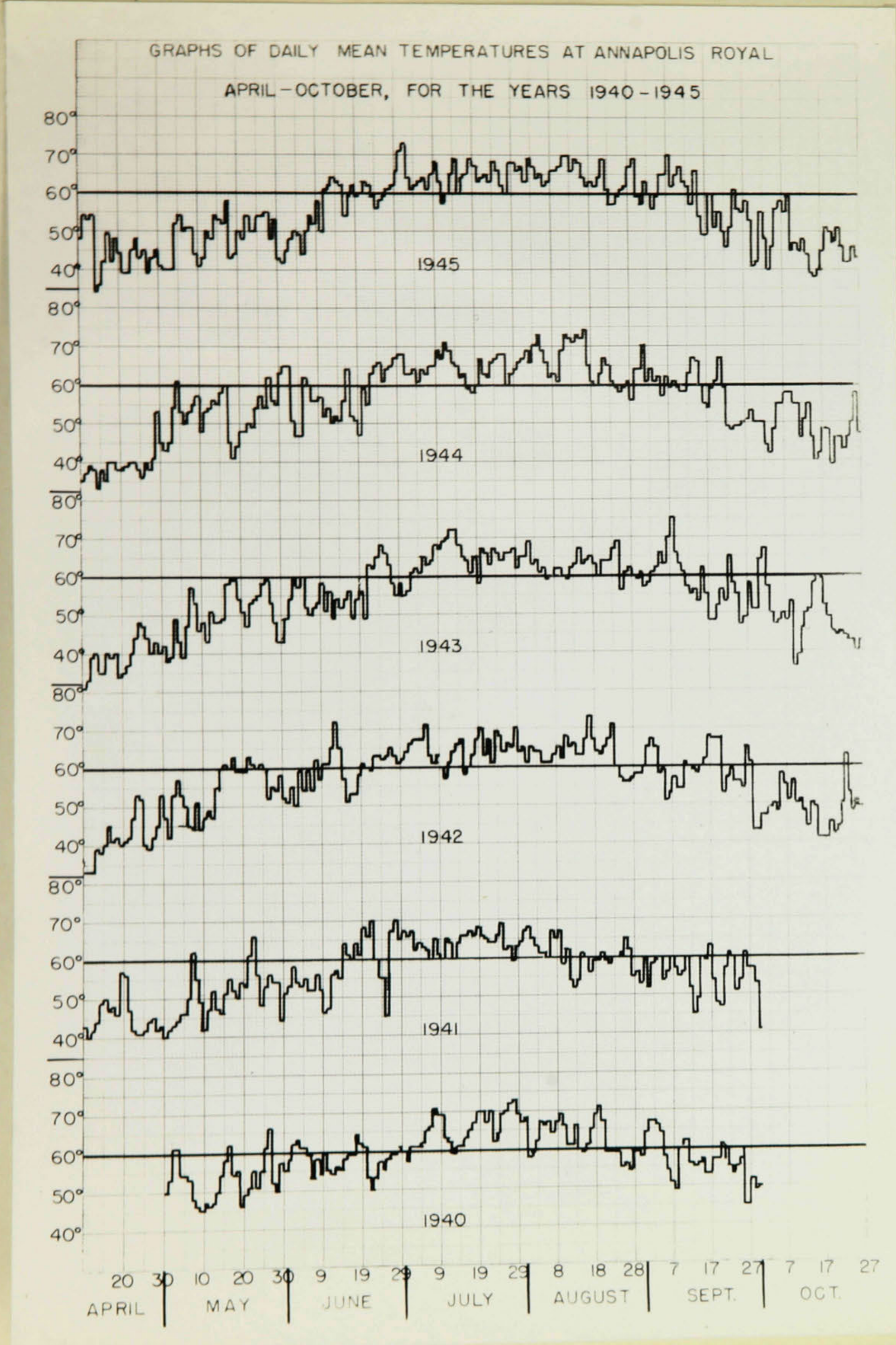

GRAPHS OF DAILY MEAN TEMPERATURES AT ANNAPOLIS ROYAL
APRIL–OCTOBER, FOR THE YEARS 1940–1945
80° 70° 60° 50° 40°
1945
1944
1943
1942
1941
1940
20 30 10 20 30 9 19 29 9 19 29 8 18 28 7 17 27 7 17 27
APRIL MAY JUNE JULY AUGUST SEPT. OCT.

Fig. 8.

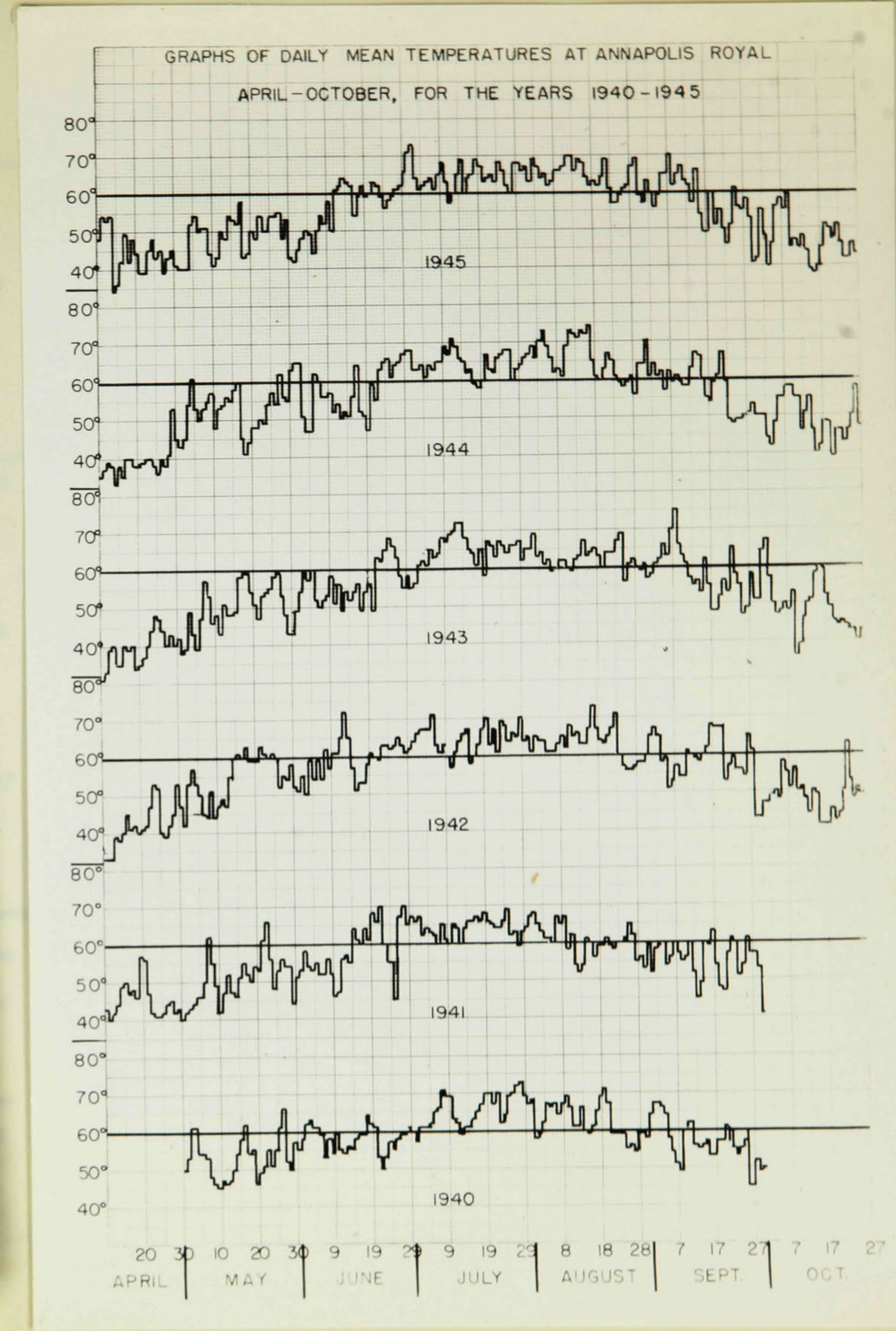
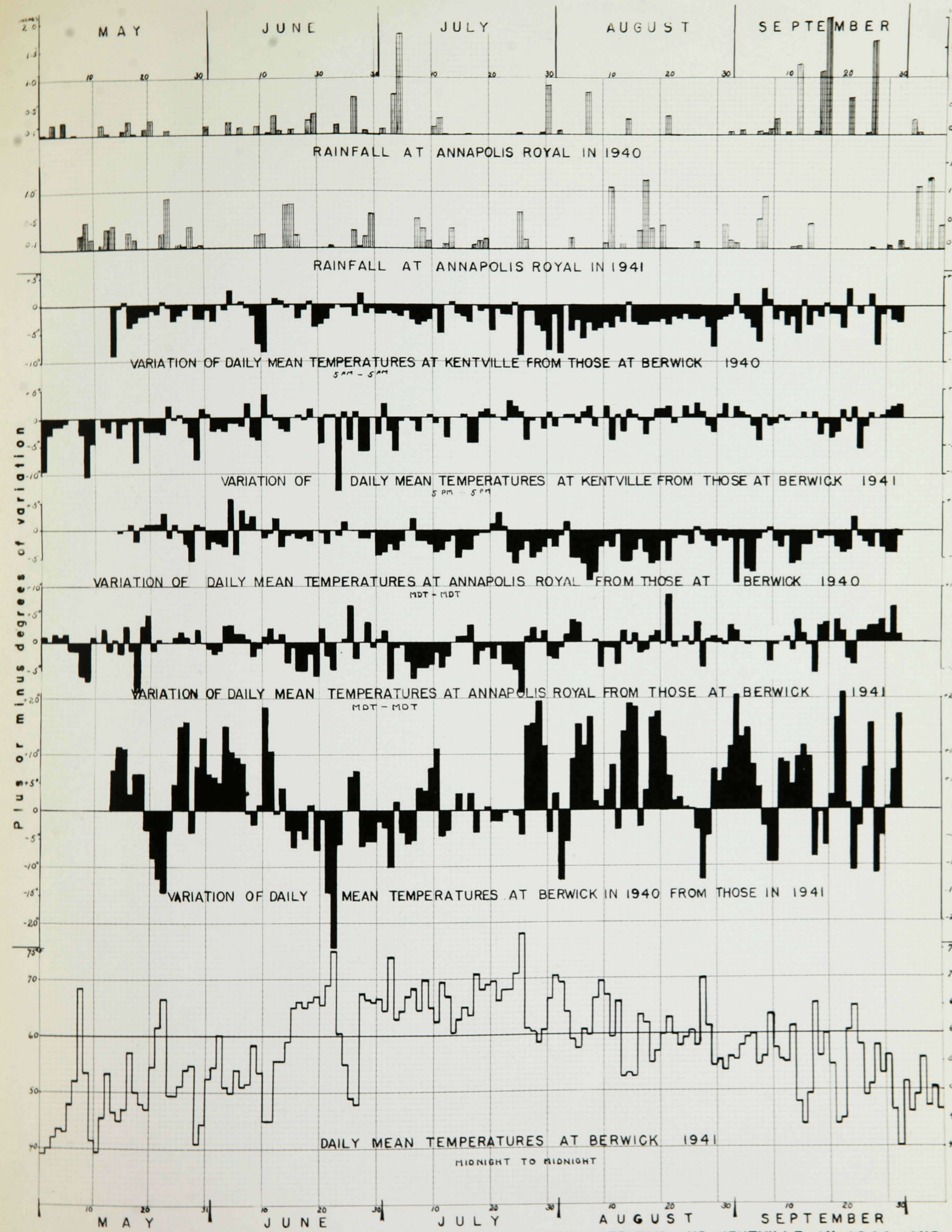
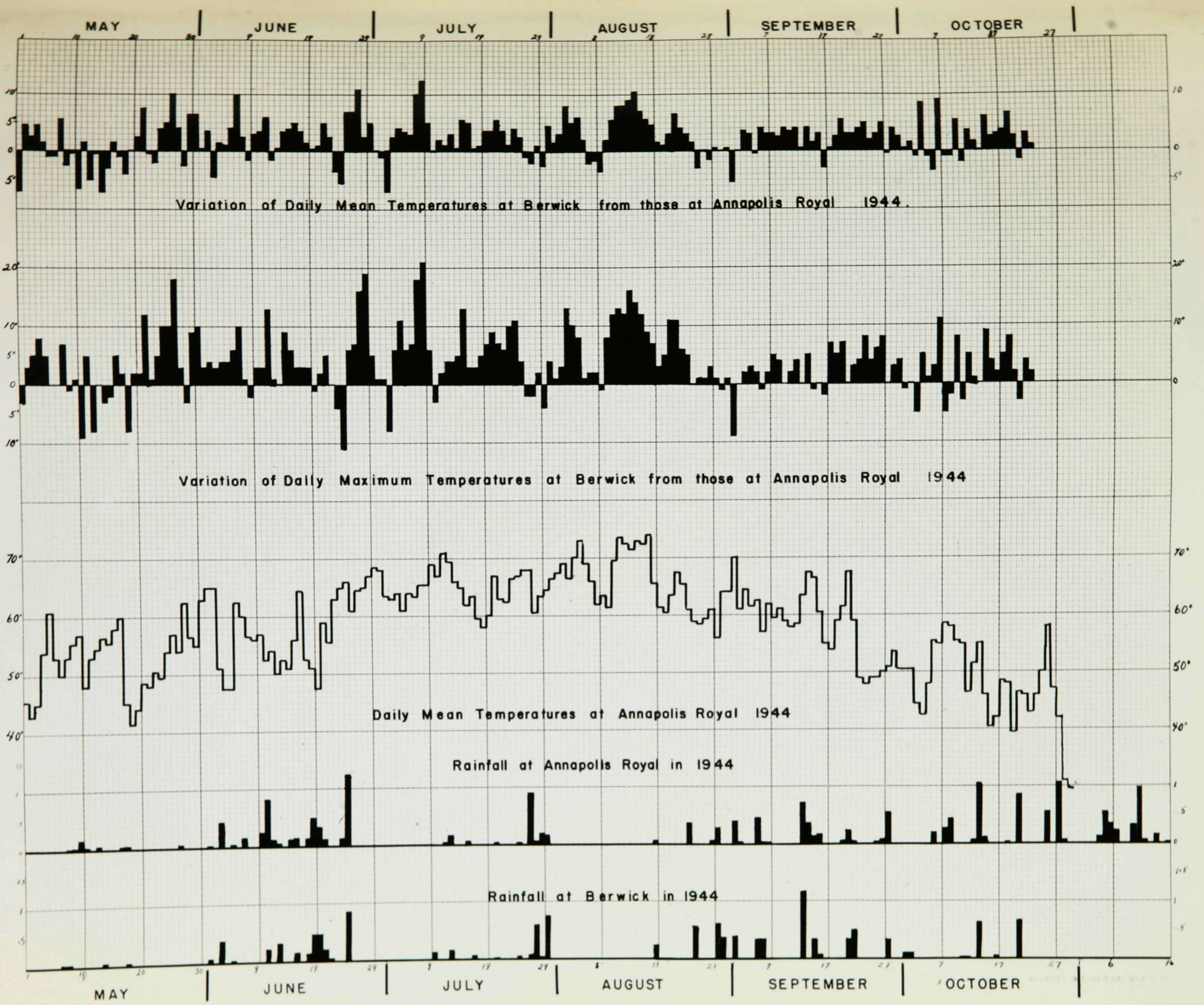

GRAPHS OF DAILY MEAN TEMPERATURES AT ANNAPOLIS ROYAL
APRIL–OCTOBER, FOR THE YEARS 1940–1945
80° 70° 60° 50° 40°
1945
1944
1943
1942
1941
1940
20 30 10 20 30 9 19 29 9 19 29 8 18 28 7 17 27 7 17 27
APRIL MAY JUNE JULY AUGUST SEPT. OCT.

Fig. 9.



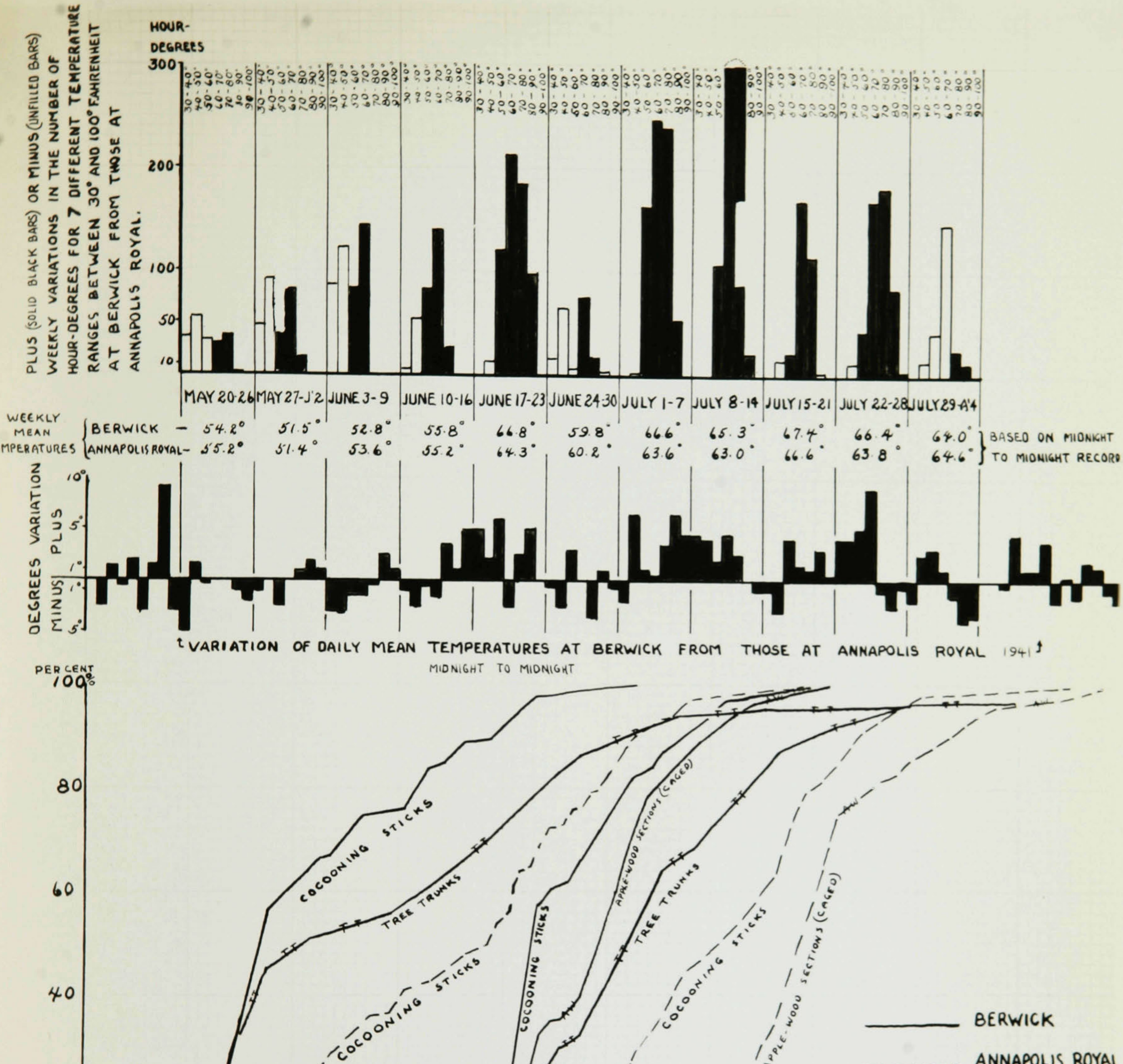
MEAN TEMPERATURE VARIATIONS BETWEEN ANNAPOLIS ROYAL, BERWICK, AND KENTVILLE IN 1940 AND 1941 FOR MAY-SEPTEMBER TOGETHER WITH PRECIPITATION RECORDS AT ANNAPOLIS ROYAL.

Fig. 10.



MAY
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
Variation of Daily Mean Temperatures at Berwick from those at Annapolis Royal 1944.
Variation of Daily Maximum Temperatures at Berwick from those at Annapolis Royal 1944
Daily Mean Temperatures at Annapolis Royal 1944
Rainfall at Annapolis Royal in 1944
Rainfall at Berwick in 1944
MAY
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER

Fig. 11.



PUPATION AND MOTH EMERGENCE COMPARED FOR CAGED COCOONING STICKS, BARK OF CAGED APPLE-WOOD SECTIONS AND TREE TRUNKS (NORMAL CONDITIONS) AT BERWICK, AS WELL AS FOR CAGED MATERIAL AT ANNAPOLIS ROYAL. 1941.

Fig. 12.

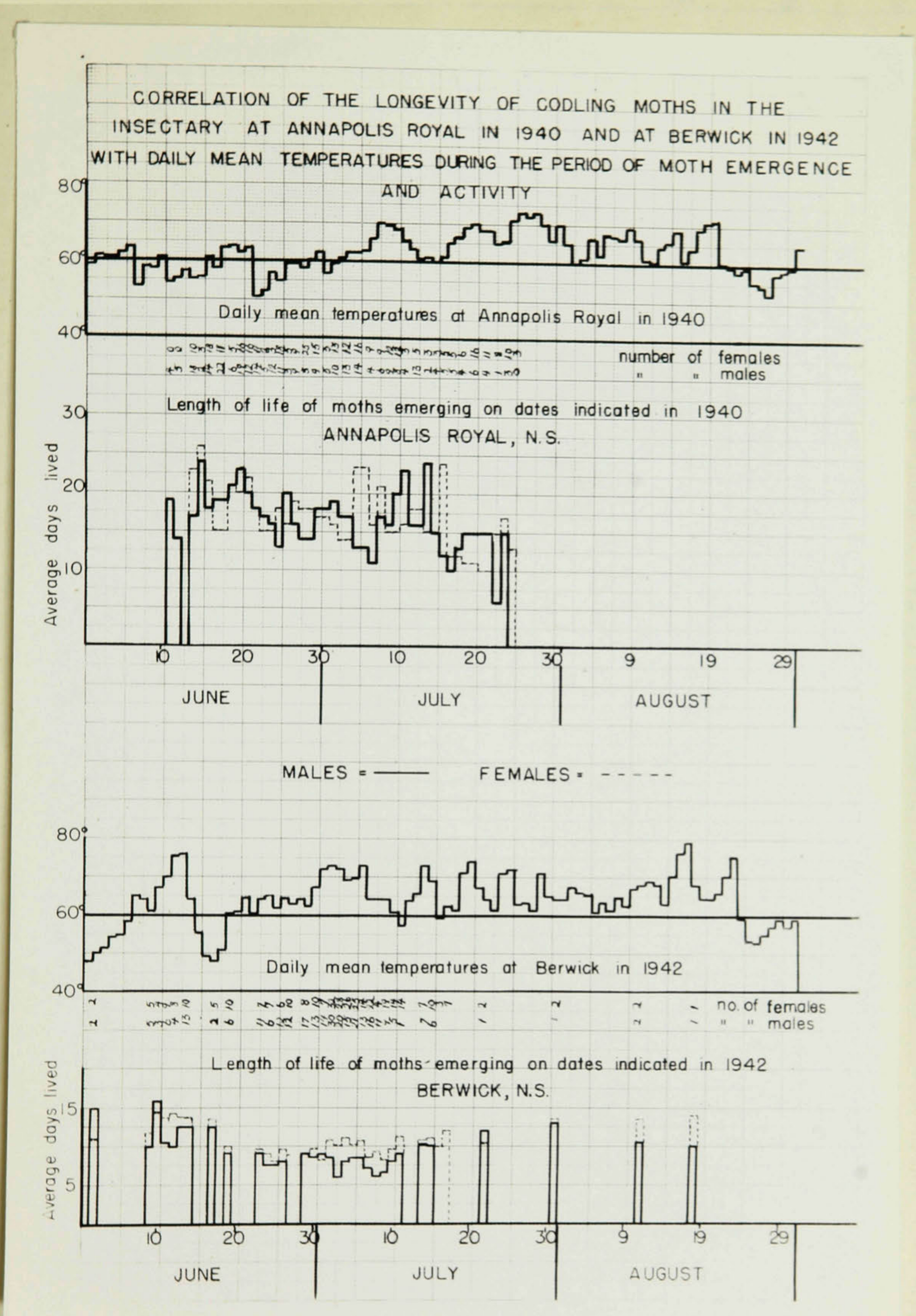

CORRELATION OF THE LONGEVITY OF CODLING MOTHS IN THE INSECTARY AT ANNAPOLIS ROYAL IN 1940 AND AT BERWICK IN 1942 WITH DAILY MEAN TEMPERATURES DURING THE PERIOD OF MOTH EMERGENCE AND ACTIVITY
80°
60°
40°
Daily mean temperatures at Annapolis Royal in 1940
number of females
" " males
Length of life of moths emerging on dates indicated in 1940
ANNAPOLIS ROYAL, N.S.
Average days lived
30
20
10
10 20 30 10 20 30 9 19 29
JUNE
JULY
AUGUST
MALES = ———
FEMALES = - - - - -
80°
60°
40°
Daily mean temperatures at Berwick in 1942
no. of females
" " males
Length of life of moths emerging on dates indicated in 1942
BERWICK, N.S.
Average days lived
15
5
10 20 30 10 20 30 9 19 29
JUNE
JULY
AUGUST

Fig. 13.

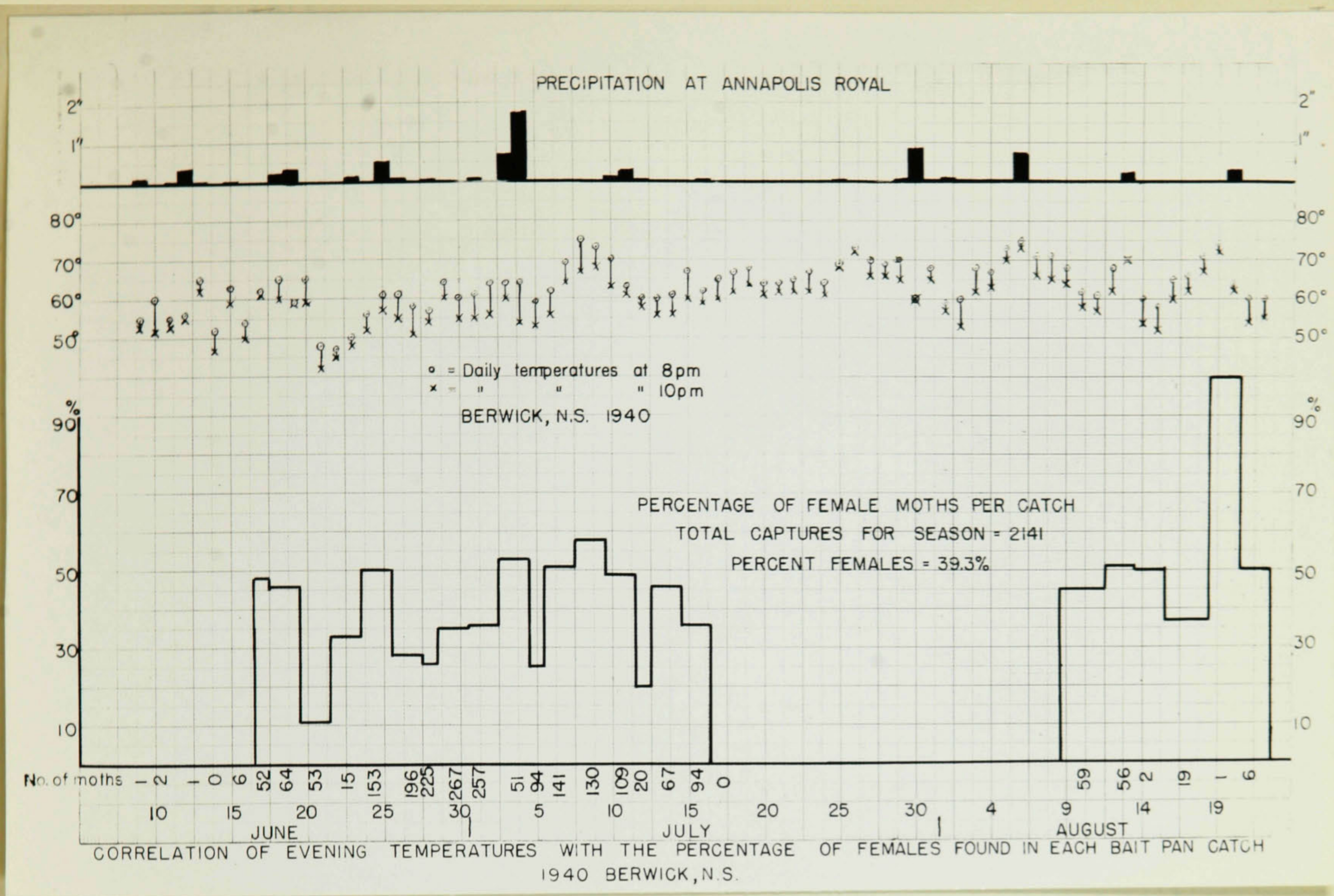
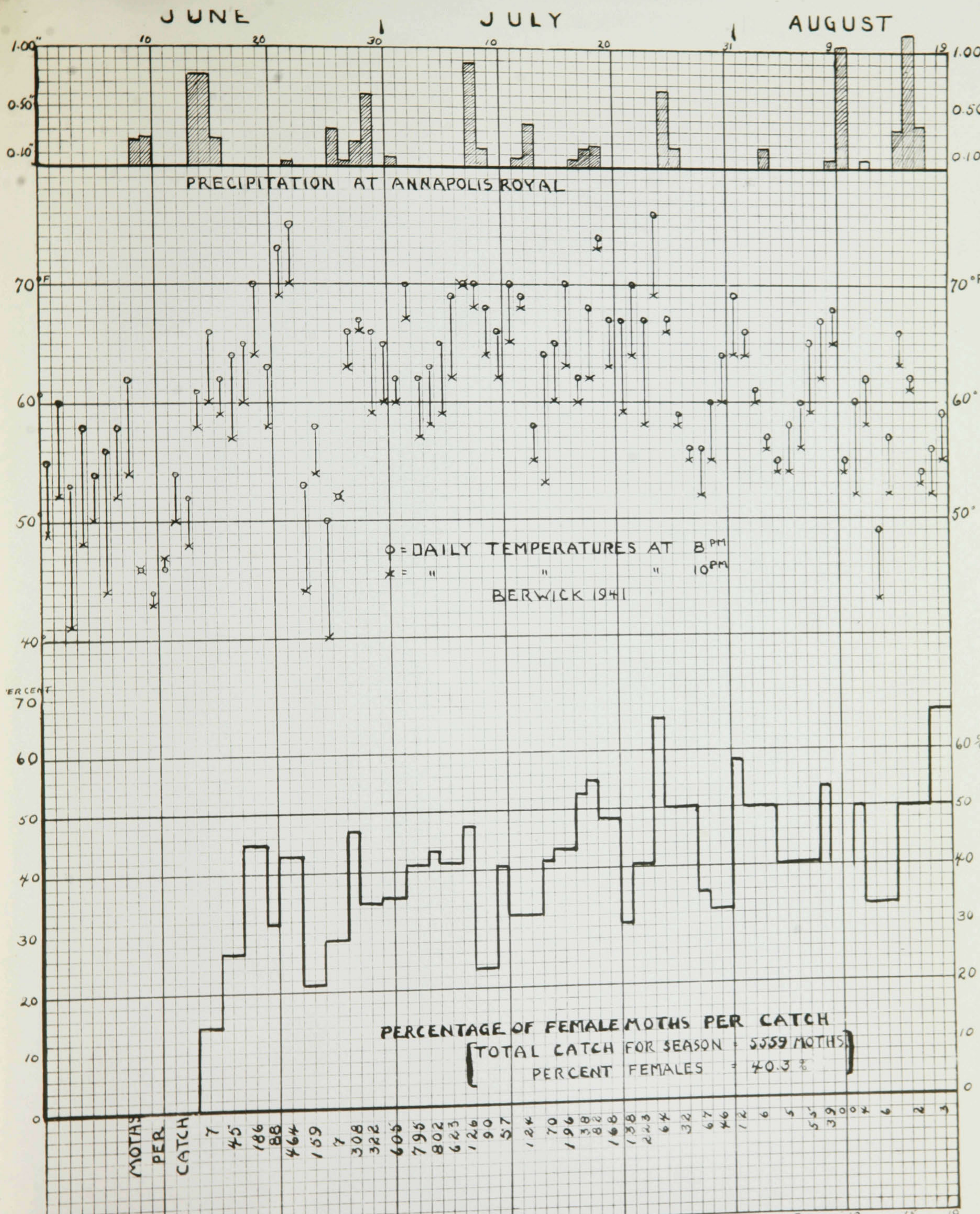

PRECIPITATION AT ANNAPOLIS ROYAL
° = Daily temperatures at 8pm
x = " " " 10pm
BERWICK, N.S. 1940
PERCENTAGE OF FEMALE MOTHS PER CATCH
TOTAL CAPTURES FOR SEASON = 2141
PERCENT FEMALES = 39.3%
No. of moths
JUNE
JULY
AUGUST
CORRELATION OF EVENING TEMPERATURES WITH THE PERCENTAGE OF FEMALES FOUND IN EACH BAIT PAN CATCH
1940 BERWICK, N.S.

Fig. 14.



CORRELATION OF EVENING TEMPERATURES WITH THE PERCENTAGE OF FEMALES FOUND IN EACH BAIT PAN CATCH. BERWICK NS 1941

Fig. 15.

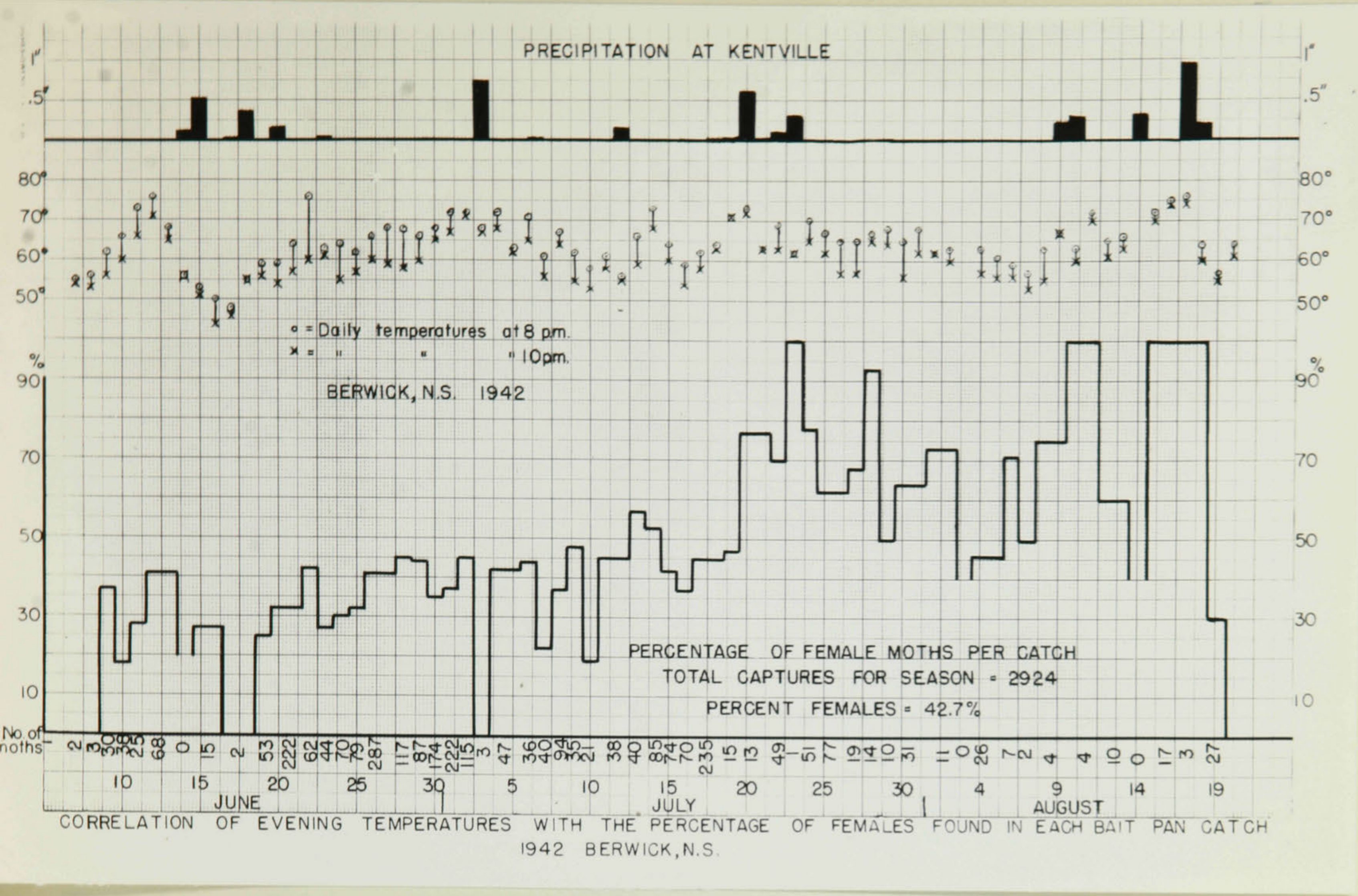

PRECIPITATION AT KENTVILLE
° = Daily temperatures at 8 p.m.
x = " " " 10pm.
BERWICK, N.S. 1942
PERCENTAGE OF FEMALE MOTHS PER CATCH
TOTAL CAPTURES FOR SEASON = 2924
PERCENT FEMALES = 42.7%
No. of moths
JUNE
JULY
AUGUST
CORRELATION OF EVENING TEMPERATURES WITH THE PERCENTAGE OF FEMALES FOUND IN EACH BAIT PAN CATCH
1942 BERWICK, N.S.

Fig. 16.

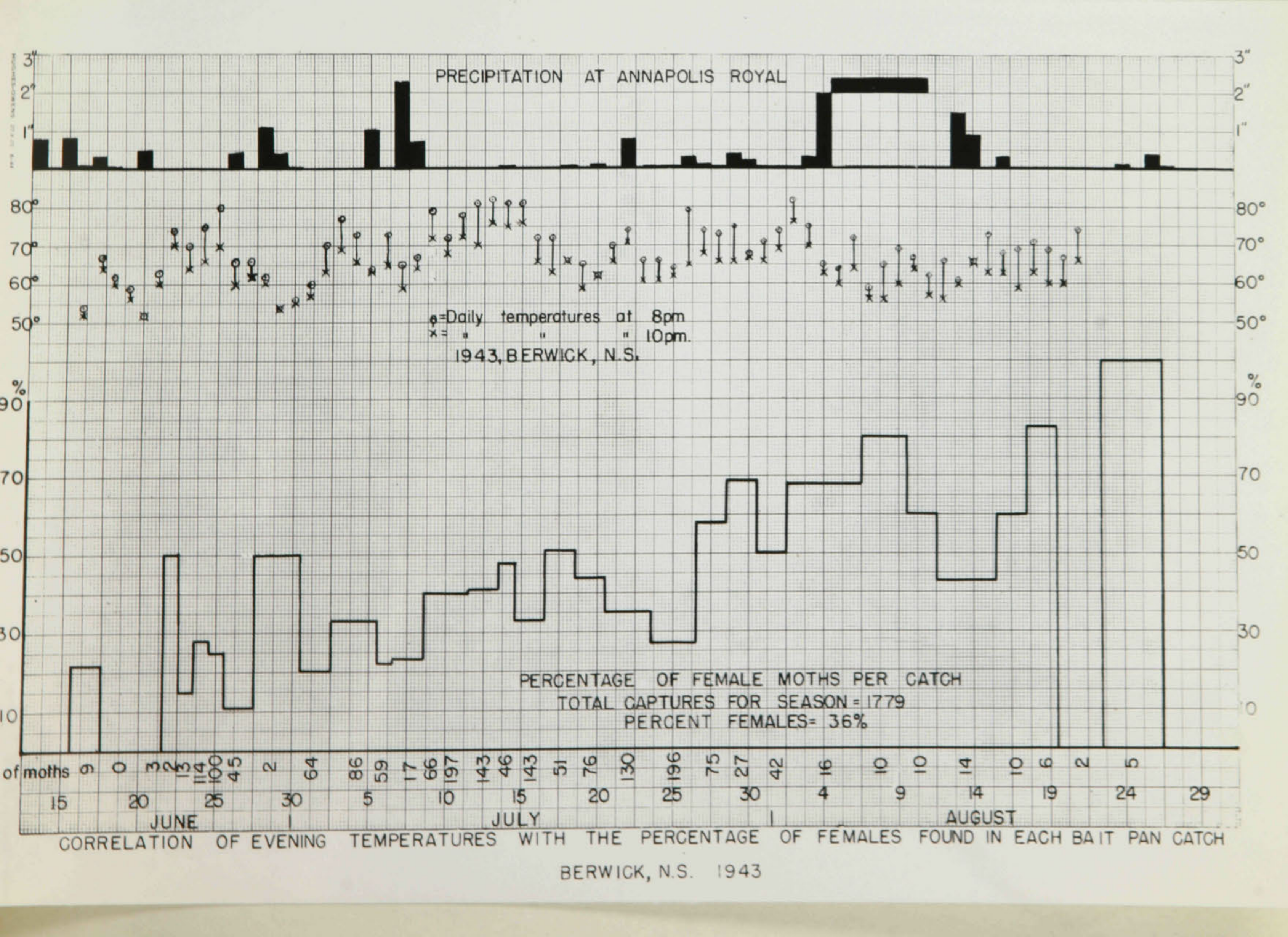
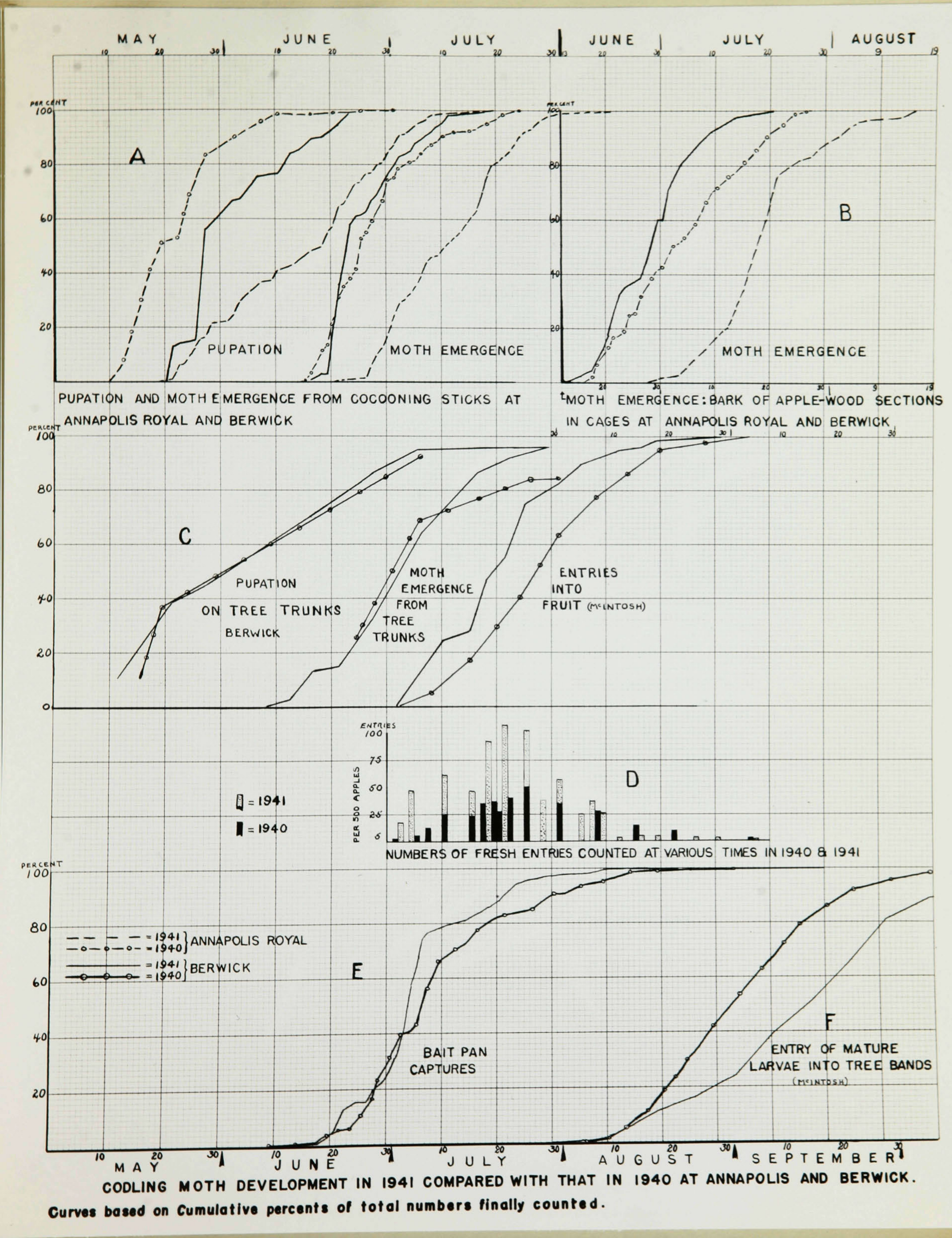
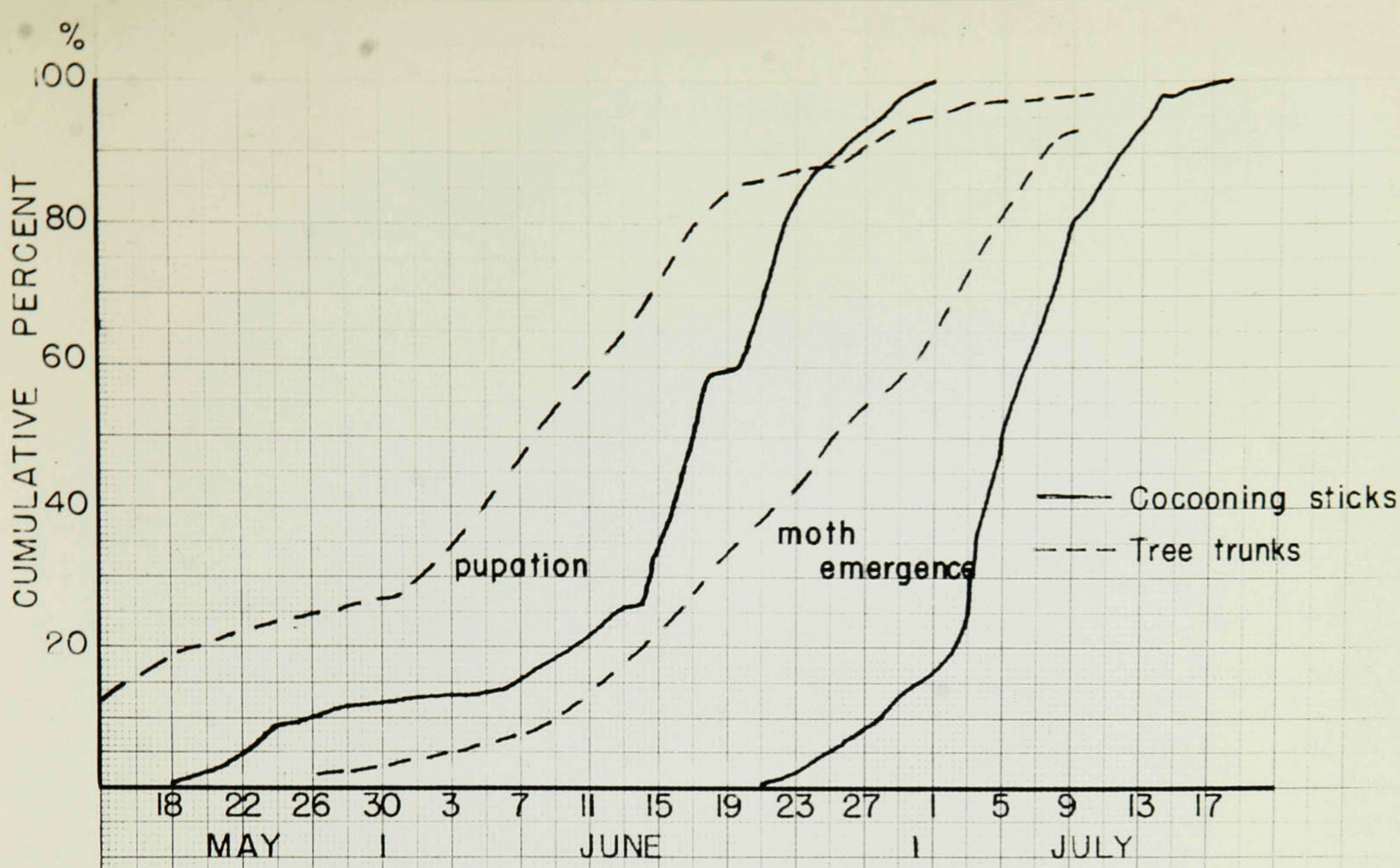

PRECIPITATION AT ANNAPOLIS ROYAL
° = Daily temperatures at 8pm
x = " " " 10pm.
1943, BERWICK, N.S.
PERCENTAGE OF FEMALE MOTHS PER CATCH
TOTAL CAPTURES FOR SEASON = 1779
PERCENT FEMALES = 36%
of moths
JUNE
JULY
AUGUST
CORRELATION OF EVENING TEMPERATURES WITH THE PERCENTAGE OF FEMALES FOUND IN EACH BAIT PAN CATCH
BERWICK, N.S. 1943

Fig. 17.



MAY JUNE JULY JUNE JULY AUGUST
A
PUPATION
MOTH EMERGENCE
B
MOTH EMERGENCE
PUPATION AND MOTH EMERGENCE FROM COCOONING STICKS AT ANNAPOLIS ROYAL AND BERWICK
MOTH EMERGENCE: BARK OF APPLE-WOOD SECTIONS IN CAGES AT ANNAPOLIS ROYAL AND BERWICK
C
PUPATION ON TREE TRUNKS BERWICK
MOTH EMERGENCE FROM TREE TRUNKS
ENTRIES INTO FRUIT (McINTOSH)
D
= 1941
= 1940
ENTRIES PER 500 APPLES
NUMBERS OF FRESH ENTRIES COUNTED AT VARIOUS TIMES IN 1940 & 1941
E
= 1941 } ANNAPOLIS ROYAL
= 1940
= 1941 } BERWICK
= 1940
BAIT PAN CAPTURES
F
ENTRY OF MATURE LARVAE INTO TREE BANDS (McINTOSH)
MAY JUNE JULY AUGUST SEPTEMBER
CODLING MOTH DEVELOPMENT IN 1941 COMPARED WITH THAT IN 1940 AT ANNAPOLIS AND BERWICK.
Curves based on Cumulative percents of total numbers finally counted.

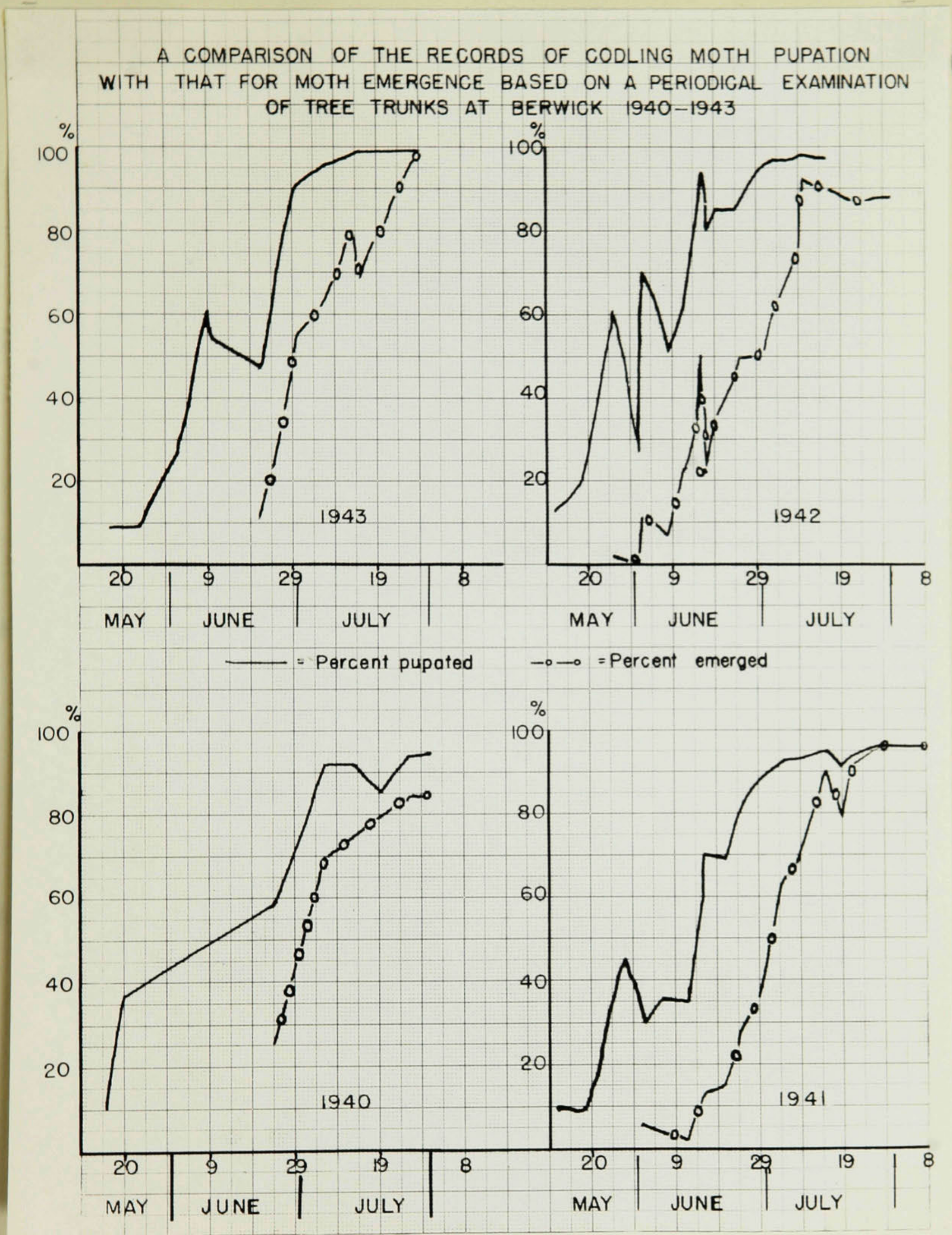
Fig. 18.



Comparison of pupation and moth emergence of codling moth material; (1) For cocooning sticks in a Cutright cage (2) Results of periodical examination of tree trunks.

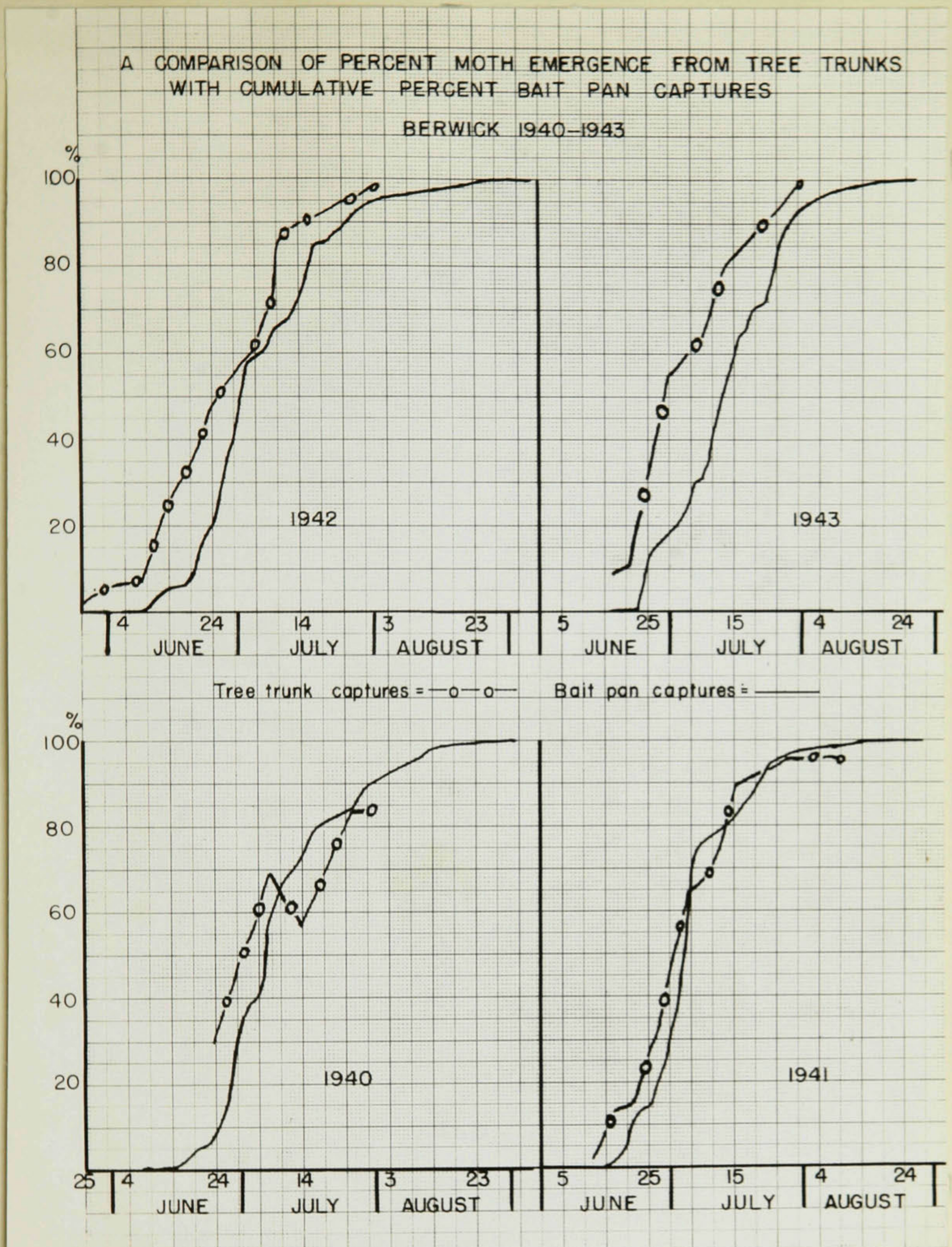
BERWICK 1942

Fig. 19.



A COMPARISON OF THE RECORDS OF CODLING MOTH PUPATION WITH THAT FOR MOTH EMERGENCE BASED ON A PERIODICAL EXAMINATION OF TREE TRUNKS AT BERWICK 1940-1943
%
100
80
60
40
20
1943
1942
1940
1941
20
9
29
19
8
MAY
JUNE
JULY
= Percent pupated
= Percent emerged

Fig. 20.



A COMPARISON OF PERCENT MOTH EMERGENCE FROM TREE TRUNKS
WITH CUMULATIVE PERCENT BAIT PAN CAPTURES
BERWICK 1940-1943
%
100
80
60
40
20
1942
1943
4
24
14
3
23
JUNE
JULY
AUGUST
5
25
15
4
24
Tree trunk captures = —o—o—
Bait pan captures = ———
1940
1941

Fig. 22.

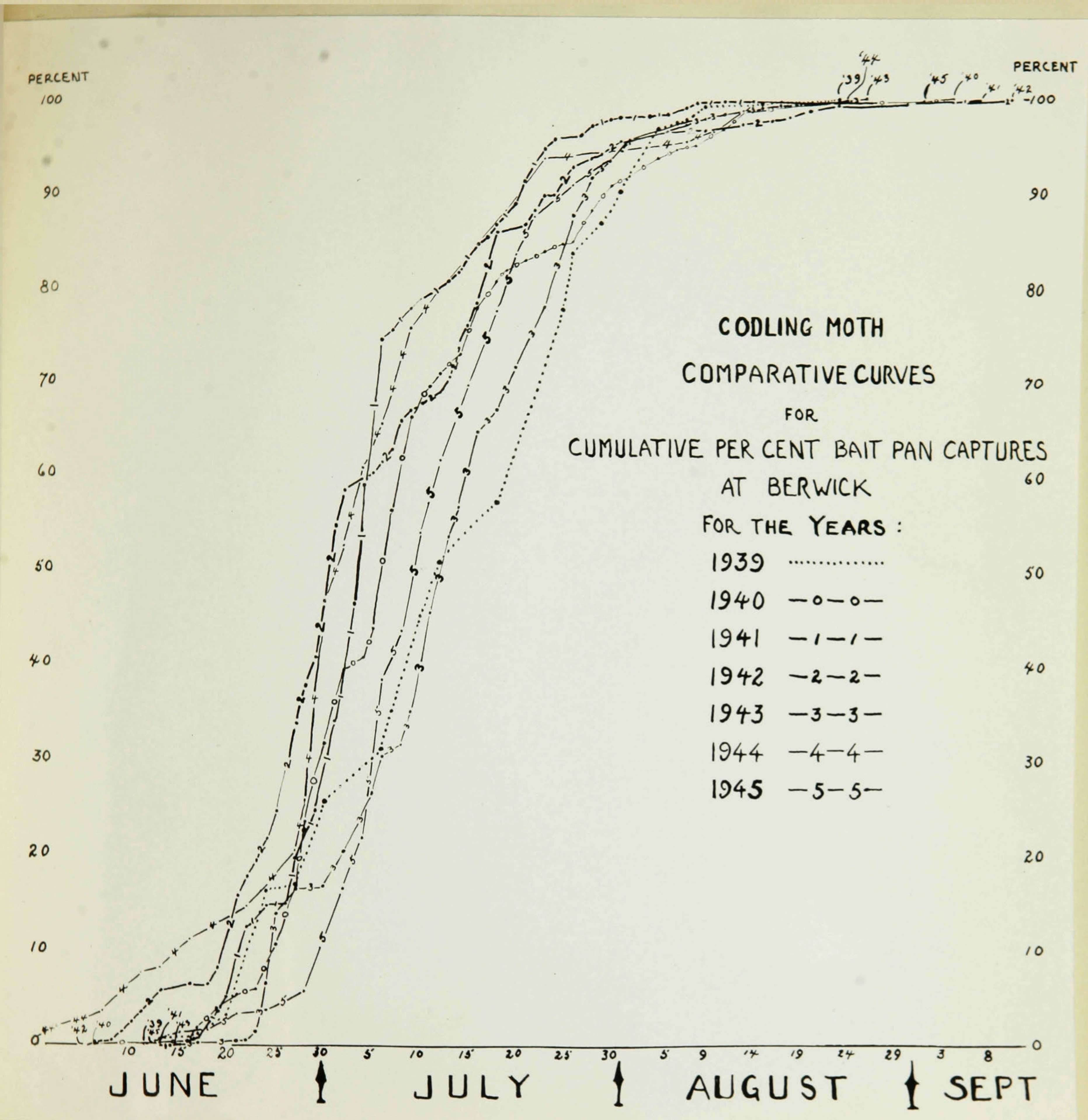
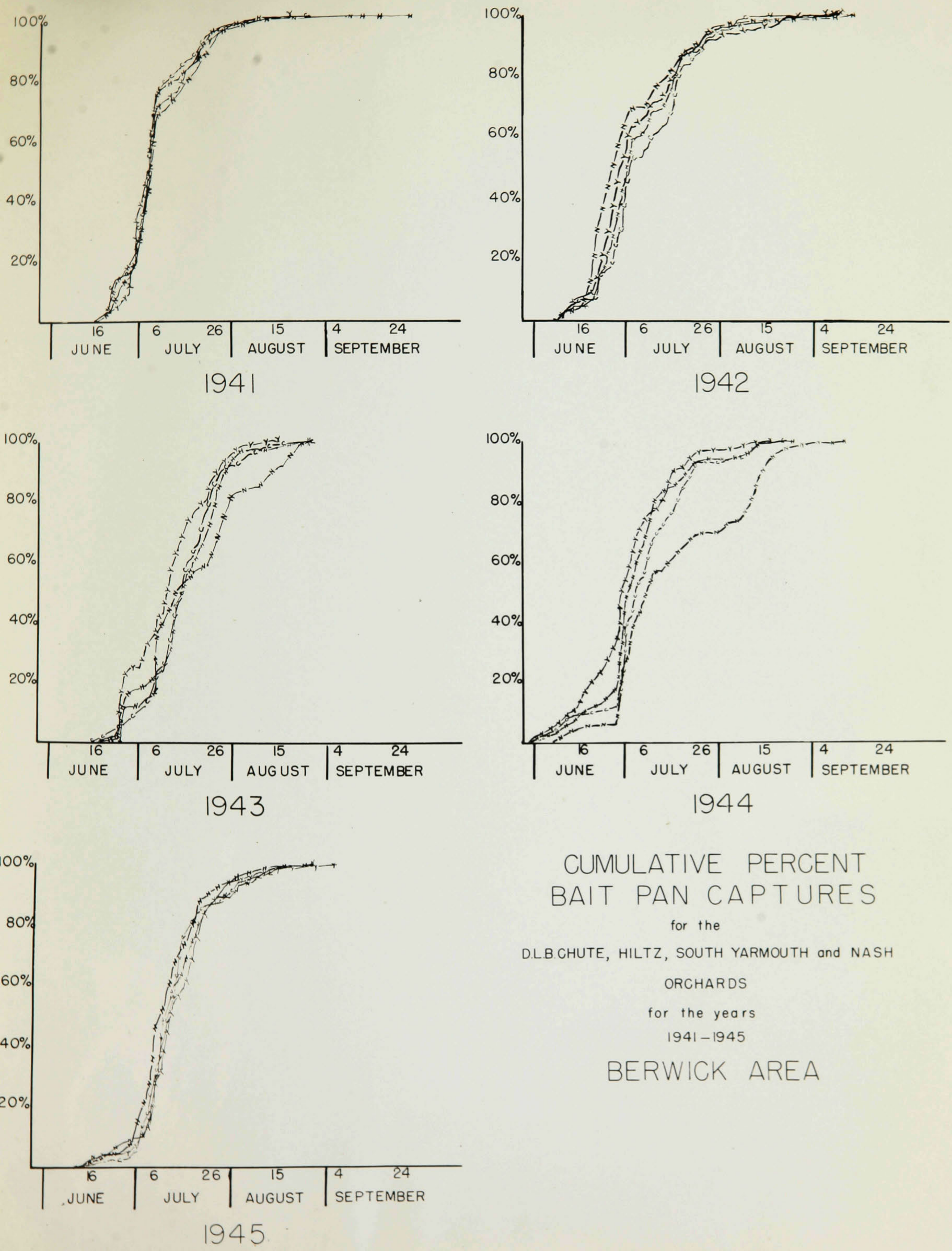

CODLING MOTH
COMPARATIVE CURVES
FOR
CUMULATIVE PER CENT BAIT PAN CAPTURES
AT BERWICK
FOR THE YEARS :
1939 ....
1940 —o—o—
1941 —1—1—
1942 —2—2—
1943 —3—3—
1944 —4—4—
1945 —5—5—
PERCENT
PERCENT
JUNE
JULY
AUGUST
SEPT

Fig. 23.



CUMULATIVE PERCENT
BAIT PAN CAPTURES
for the
D.L.B. CHUTE, HILTZ, SOUTH YARMOUTH and NASH
ORCHARDS
for the years
1941 – 1945
BERWICK AREA

Fig. 24.

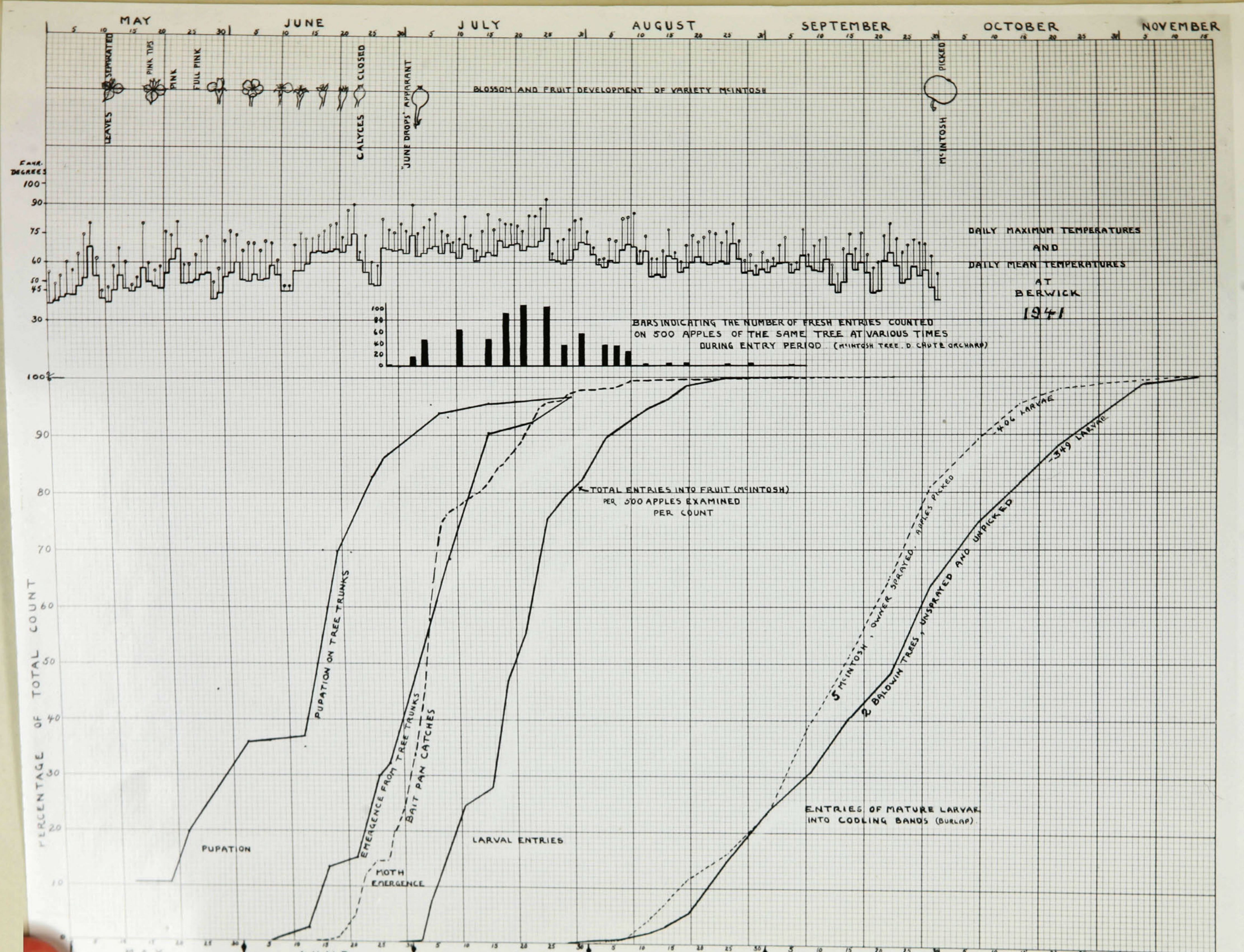


FIG. CODLING MOTH DEVELOPMENT IN THE HILTZ ORCHARD AT BERWICK AS INDICATED BY CUMULATIVE PERCENTAGES OF: PUPATION AND MOTH EMERGENCE FROM TREE TRUNKS, BAIT PAN CAPTURES, LARVAL ENTRIES INTO FRUIT ON TREES, AND ENTRIES OF MATURE LARVAE INTO CODLING BANDS.

Fig. 26.

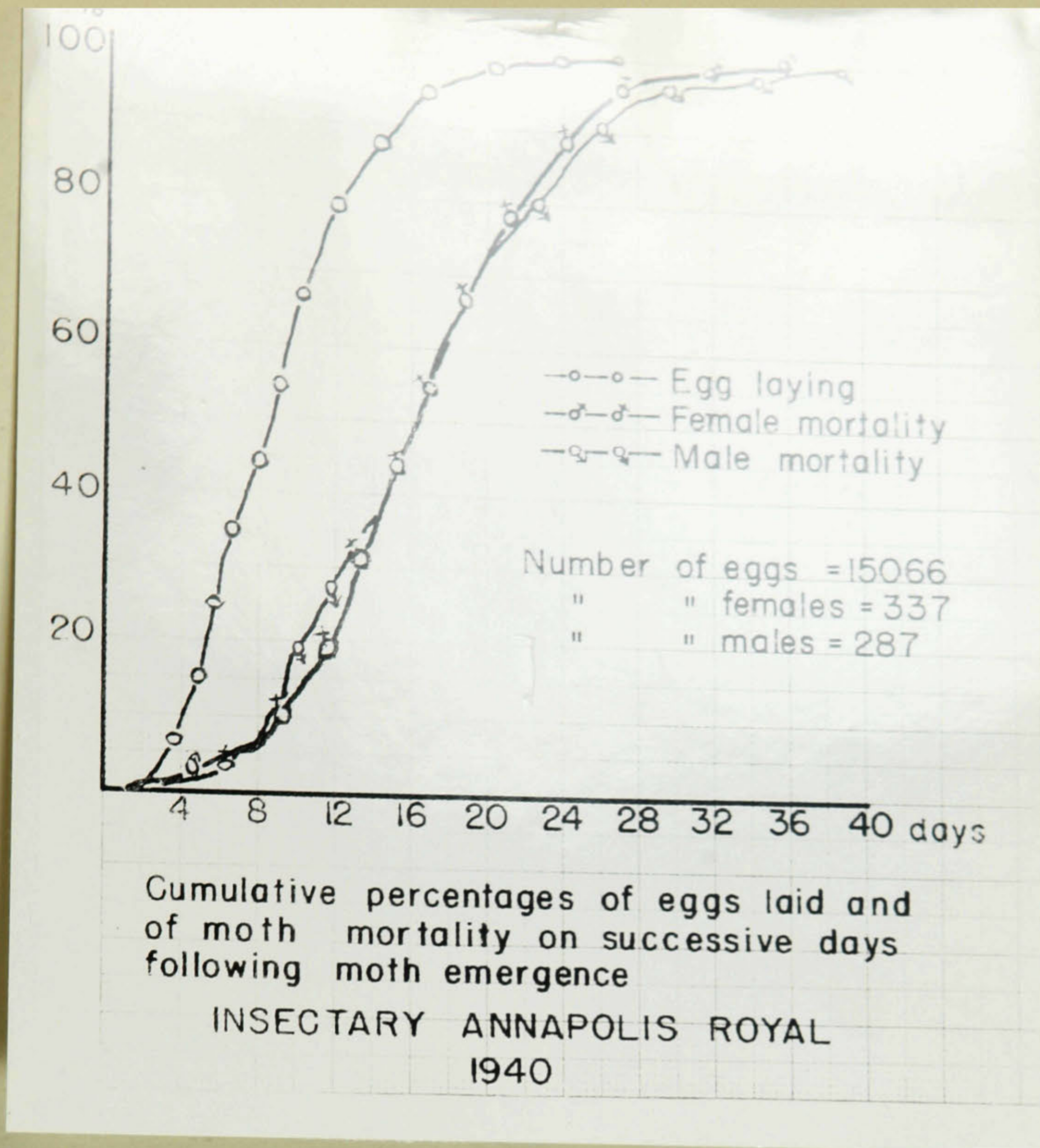

%
100
80
60
40
20
4 8 12 16 20 24 28 32 36 40 days
Egg laying
Female mortality
Male mortality
Number of eggs = 15066
" " females = 337
" " males = 287
Cumulative percentages of eggs laid and of moth mortality on successive days following moth emergence
INSECTARY ANNAPOLIS ROYAL
1940

Fig. 27.

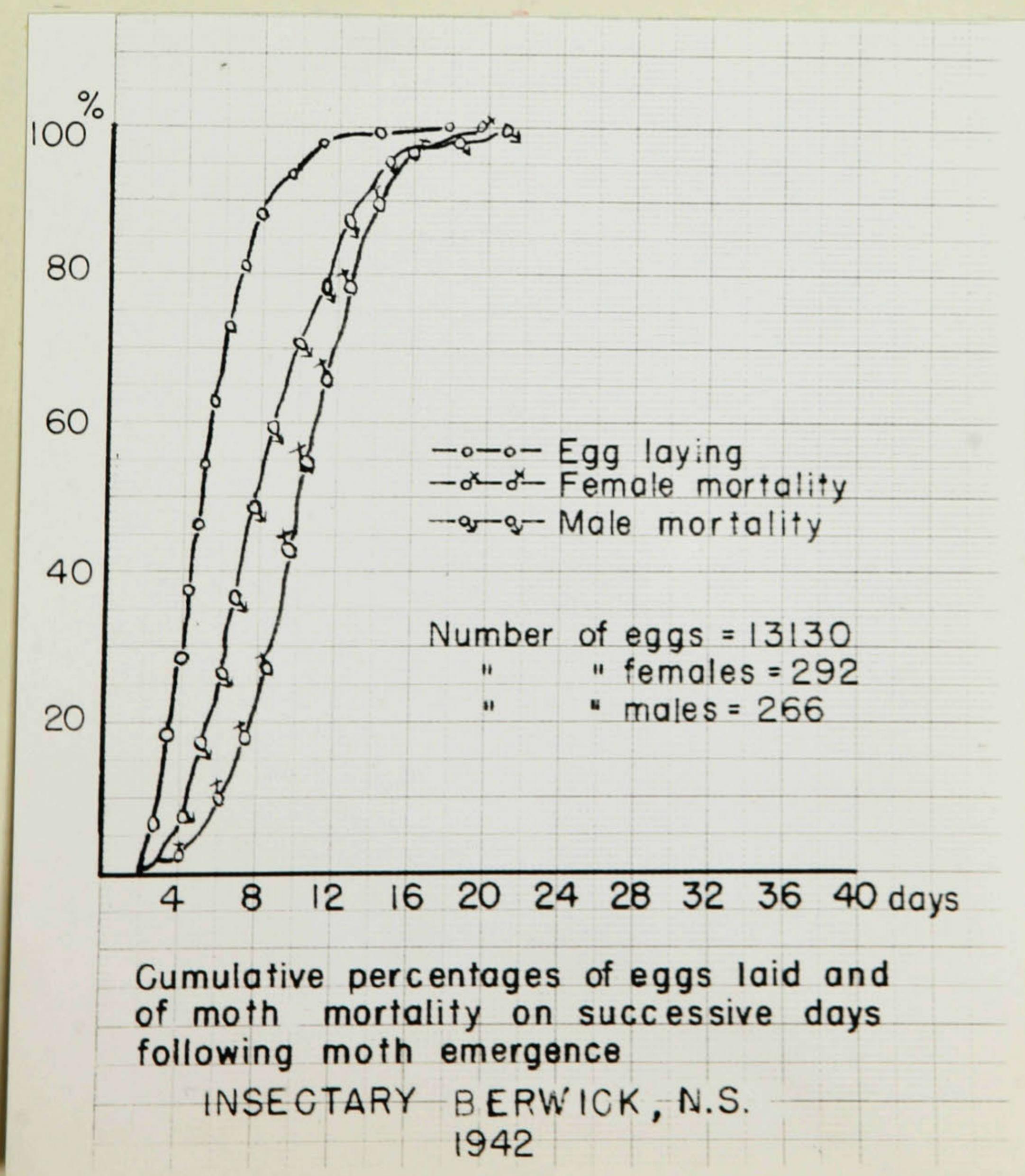

%
100
80
60
40
20
4 8 12 16 20 24 28 32 36 40 days
Egg laying
Female mortality
Male mortality
Number of eggs = 13130
" " females = 292
" " males = 266
Cumulative percentages of eggs laid and of moth mortality on successive days following moth emergence
INSECTARY BERWICK, N.S.
1942

Fig. 28.

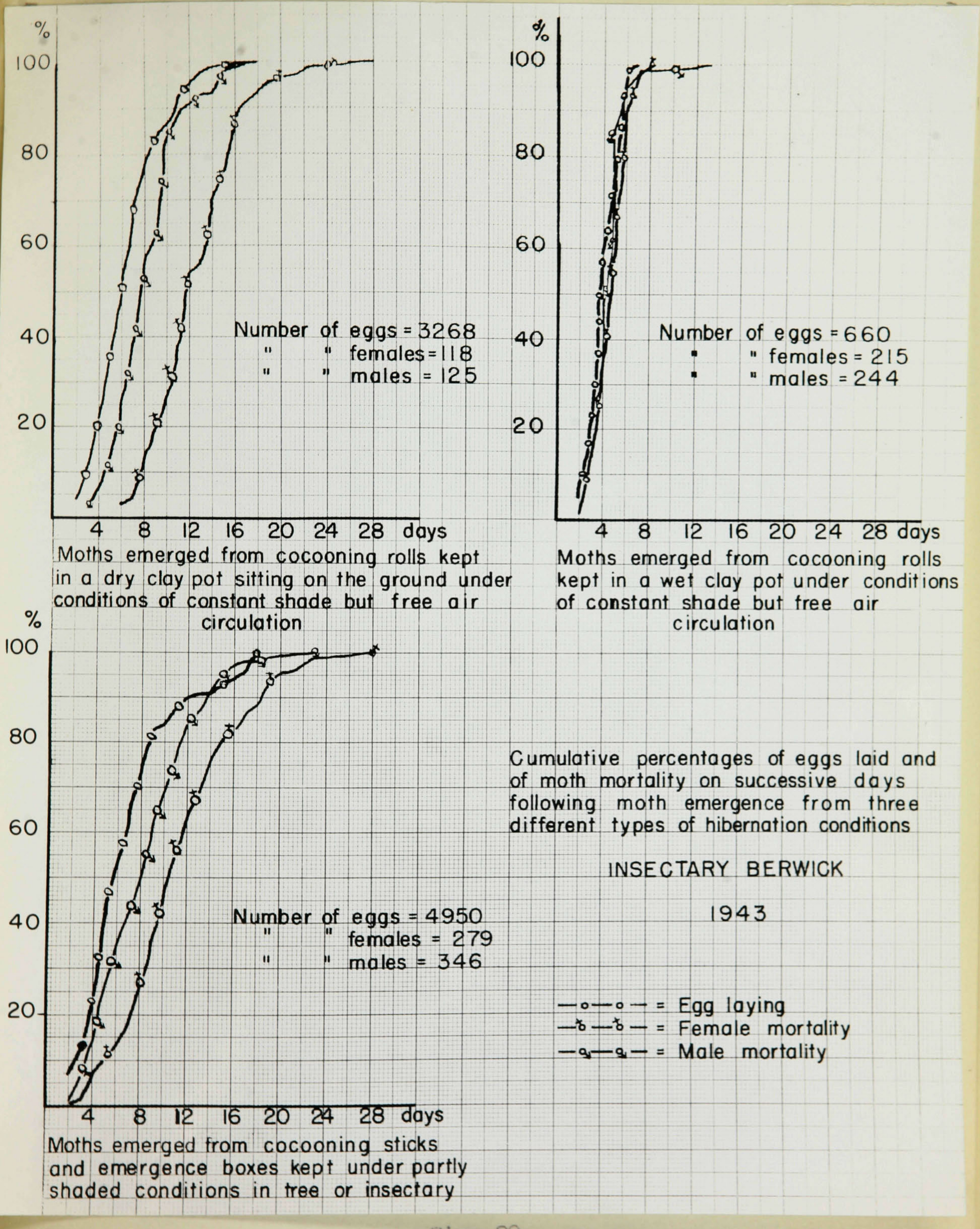
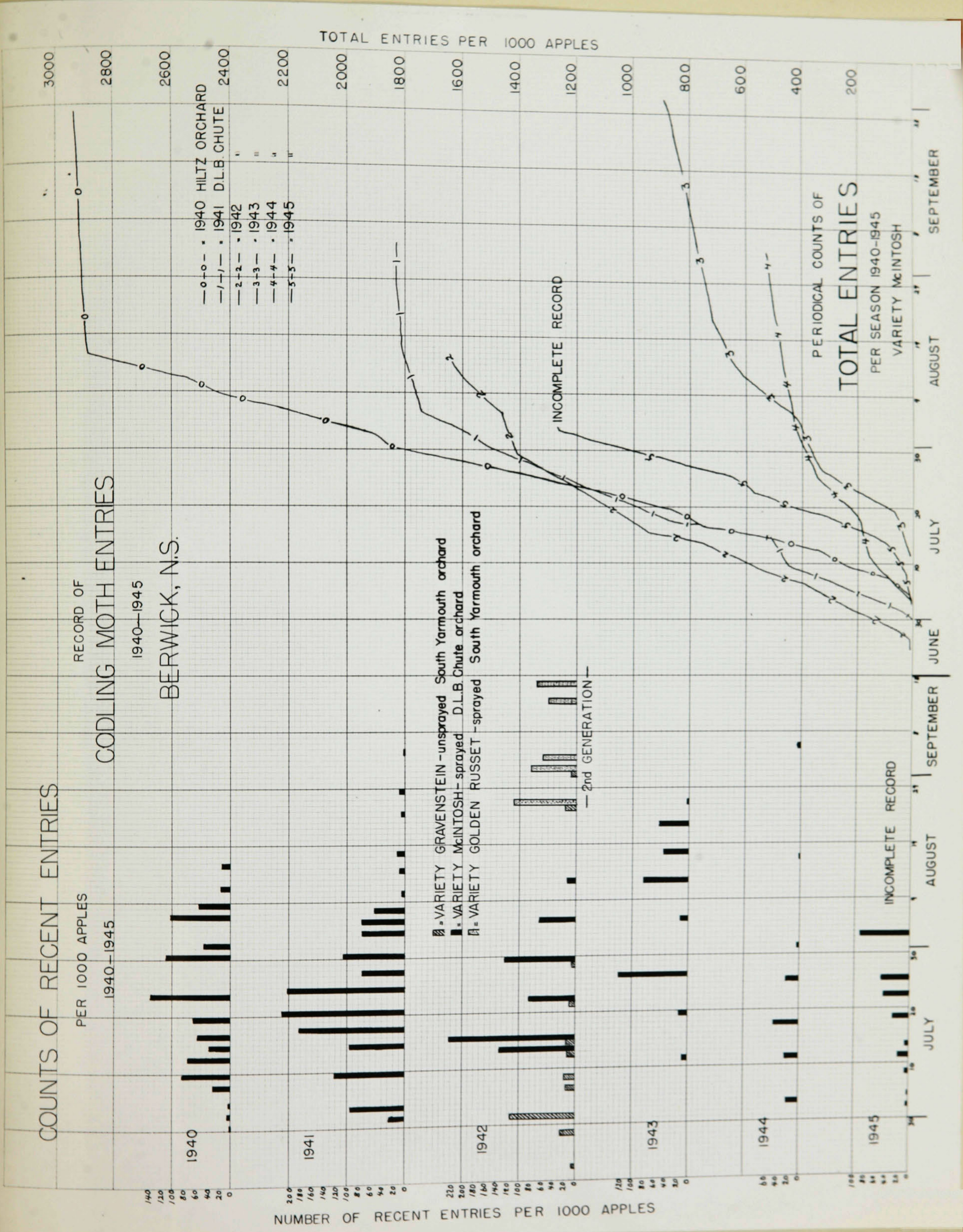
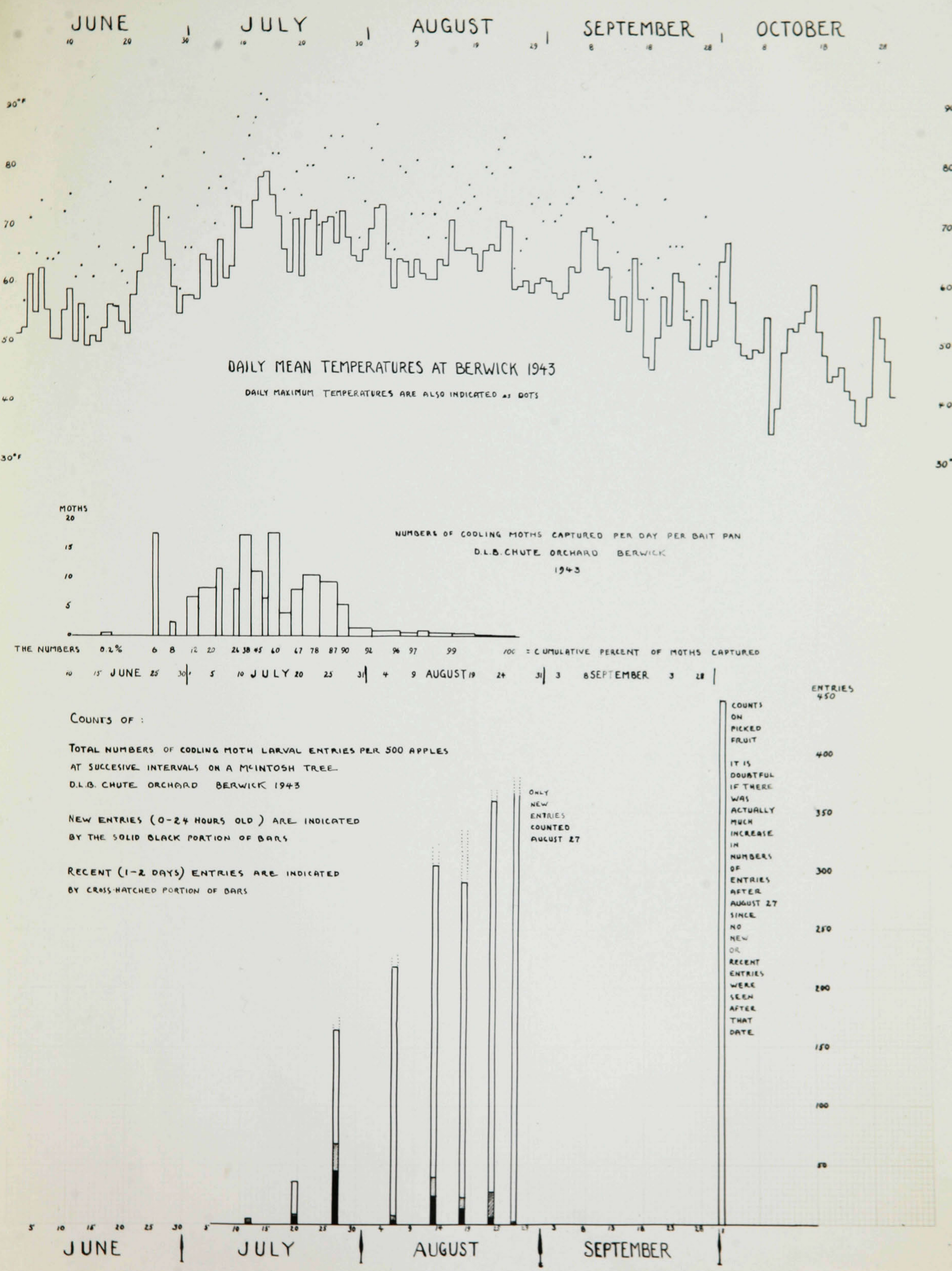

%
100
80
60
40
20
4 8 12 16 20 24 28 days
Number of eggs = 3268
" " females = 118
" " males = 125
Moths emerged from cocooning rolls kept in a dry clay pot sitting on the ground under conditions of constant shade but free air circulation
%
100
80
60
40
20
4 8 12 16 20 24 28 days
Number of eggs = 660
" " females = 215
" " males = 244
Moths emerged from cocooning rolls kept in a wet clay pot under conditions of constant shade but free air circulation
%
100
80
60
40
20
4 8 12 16 20 24 28 days
Number of eggs = 4950
" " females = 279
" " males = 346
Moths emerged from cocooning sticks and emergence boxes kept under partly shaded conditions in tree or insectary
Cumulative percentages of eggs laid and of moth mortality on successive days following moth emergence from three different types of hibernation conditions
INSECTARY BERWICK
1943
= Egg laying
= Female mortality
= Male mortality

Fig. 29.



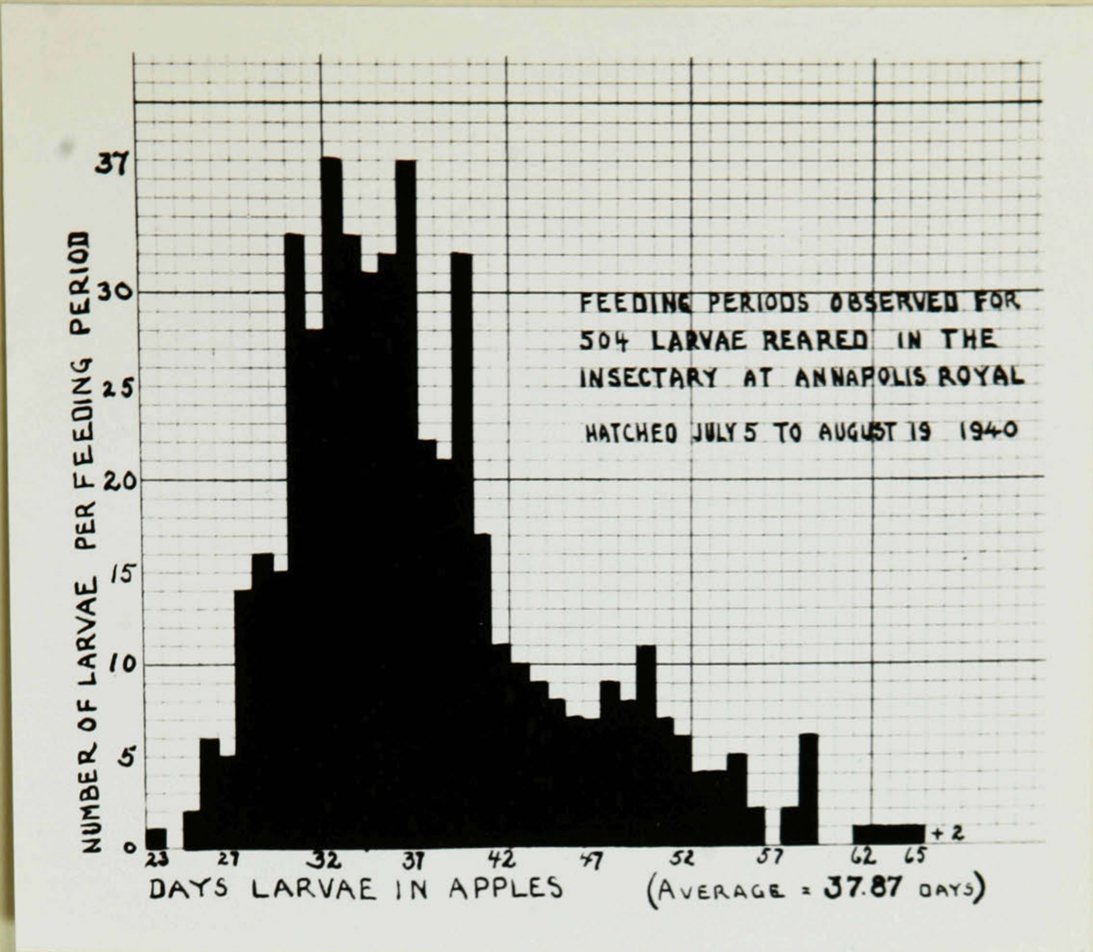
COUNTS OF RECENT ENTRIES
PER 1000 APPLES
1940-1945
RECORD OF
CODLING MOTH ENTRIES
1940—1945
BERWICK, N.S.
TOTAL ENTRIES PER 1000 APPLES
NUMBER OF RECENT ENTRIES PER 1000 APPLES
—0-0— = 1940 HILTZ ORCHARD
—1-1— = 1941 D.L.B. CHUTE
—2-2— = 1942
—3-3— = 1943
—4-4— = 1944
—5-5— = 1945
INCOMPLETE RECORD
PERIODICAL COUNTS OF
TOTAL ENTRIES
PER SEASON 1940-1945
VARIETY McINTOSH
= VARIETY GRAVENSTEIN - unsprayed South Yarmouth orchard
= VARIETY McINTOSH - sprayed D.L.B. Chute orchard
= VARIETY GOLDEN RUSSET - sprayed South Yarmouth orchard
— 2nd GENERATION —
INCOMPLETE RECORD
1940
1941
1942
1943
1944
1945
JUNE
JULY
AUGUST
SEPTEMBER

Fig. 30.



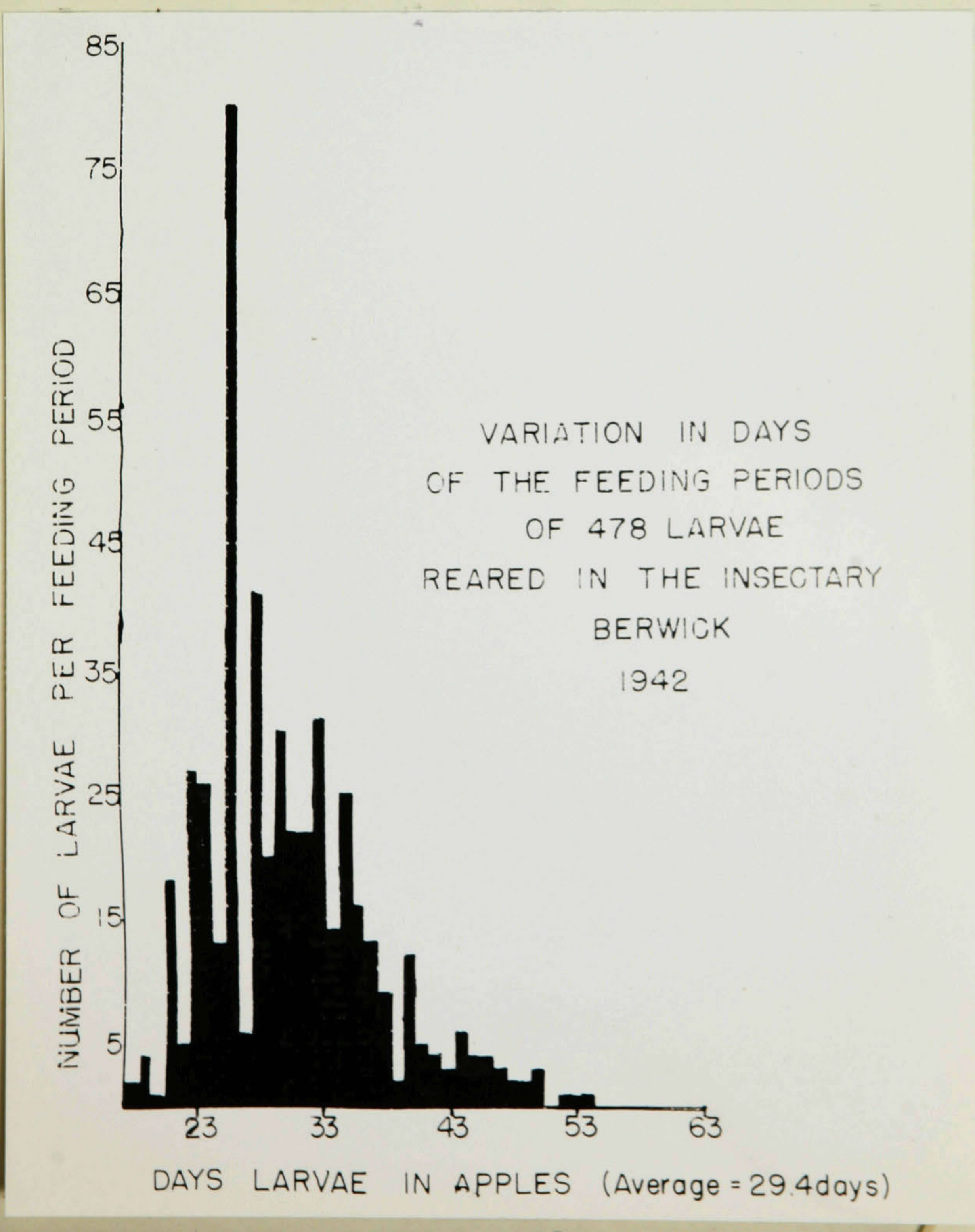
JUNE JULY AUGUST SEPTEMBER OCTOBER
DAILY MEAN TEMPERATURES AT BERWICK 1943
DAILY MAXIMUM TEMPERATURES ARE ALSO INDICATED AS DOTS
MOTHS
NUMBERS OF CODLING MOTHS CAPTURED PER DAY PER BAIT PAN
D.L.B. CHUTE ORCHARD BERWICK
1943
THE NUMBERS = CUMULATIVE PERCENT OF MOTHS CAPTURED
COUNTS OF :
TOTAL NUMBERS OF CODLING MOTH LARVAL ENTRIES PER 500 APPLES
AT SUCCESIVE INTERVALS ON A McINTOSH TREE
D.L.B. CHUTE ORCHARD BERWICK 1943
NEW ENTRIES (0-24 HOURS OLD) ARE INDICATED
BY THE SOLID BLACK PORTION OF BARS
RECENT (1-2 DAYS) ENTRIES ARE INDICATED
BY CROSS-HATCHED PORTION OF BARS
ONLY NEW ENTRIES COUNTED AUGUST 27
COUNTS ON PICKED FRUIT
IT IS DOUBTFUL IF THERE WAS ACTUALLY MUCH INCREASE IN NUMBERS OF ENTRIES AFTER AUGUST 27 SINCE NO NEW OR RECENT ENTRIES WERE SEEN AFTER THAT DATE
ENTRIES

Fig. 31.



NUMBER OF LARVAE PER FEEDING PERIOD
0
5
10
15
20
25
30
37
FEEDING PERIODS OBSERVED FOR 504 LARVAE REARED IN THE INSECTARY AT ANNAPOLIS ROYAL
HATCHED JULY 5 TO AUGUST 19 1940
+2
23
27
32
37
42
47
52
57
62
65
DAYS LARVAE IN APPLES
(AVERAGE = 37.87 DAYS)

Fig. 32.



NUMBER OF LARVAE PER FEEDING PERIOD
5
15
25
35
45
55
65
75
85
VARIATION IN DAYS OF THE FEEDING PERIODS OF 478 LARVAE REARED IN THE INSECTARY BERWICK 1942
23
33
43
53
63
DAYS LARVAE IN APPLES (Average = 29.4days)

Fig. 33.

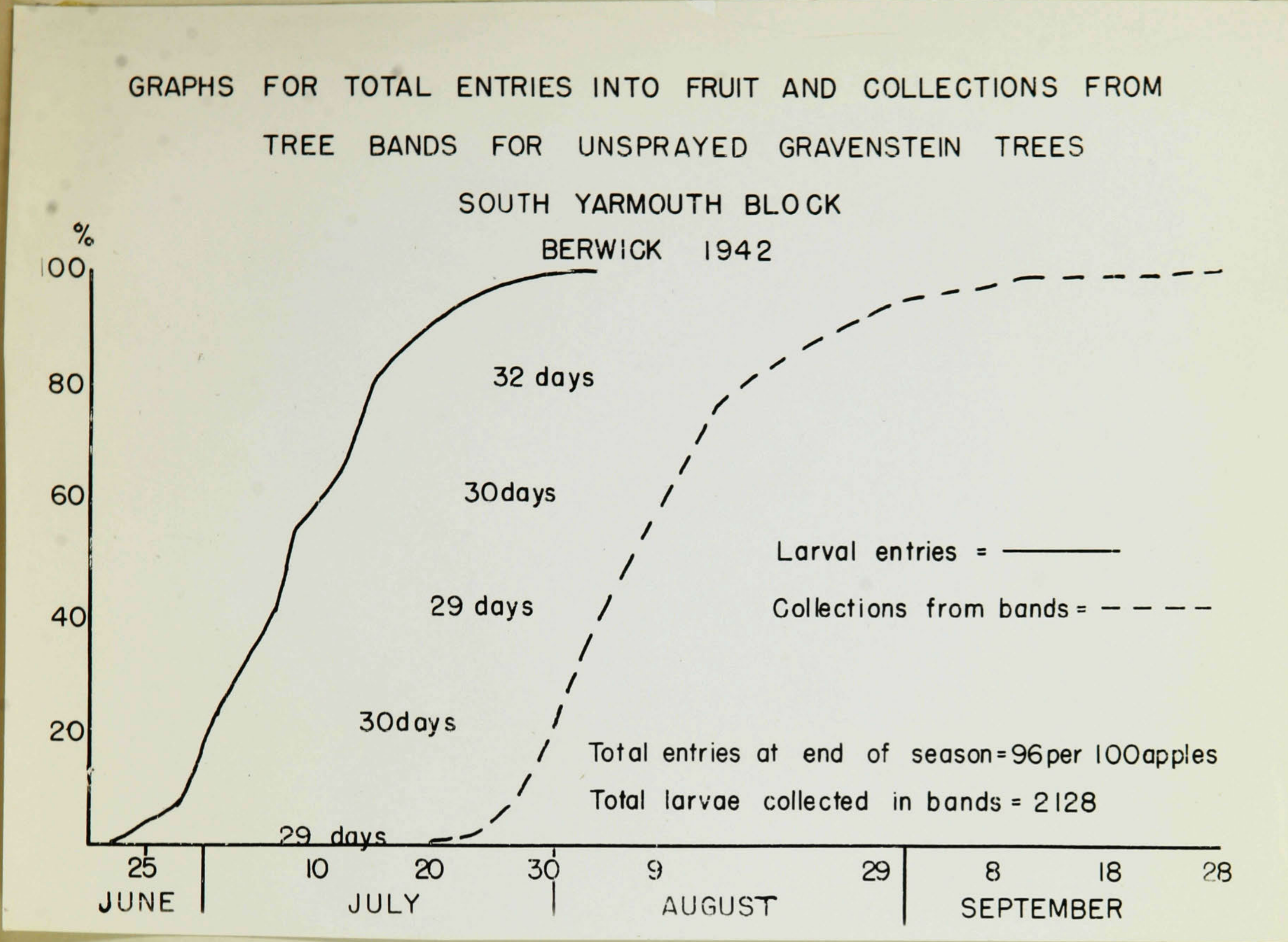

GRAPHS FOR TOTAL ENTRIES INTO FRUIT AND COLLECTIONS FROM
TREE BANDS FOR UNSPRAYED GRAVENSTEIN TREES
SOUTH YARMOUTH BLOCK
BERWICK 1942
%
100
80
60
40
20
32 days
30days
29 days
30days
29 days
Larval entries =
Collections from bands =
Total entries at end of season = 96 per 100 apples
Total larvae collected in bands = 2128
25
JUNE
10
20
30
JULY
9
29
AUGUST
8
18
28
SEPTEMBER

Fig. 34.

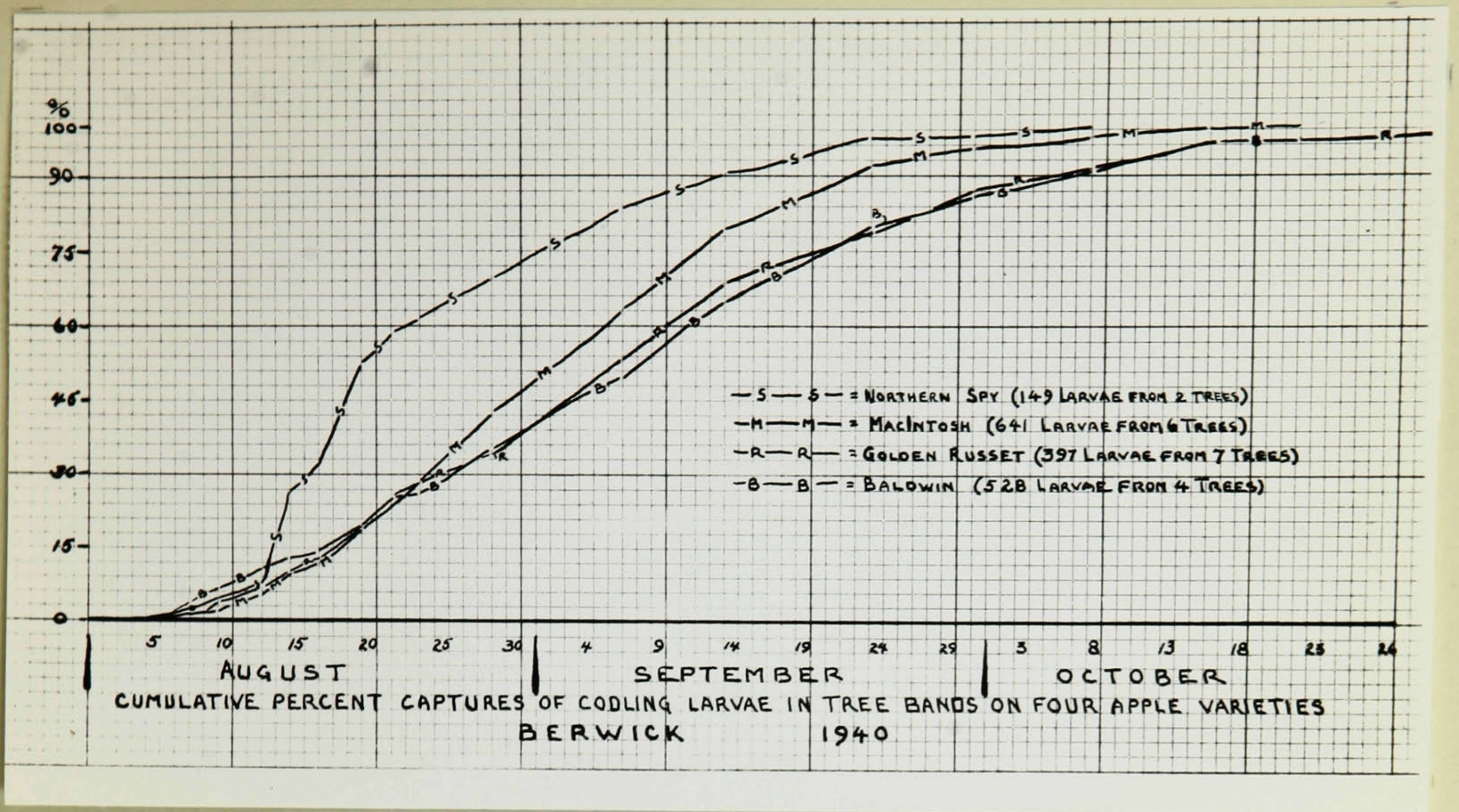

%
100
90
75
60
45
30
15
0
5
10
15
20
25
30
4
9
14
19
24
29
3
8
13
18
23
28
AUGUST
SEPTEMBER
OCTOBER
—S—S— = NORTHERN SPY (149 LARVAE FROM 2 TREES)
—M—M— = MACINTOSH (641 LARVAE FROM 6 TREES)
—R—R— = GOLDEN RUSSET (397 LARVAE FROM 7 TREES)
—B—B— = BALDWIN (528 LARVAE FROM 4 TREES)
CUMULATIVE PERCENT CAPTURES OF CODLING LARVAE IN TREE BANDS ON FOUR APPLE VARIETIES
BERWICK 1940

Fig. 35.

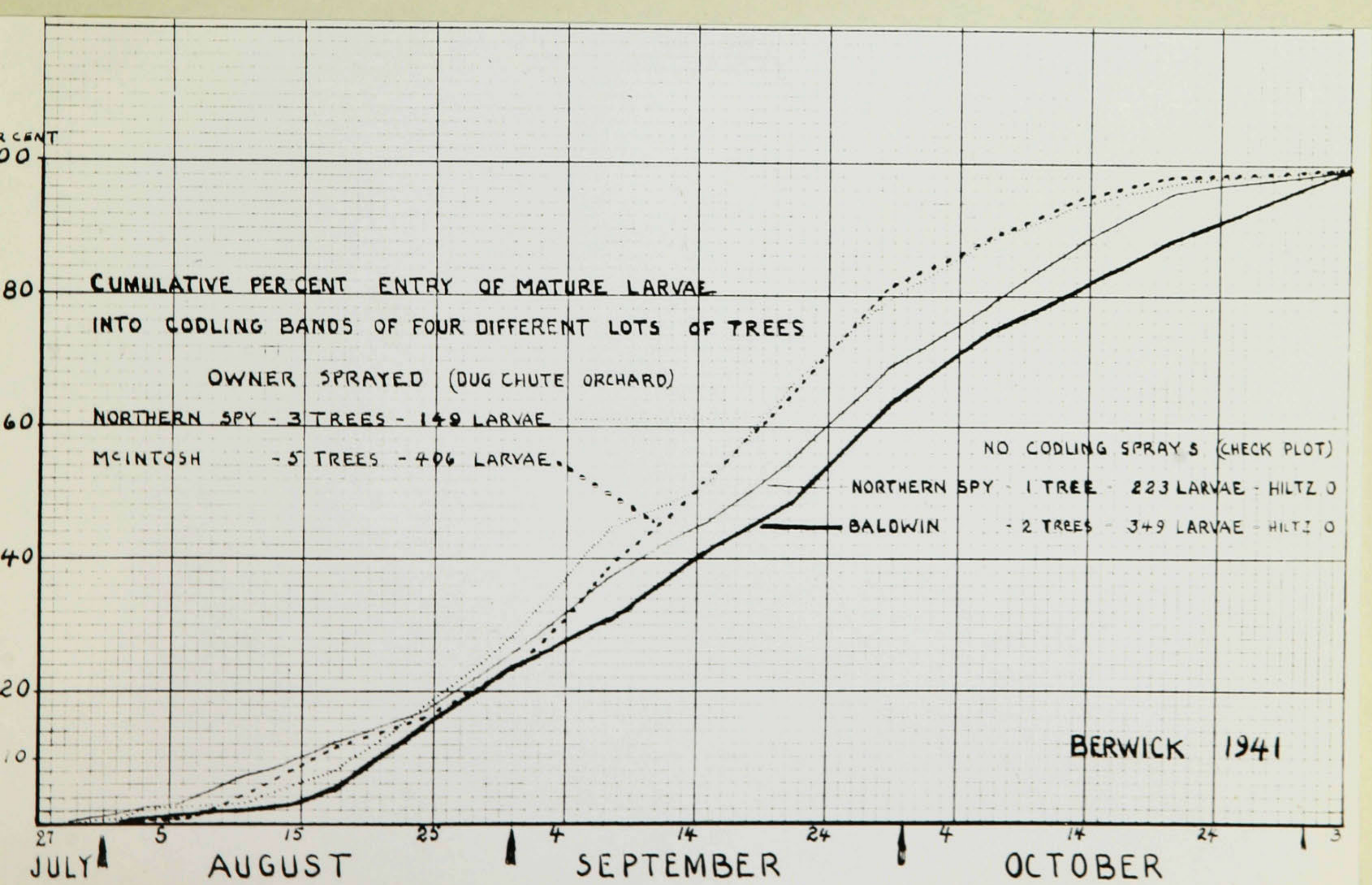

80
60
40
20
10
CUMULATIVE PER CENT ENTRY OF MATURE LARVAE
INTO CODLING BANDS OF FOUR DIFFERENT LOTS OF TREES
OWNER SPRAYED (DUG CHUTE ORCHARD)
NORTHERN SPY - 3 TREES - 149 LARVAE
McINTOSH - 5 TREES - 406 LARVAE
NO CODLING SPRAYS (CHECK PLOT)
NORTHERN SPY - 1 TREE - 223 LARVAE - HILTZ O
BALDWIN - 2 TREES - 349 LARVAE - HILTZ O
BERWICK 1941
27
5
15
25
4
14
24
4
14
24
3
JULY
AUGUST
SEPTEMBER
OCTOBER

Fig. 36.

Fig. 37.

Two views showing Gravenstein tree with jute bands on trunk and on four short sticks of apple wood placed 3, 10, 20 and 30 feet from trunk.

Fig. 38.

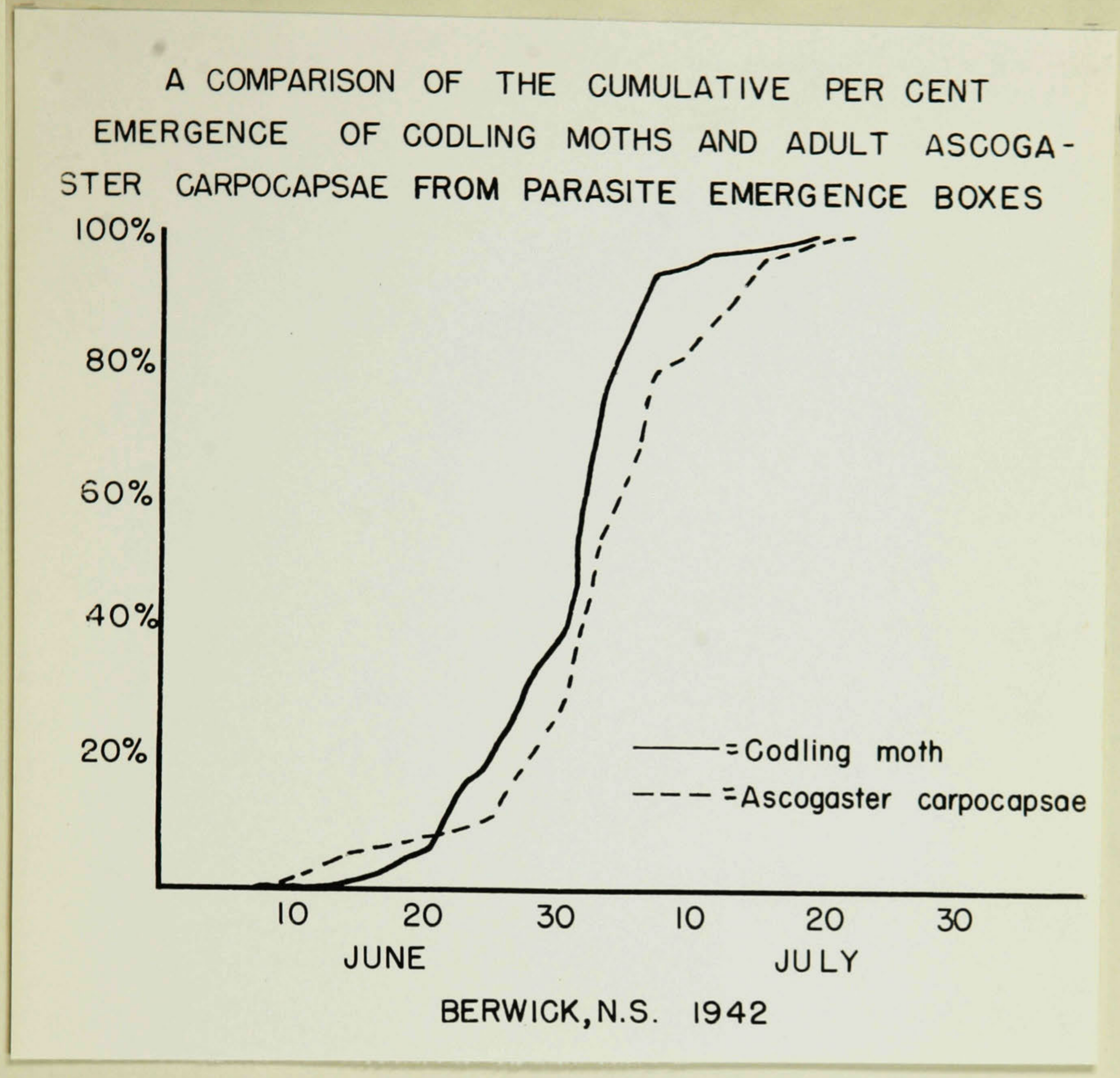

A COMPARISON OF THE CUMULATIVE PER CENT EMERGENCE OF CODLING MOTHS AND ADULT ASCOGA-STER CARPOCAPSAE FROM PARASITE EMERGENCE BOXES
100%
80%
60%
40%
20%
=Codling moth
=Ascogaster carpocapsae
10
20
30
10
20
30
JUNE
JULY
BERWICK, N.S. 1942

Fig. 39.

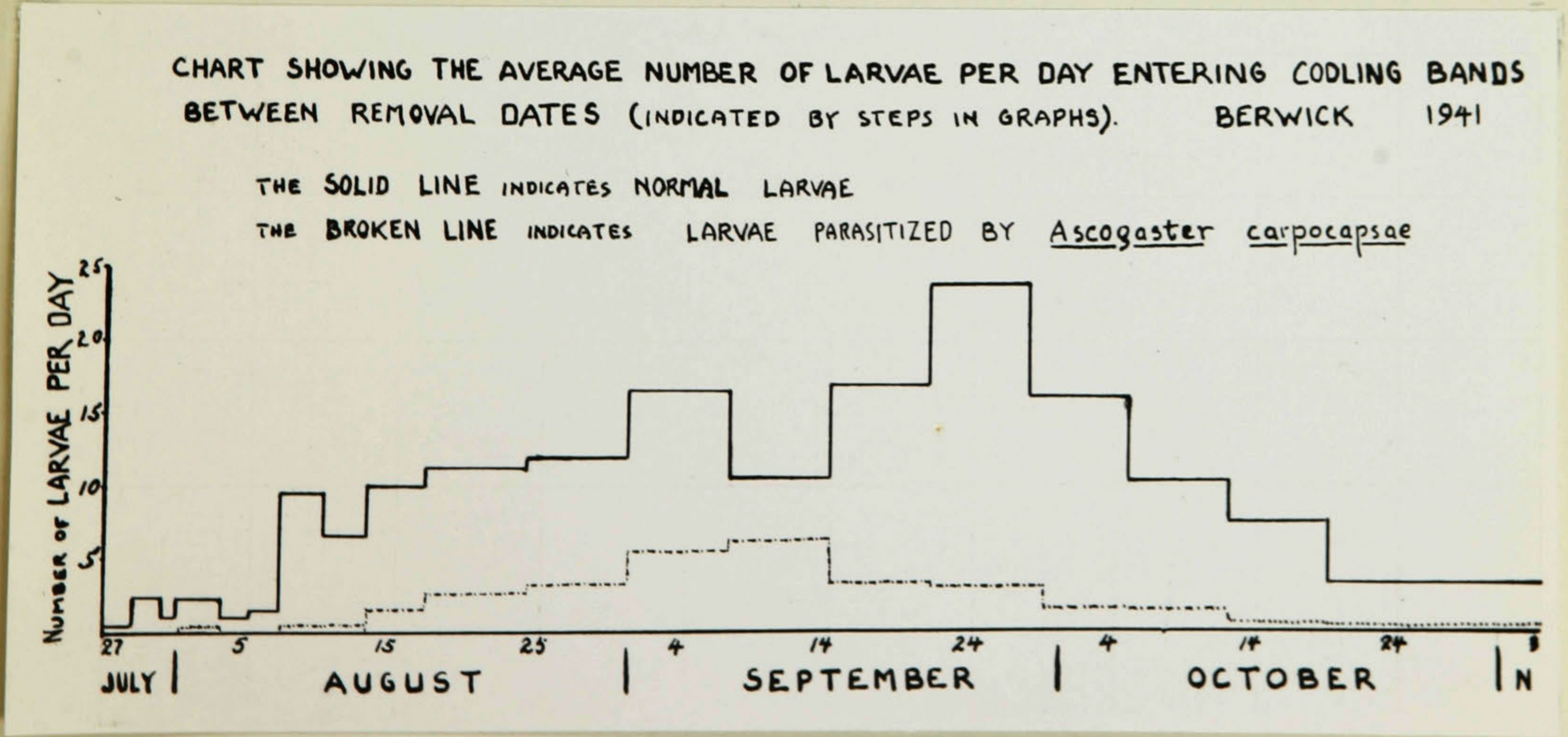


CHART SHOWING THE AVERAGE NUMBER OF LARVAE PER DAY ENTERING CODLING BANDS BETWEEN REMOVAL DATES (INDICATED BY STEPS IN GRAPHS). BERWICK 1941
THE SOLID LINE INDICATES NORMAL LARVAE
THE BROKEN LINE INDICATES LARVAE PARASITIZED BY Ascogaster carpocapsae
NUMBER OF LARVAE PER DAY
25
20
15
10
5
27
5
15
25
4
14
24
4
14
24
JULY
AUGUST
SEPTEMBER
OCTOBER
N

Fig. 40.