POPULATION DYNAMICS OF PACHYDIPLAX LONGIPENNIS (BURMEISTER) (ODONATA: ANISOPTERA) OF MONTGOMERY COUNTY, TENNESSEE

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POPULATION DYNAMICS OF PACHYDIPLAX LONGIPENNIS (BURMEISTER) (ODONATA: ANISOPTERA) OF MONTGOMERY COUNTY, TENNESSEE

An Abstract

Presented to

the Graduate Council of

Austin Peay State University

In Partial Fulfillment

of the Requirements for the Degree

Master of Science

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by

Rosemary Tipton Hackney

August 1974

ABSTRACT

A population of *Pachydiplax longipennis* nymphs was studied in its natural environment, a traditional temporary pond, from January 23, 1972, to June 23, 1972. A total of 2074 nymphs was collected. Morphological measurements were made and the nymphs were assigned to the appropriate instar classes. Dynamics of the over-wintering population, resumption of morphogenesis, and eclosion revealed that individuals of each class emerged synchronously both with respect to each other and to members of the adjacent classes.

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To the Graduate Council:

I am submitting herewith a Thesis written by Rosemary Tipton Hackney entitled "Population Dynamics of Pachydiplax longipennis (Burmeister) (Odonata: Anisoptera) of Montgomery County, Tennessee." I recommend that it be accepted in partial fulfillment of the requirements of the degree of Master of Science, with a major in Biology.

Floyd M. Ford

Major Professor

We have read this thesis and recommend its acceptance:

Charles S. Boehms

Second Committee Member

David L. Findley

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Accepted for the Council:

Wayne C. Stamper

Dean of the Graduate School

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

Under natural conditions, different species of Odonata vary greatly in the time they take to complete larval development. The species which take the longest are almost all inhabitants of permanent upland waters. Most species of Anisoptera and Zygoptera there develop in three years or less. Some species such as *Uropetala carovei* and *Epiophlebia superstes* are known to require five to six years or longer to complete larval development (Corbet, 1963).

Dragonflies which show the most rapid larval development are inhabitants of temporary pools in the tropics. Some species such as *Gynacantha vesiculata* and *Gynacantha villosa* complete larval development in approximately seventy days. Other species such as *Anax tristis* complete larval development in one hundred days (Corbet, 1963).

Although the environmental temperature influences rate of growth, according to Corbet (1963), it is not the only determinant. Species which develop rapidly in small pools do so not only because the water temperature is high, but also because they have high thermal growth coefficients.

In tropical regions, if sufficient food is available, it is likely that larval growth-rate is a simple resultant of the thermal growth coefficient and the environmental temperature. In temperate regions, however, the duration of larval development is controlled by additional factors, the main ecological significance of which appears to be synchronized emergence of the adult (Corbet, 1963).

The most significant factor is the diapause which may occur in the final larval instar. In Anax imperator, a semivoltine species studied by Corbet (1963), most larvae enter the final instar in August. No further visible growth is apparent throughout the remainder of the summer. Diapause development is completed in autumn, since it is a temperature dependent process occurring most rapidly at about 10 degrees Celsius. Larvae are physiologically capable of metamorphosing, but are prevented from doing so until spring because the temperature is still below the threshold for this process. In this way, emergence is efficiently synchronized and is restricted to a short period lasting about fifty days a year.

Many temperate dragonfly species appear to have a diapause in the final larval instar. These species have been termed "spring species" by Corbet (1963) since they usually emerge synchronously and early during the eclosion period. Dragonflies which do not possess a diapause in the final larval instar have been termed "summer species" and emergence is relatively poorly synchronized.

Because certain Odonata exhibited an emergence which was widely dispersed, Corbet (1963) classified them as a "summer species." Because of its life history, *Pachydiplax longipennis* was included in this classification.

Eller (1963), in his two year study of seasonal regulation of *Pachydiplax longipennis*, examined a population inhabiting a permanent pond in Chapel Hill, North Carolina. By studying the instars in their natural habitat, he determined that the most reliable indicator of intermoult development was the measurement between the mesial ends of the posteriomesial extensions of the compound eyes. Position of the wing sheath was frequently used to determine stage of nymphal intermoult development. Measurement across the widest part of the head proved to be the most reliable single indicator of the instar class. Certain other measurements such as total body length, body width, and relative wing length were useful in determining only the final two or three instar classes.

Eller (1963) reported that the life cycle of *Pachydiplax longipennis* was primarily univoltine and emergence was well synchronized with individuals of each class emerging synchronously both with respect to each other and to members of the adjacent classes. Thus he found *Pachydiplax longipennis* different from any "summer species" studied by Corbet. Eller (1963) insisted that *Pachydiplax longipennis* was a "summer species" with a life cycle similar to that of the "spring species," _Tetragoneuria cynosura_.

Paulson and Jenner (1970) after studying Odonata nymphs in North Carolina, reported that the spring _versus_ summer species classification was valid at high latitudes, but broke down at the latitude of North Carolina, where there was a high degree of variance from one type of life history to another.

The present investigation was undertaken to determine, under natural conditions, the pattern of development in _Pachydiplax longipennis_ nymphs inhabiting a traditional temporary pond in Tennessee: 1) the composition of the instar classes and the dominant instar class in the overwintering population; 2) the resumption of morphogenesis; 3) the period of emergence and the beginning of the flight season.

The investigation was undertaken, secondly, to determine if there was any difference between the life history exhibited by _Pachydiplax longipennis_ in North Carolina and _Pachydiplax longipennis_ in Tennessee since both areas of study were located at approximately the same latitude, but different longitudes.

Thirdly, this study was undertaken to determine if there was any difference between the life history of a population of _Pachydiplax longipennis_ nymphs inhabiting a permanent pond situation and a population of _Pachydiplax longipennis_ nymphs inhabiting a temporary pond situation.

CHAPTER II

LITERATURE REVIEW

One of the first reports on the dragonfly fauna of Tennessee was published by Williamson (1903) His work on odonate fauna was centered in the Nashville area from September 3, 1900 to June 7, 1901. His later studies included a survey of the Odonata of Kentucky, Indiana, and Tennessee (1923) and a similar study of the Odonata of Kentucky, Tennessee, North and South Carolina, and Georgia (1934).

Wilson (1909) collected on the Tennessee River from Paducah, Kentucky to Riverton, Alabama. That work was followed by a survey of the Odonata of the Cumberland River and its valley regions (1912).

The next major work conducted on the odonate fauna in Tennessee was by Byers (1931) in the eastern portion of the state. He collected dragonflies in that area with emphasis centering on the Sevierville, Gatlinburg, and Elkmont areas.

By 1937 interest had shifted to the western portion of the state, particularly the Reelfoot Lake area. Koen (1937) made a survey of the odonate fauna at the Reelfoot Lake area. This study was later followed by Wright (1938).

An extensive study on the dragonflies of the Obey River and its tributaries, which include drainage areas of the Cumberland Plateau and the Eastern Highland Rim, was made by Wright and Shoup (1945). The fauna of the Central portion of the state including Davidson, Cheatham, Williamson, and Rutherford Counties were later examined by Wright (1946).

The preceding studies on the dragonfly fauna were collected by Kormondy (1957), who compiled them and made distributional analyses of the odonates of Tennessee.

Other studies in the Southeastern United States were conducted at Chapel Hill, North Carolina. Eller (1963) studies the seasonal regulation of Pachydiplax longipennis (Burmeister). Paulson and Jenner (1970) studied the population structure in overwintering larval odonates of North Carolina.

Diapause, as defined by Andrewartha (1952), was a period in the life cycle, during which, morphogenesis was more or less at a standstill. It may be considered as a stage in physiogenesis which must be completed as a prerequisite for the resumption of morphogenesis. Frequently, diapause occurred in that stage of the life cycle which was highly adapted to resist rigours of the climate. In species adapted to cool temperate zones of the Northern Hemisphere, diapause occurred in a stage of the life cycle which was able to withstand extremes of cold. Diapause was considered to be of value to the species because it induced a rhythm in the life cycle which synchronized with the rhythm of the environment. This ensured that the active stages of the life cycle should be present when there was an abundance of food and other components of the environment which favored rapid development and high survival.

Dragonflies are variably efficient in the extent to which they achieve seasonal regulation, and according to Corbet _et al_ (1960) it is possible to recognize two fairly distinct types.

Dragonflies of the first type have been called "spring species." These fly early in the year and have a highly synchronized emergence with an early peak. They have a short flight season and diapause occurs in the final instar stage.

The second type is represented by species which emerge later in the year and do not show a close synchronization. Such dragonflies have been called a "summer species." They have a longer flight season and diapause does not occur in the final instar stage (Corbet _et al_, 1960; Corbet 1963).

Corbet (1963) discovered that in a "spring species," _Anax imperator_, fifty per cent of the annual emergence occurred in the first three days and seventy-five per cent in the first four days of a fifty day emergence period. Over ninety per cent of the population had emerged in the first ten days of the emergence period. In a "summer species," *Aeschna cyanea*, which has an emergence period of comparable duration, fifty per cent of the annual emergence occurred in twenty-five days and seventy-five per cent in thirty-three days.

It occasionally happened that dragonflies believed to be "summer species" were reported to exhibit mass emergence. Corbet (1963) believed that this resulted from the accumulation of the larval population in a late stage of metamorphosis from which they were unable to emerge because the lower temperature threshold for emergence had not yet been reached.

From the above conditions described by Corbet (1963), *Pachydiplax longipennis* was classified as a "summer species."

Eller (1963) in his study of the seasonal regulation of *Pachydiplax longipennis* found that it was different from any "summer species" studied by Corbet. Eller (1963) reported that the life cycle was primarily univoltine and emergence was well-synchronised with individuals of each class emerging synchronously both with respect to each other and to members of the adjacent classes.

Paulson and Jenner (1970), after studying Odonata nymphs in North Carolina, reported that the spring *versus* summer species classification was valid at high latitudes, but broke down at the latitude of North Carolina, where there was a high degree of variance from one type of life history to another.

CHAPTER III

MATERIALS AND METHODS

The research animal: Dragonflies (Odonata) belong to the largest single group of animals, the Insecta. Insects belong to the phylum Arthropoda, those animals with a hard, impermeable external skeleton and jointed appendages. Of the million species of insects, only about 5,000 species are dragonflies (Corbet et al, 1960). In Tennessee there have been found 63 species of Anisoptera and 29 species of Zygoptera (Kormandy, 1957).

Pachydiplax longipennis (Burmeister), the Blue Pirate (Needham and Heywood, 1929), is one of the most common dragonfly species of Tennessee. The nymph is smooth and depressed of body, with a wide head (Needham and Westfall, 1955). The total body length is 17 millimeters; the length of the abdomen is 10 millimeters; and the epiproct, 2.3 millimeters; the cerci, 1.1 millimeters; and the paraprocts, 3.4 millimeters. The antennae are 7-segmented, ringed with dark brown bands on segments II, III, and VI. The prementum has a 9-10 palpal setae and 12-13 premental setae. There are no dorsal hooks. On segments VIII and IX of the body are located lateral abdominal spines. The abdominal spine on segment VIII is one-fourth the length of its perspective segment, and the spine on segment IX is one-third the length of its segment. Coloration of the nymph is cream with dark bands (Musser, 1962).

Pachydiplax longipennis is considered by Kormondy (1957) to be transcontinental in distribution in the United States. Needham and Westfall (1955) consider it to be a species of common occurrence and wide distribution with a range from British Columbia, Manitoba, and Ontario in Canada to Mexico, Baja California, the Bermudas, and the Bahamas.

The nymphs of Pachydiplax longipennis are found in a variety of habitats such as lakes, ponds, rivers, and creeks (Wright, 1946). Bick (1950) found most of his nymphs in static water with mud bottoms. The nymphs are typical inhabitants of the vegetated areas of ponds and lakes (Wright and Shoup, 1945), and are most abundant in areas around floating and emergent vegetation (Williamson, 1903; Koen, 1937; Wright and Shoup, 1945; Wright, 1946; Needham and Westfall, 1955; Eller, 1963).

Most life-history or life cycle studies have been concerned with rearing nymphs under artificial and usually variable conditions (Lutz and Jenner, 1964). A more desirable method of studying patterns of nymphal development is to sample regularly, populations in nature throughout the year. This method has been utilized effectively by Corbet (1957) and Eller (1963) on Pachydiplax longipennis, Lutz and Jenner (1964) on Tetragoneuria cynosura, Kormondy and Gower (1965) and Paulson and Jenner (1970) on a variety of species of dragonflies.

The habitat: An overwintering nymphal population of Pachydiplax longipennis was studied in a temporary pond located on the Stroudsville Road approximately two miles east of Sango and ten miles east of Clarksville, Tennessee, The one-fourth acre pond was situated in the corner of an open field used for cultivation. The pond varied in depth from a few centimeters on the margins to a meter in the central area. In periods of extreme climatic drought, it was reduced to a dry bed.

In the summer the entire surface was characterized by thick growths of emergent Typha latifolia. The leaves of Typha grew to a height of two to two and one-half meters when mature, and in the winter left thick stands of dry stalks scattered throughout the entire surface area. The subsurface masses of decaying stems, leaves, and other debris furnished shelter for the overwintering nymphs.

In addition to Typha latifolia, other minor plants associated with the habitat were Alisma subcordatum and Ludwigia pulustris. The perimeter of the pond was ringed by Liquidamber styraciflua, Plantanus occidentalis, Salix nigra, and Rubus argutus.

Large populations of amphipods, cladocerans, annelids, and the larvae of several orders of insects, dominated by Ephemeroptera (mayflies) and Plecoptera (stoneflies), provided sufficient food to support the populations of Odonata nymphs.

In addition to _Pachydiplax_, nymphs of _Sympetrum sp._, _Anax junius_, _Aeschna sp._, _Somatachlora sp._, and _Libellula sp._ were present in the population structure of the pond. Cannibalism occasionally occurred among the different species, both interspecifically and intraspecifically. However, the chief predators of the Odonata mymphs were the frogs _Hyla crucifer_, _Pseudacris nigrita_, and _Rana sp._; the salamander _Notophthalmus viridescens louisianensis_; the crayfish _Cambarus sp._; and the sunfish _Lepomis sp._

Thermal conditions within the pond were recorded on a monthly basis. In the winter a vertical gradient existed in the deeper central area of the pond. Differences of 4-7 degrees Celsius were recorded between the bottom and surface waters. A layer of ice, varying in thickness from one to two centimeters, covered over ninety per cent of the surface area during the months of January and February. In the spring and summer months, no vertical gradient was present between the bottom and surface waters. By June 20, the water temperature had attained a reading of thirty-two degrees Celsius.

Materials: Twenty collections of 2074 _Pachydiplax longipennis_ nymphs were made in a temporary pond between

January 23, 1972 and June 23, 1972. Collections varied from 26 to 140 nymphs with an average of 100. During the winter, monthly collections were made. In April, after resumption of morphogenesis, weekly collections were made. Between May 25 and June 23, biweekly collections were made.

A triangular "Turtox" dip net was used to capture the nymphs from the pond. It was necessary to place the debris into white enameled pans where sighting of the smaller instars depended mainly upon their movements. The nymphs would swim freely when the debris was agitated.

After capture, the nymphs were transported to the laboratory in buckets of water. After identification was made and morphological measurements were recorded, the nymphs were returned to the pond.

Morphological measurements: To facilitate measurement, nymphs were placed individually into small specimen jar lids which had white linings. Measurements were then made with an "Apsco Stereograph Model A 0202" binocular dissecting microscope equipped with 10x objectives and 5x oculars. The right ocular contained a micrometer, on which, the units were calibrated to 0.03 millimeters at a resolution of 50x.

To determine instar class, a total of six morphological measurements were made and recorded for each specimen; the total body length, the body width, the relative wing length, the position of the wing sheaths, the distance between the posteriomesial extensions of the compound eyes, and the head width.

Measurement of total body length included the distance between the anterior margin of the head and the posterior tips of the paraprocts. The results found by Eller (1963) proved total body length to be useful only for separation of the final three instar classes. Total body length was completely unreliable in the smaller classes due to the degree of overlap in measurements between these instar classes.

The body width was measured at the widest point, the posterior margin of the sixth abdominal segment.

The abdominal segment adjacent to the posterior tip of the wing sheath was recorded as an index of relative wing length. Eller (1963) found that the number of abdominal segments covered by the metathoracic wing sheath was invariably discontinuous only in the final two instar classes. Relative wing length measurements were subject to error due to the different degrees of contraction of the abdominal segments by the nymphs.

The position of the wing sheaths was frequently used to determine stages of nymphal intermoult development. Eller (1963) recognized three stages: teneral, the stage containing newly moulted nymphs or new recruits; intermediate, the stage of nymphal development between moults; pre-moulting, the stage prior to moulting.

In the teneral stage, the mesothoracic wing sheaths are obscured by the metathoracic sheaths except along their mesial borders. Inner margins of the distal ends of the metathoracic sheaths may touch one another in the mid-line (Eller, 1963).

In the intermediate intermoult stage, there is an unfolding of the metathoracic wing sheaths as they gradually diverge from one another.

The pre-moulting intermoult stage was marked by heavy, granular bodies appearing in the wing pads, the undeveloped wings of the nymphs.

The compound eyes in each of the instar classes were characterized by narrow, attenuated posteriomesial extensions which were rendered very conspicuous by dense black pigment. Eller (1963) determined that the measurement between the mesial ends of the extensions of the compound eyes was the most reliable indicator of intermoult development. From his measurements, he devised an "Eye Index" scale which provided parameters for delimiting intermoult development.

Measurements taken across the widest part of the head were used to place the instars into classes. Eller (1963) determined that the head width measurements proved to be the most reliable single indicator of the instar class. Based on the measurements from his study, he devised a "Head Width Index" which placed a nymph into one of the six observed instar classes; the Antepenultimate-minus-three (A-3), the Antepenultimate-minus-two (A-2), the Antepenultimate-minus one (A-1), the Antepenultimate (A), the Penultimate (P), and the Ultimate (U).

Recovery of Exuviae: In an effort to establish the beginning of seasonal emergence of the imagoes and the rate at which it occurred, the exuviae were collected. Because of the density of the vegetation and the surface area of the pond, one-fourth of the area was designated for collection of the exuviae.

CHAPTER IV

RESULTS OF FIELD OBSERVATIONS

Population dynamics of <u>Pachydiplax longipennis</u> were studies over a six month period between January 23, 1972 and June 23, 1972. Nymphs were measured and assigned into appropriate instar classes by using Eller's (1963) head-width frequency histogram. The per cent composition of each instar class was then computed for each collection date (Table I). For organizational purposes these data were analyzed from three different aspects: the over-wintering nymphal population; the population structure after the resumption of morphogenesis; the population structure after the first date of eclosion.

<u>The overwintering nymphal population</u>: The over-wintering population was studied from January to March. The water temperature during this period ranged from 4 degrees Celsius in January to 16 degrees Celsius at the later part of March. During that time, the nymphal population had reached a plateau in development and maintained a constant class composition.

Five instar classes were encountered with the Ante-penultimates being the dominant class (Table II). The average per cent composition of each instar class of the overwintering population was as follows: the Antepenultimate-minus two (A-2), 3.85 per cent; the Antepenultimate-

TABLE I

Per cent composition of instar classes per field collection from January 23, 1972 to June 23, 1972

N = Number of specimens collected
A-2 = two stages preceding the Antepenultimate
A-1 = one stage preceding the Antepenultimate
A = Antepenultimates
P = Penultimates
U = Ultimates

Date	N	A-2	A-1	A	P	U
Jan. 23	64	1.56	21.88	46.88	26.69	0.00
Feb. 25	90	6.67	16.67	46.67	26.67	3.33
Mar. 18	120	3.33	20.00	46.67	23.33	6.67
Ap. 12	125	8.80	20.00	32.00	36.80	2.40
Ap. 19	139	0.00	17.98	28.06	46.76	7.19
Ap. 27	111	2.70	30.63	15.32	45.04	6.31
May 10	103	0.00	8.74	9.80	55.34	25.24
May 15	116	0.00	6.90	10.34	51.72	31.03
May 17	115	0.00	1.74	3.48	51.30	43.48
May 22	103	0.00	0.97	5.82	42.72	50.48
May 24	105	0.00	0.00	0.95	33.33	65.71
May 25	114	0.00	0.88	1.75	34.21	63.16
June 1	116	0.00	0.00	2.59	31.03	66.38
June 6	103	0.00	0.00	1.94	19.42	78.64
June 9	104	0.00	0.00	1.92	5.77	92.31

TABLE I

(continued)

Date	N	A-2	A-1	A	P	U
June 12	110	0.00	0.00	0.91	6.36	92.73
June 15	140	0.00	0.00	0.71	4.28	95.00
June 19	118	0.00	0.00	0.00	1.69	98.31
June 22	52	0.00	0.00	0.00	9.62	90.38
June 23	26	0.00	0.00	0.00	3.85	96.15

TABLE II

Per cent composition of instar classes per field collection of the overwintering nymphal population from January 23, 1972 to March 18, 1972

N = Number of specimens collected
A-2 = two stages Preceding the Antepenultimate
A-1 = one stage preceding the Antepenultimate
A = Antepenultimates
P = Penultimates
U = Ultimates

Month	N	A-2	A-1	A	P	U
Jan.	64	1.56	21.88	46.88	29.69	0.00
Feb.	90	6.67	16.67	46.67	26.67	3.33
Mar.	120	3.33	20.0	46.67	23.33	6.67
Average	91	3.85	19.52	46.67	26.56	3.33

minus-one (A-1), 19.52 per cent; the Antepenultimate (A), 46.74 per cent; the Penultimate (P), 26.56 per cent; and the Ultimate (U), 3.33 per cent.

Resumption of morphogenesis: The first indication of the resumption of morphogenesis occured at the first part of April, when the water temperature had attained a reading of 23 degrees Celsius. At that time, the per cent composition of each of the five observed instar classes were as follows: A-2, 8.80 per cent; A-1, 20.0 per cent; Antepenultimate, 32.0 per cent; Penultimate, 36.8 per cent; and Ultimate; 2.4 per cent. There was a noticeable shift in dominance from the Antepenultimate class to the Penultimate class (Table III).

The most reliable indicator of intermoult development was the measurement between the mesial ends of the extensions of the compound eyes. Those measurements were compared to Eller's (1963) Eye Index which provided parameters for delimiting instar classes into teneral, intermediate, and pre-moulting instars.

Eye Index measurements for denoting teneral or newly moulted instars were 1.20 millimeters for the A-1, Antepenultimate, and Penultimate classes and 0.96 millimeters for the Ultimate class. Eye Index-frequency histograms for each collection date (Figure 1.) illustrate percentages of the instar classes at points of instar class exchange.

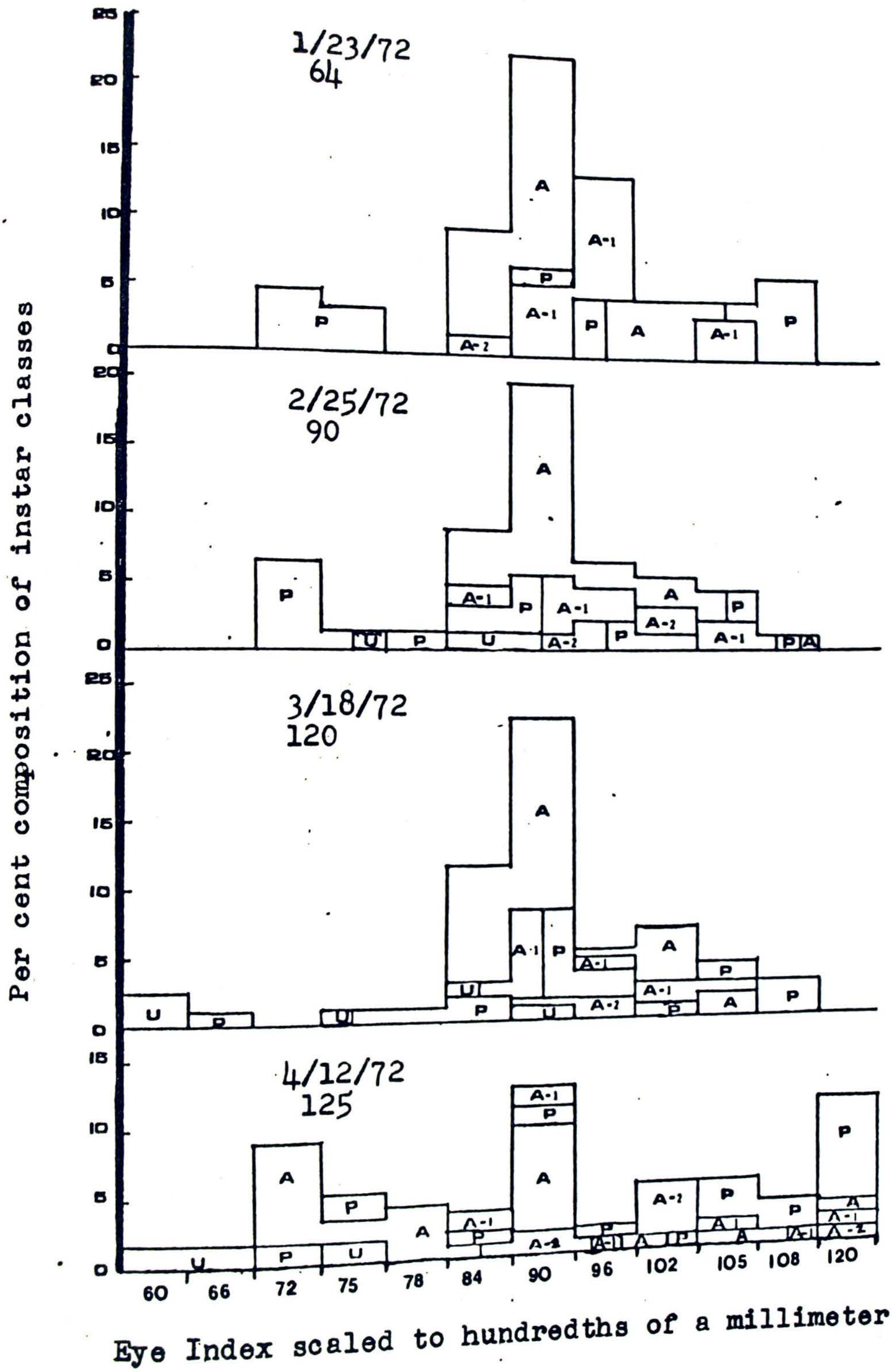
TABLE III

Per cent composition of instar classes after resumption of morphogenesis from April 12, 1972 to May 24, 1972

N = Number of specimens collected
A-2 = two stages preceding the Antepenultimate
A-1 = one stage preceding the Antepenultimate
A = Antepenultimates
P = Penultimates
U = Ultimates

Date	N	A-2	A-1	A-2	P	U
Ap. 12	125	8.80	20.00	32.00	36.80	2.40
Ap. 19	139	0.00	17.98	28.06	46.76	7.19
Ap. 27	111	2.70	30.63	15.32	45.04	6.31
May 10	103	0.00	8.74	9.80	55.34	25.24
May 15	116	0.00	6.90	10.34	51.72	31.03
May 17	115	0.00	1.74	3.48	51.30	43.48
May 22	103	0.00	0.97	5.82	42.72	50.48
May 24	105	0.00	0.00	0.95	33.33	65.71

Figure 1. Eye Index-frequency histogram of Pachydiplax longipennis collected in a traditional temporary pond from January 23, 1972 to June 23, 1972.



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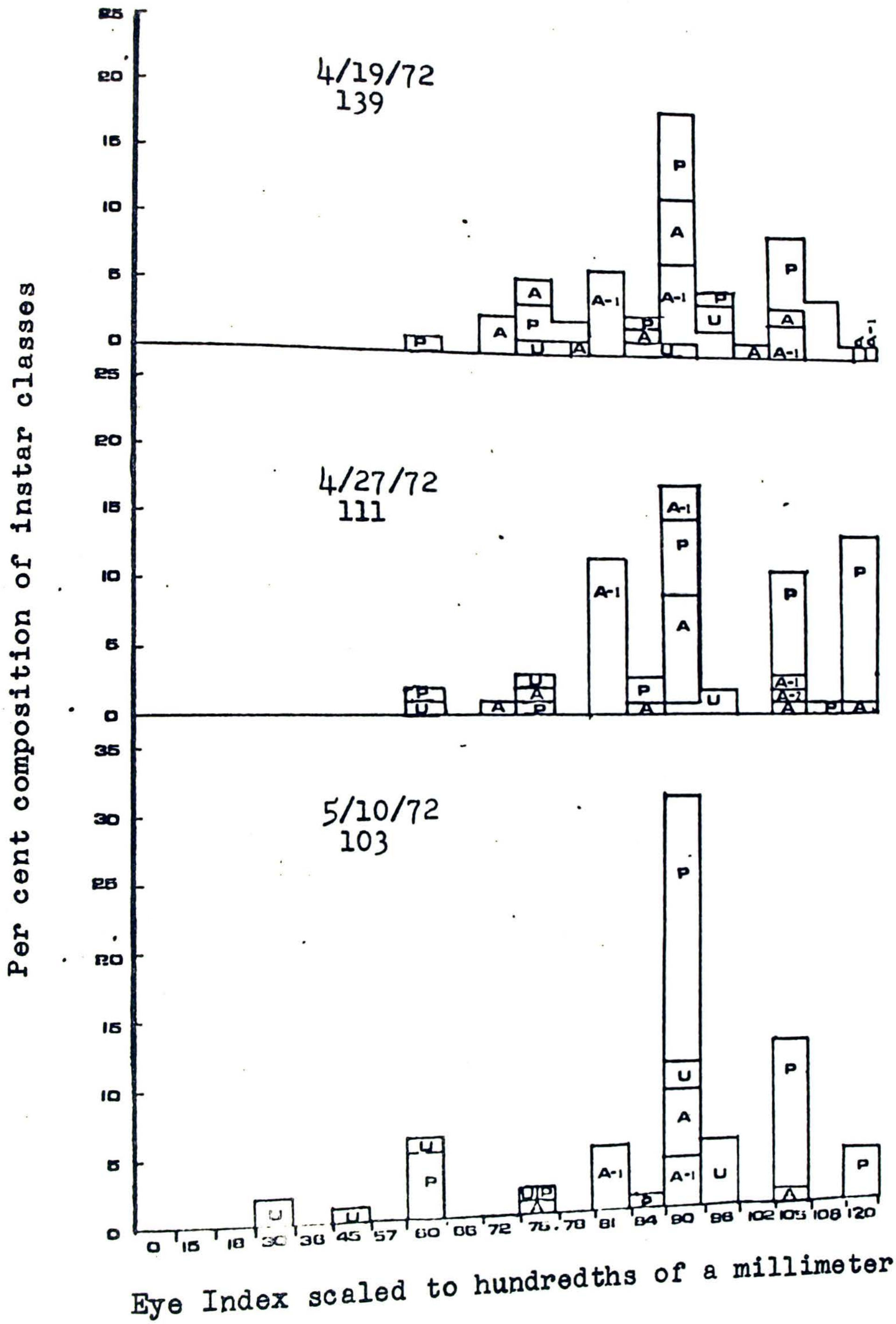

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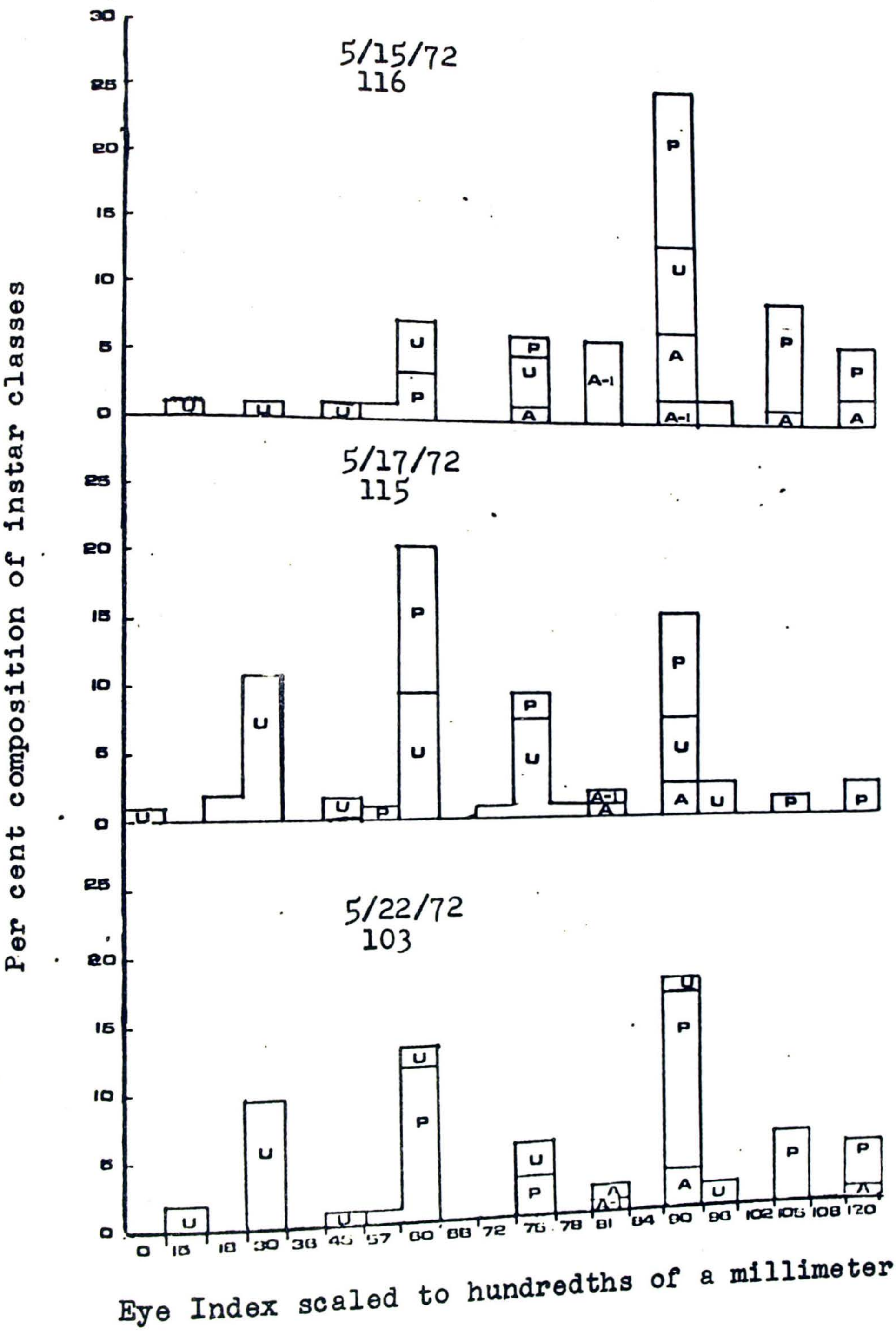

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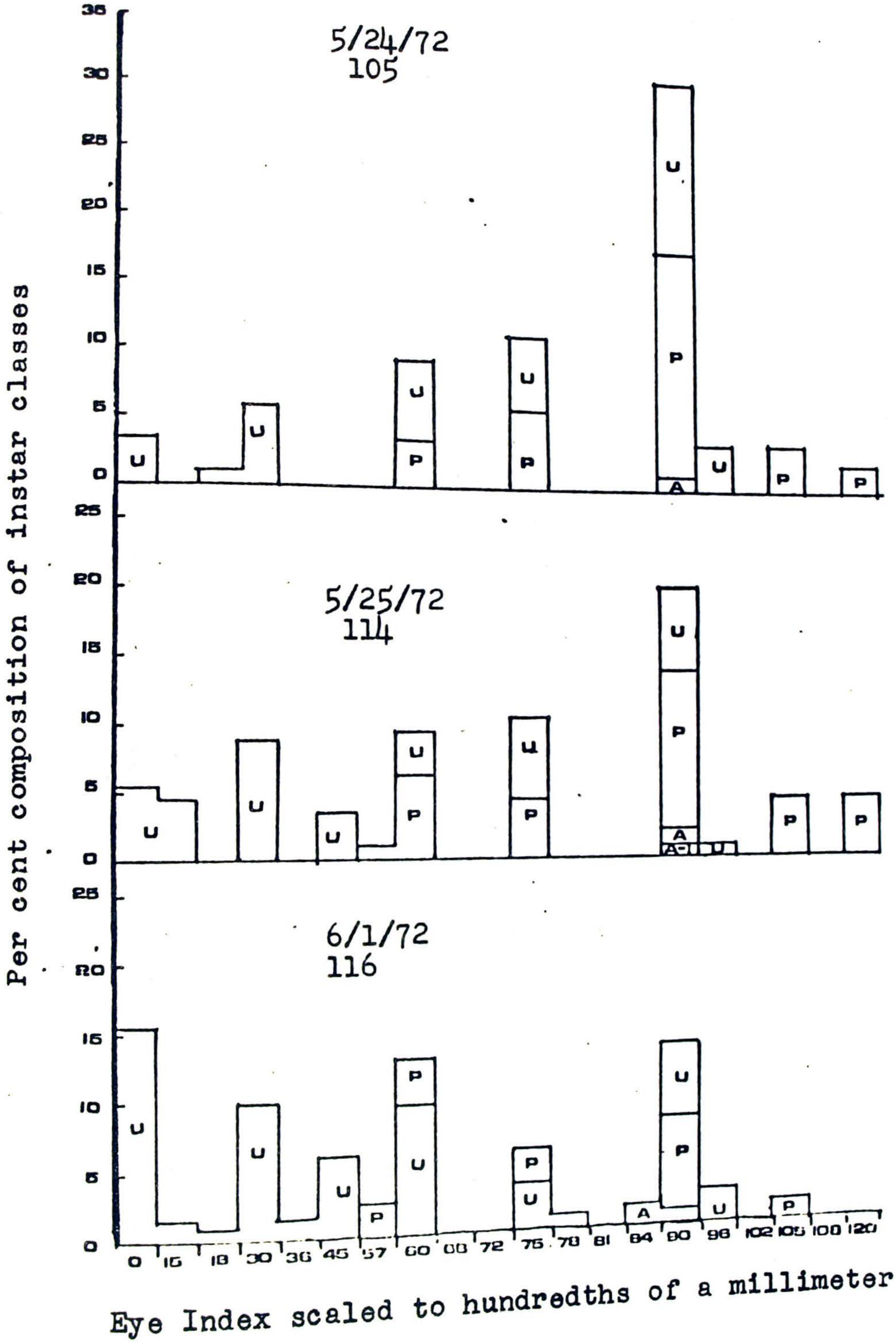

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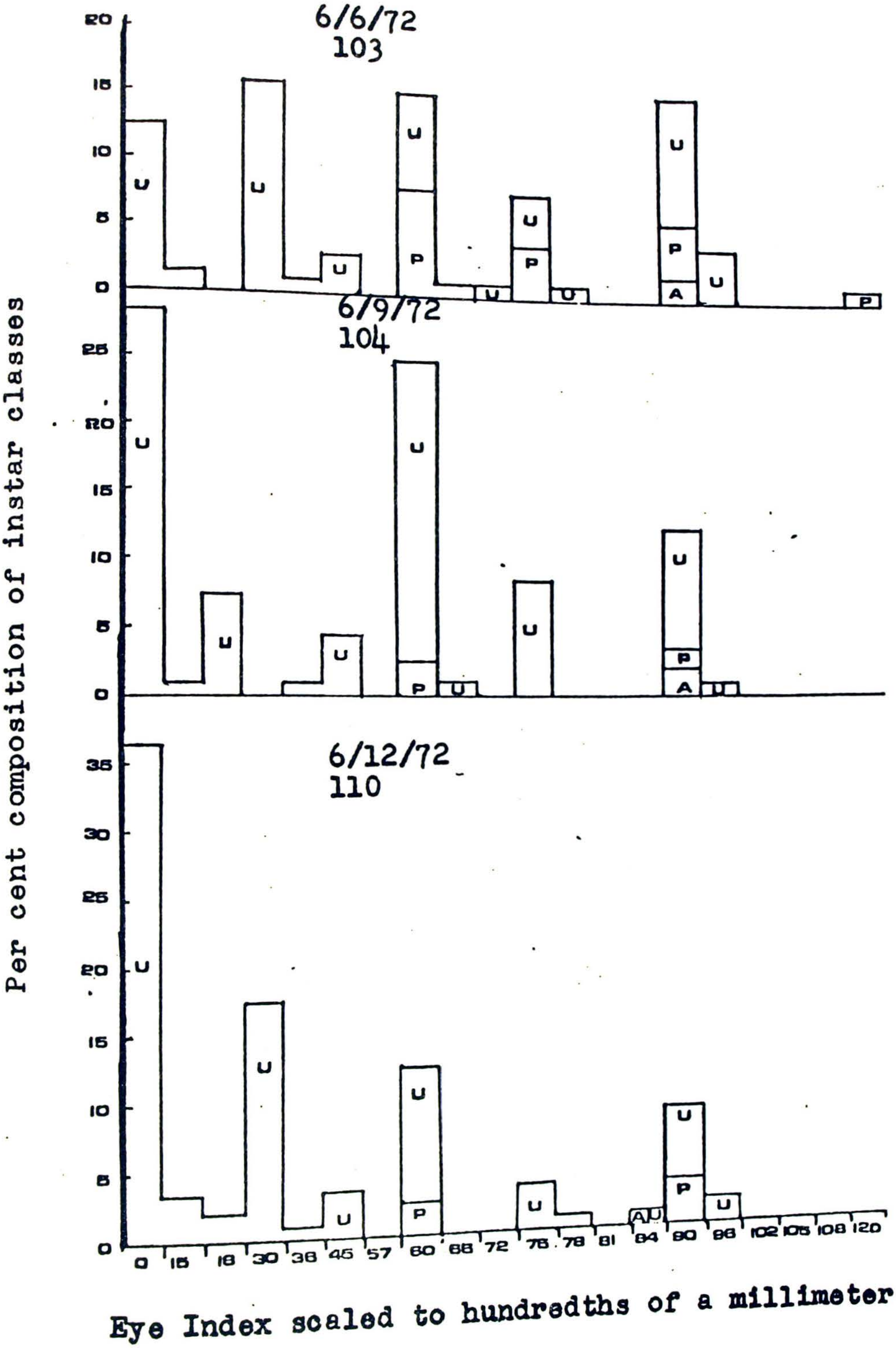

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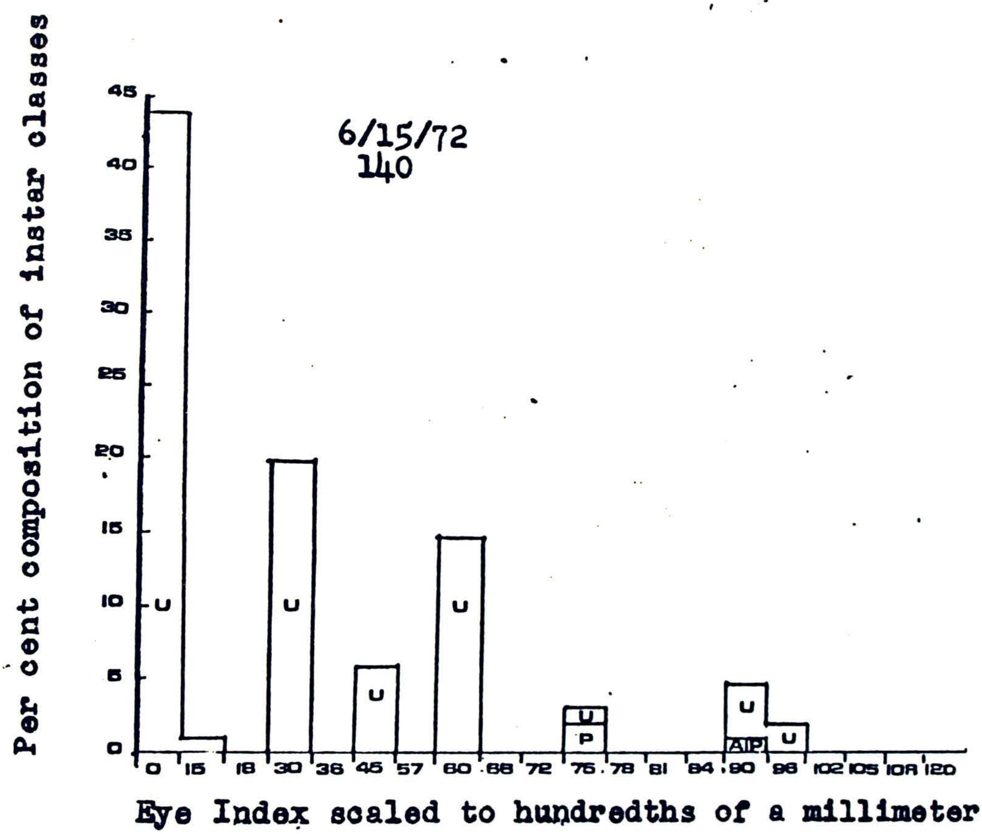

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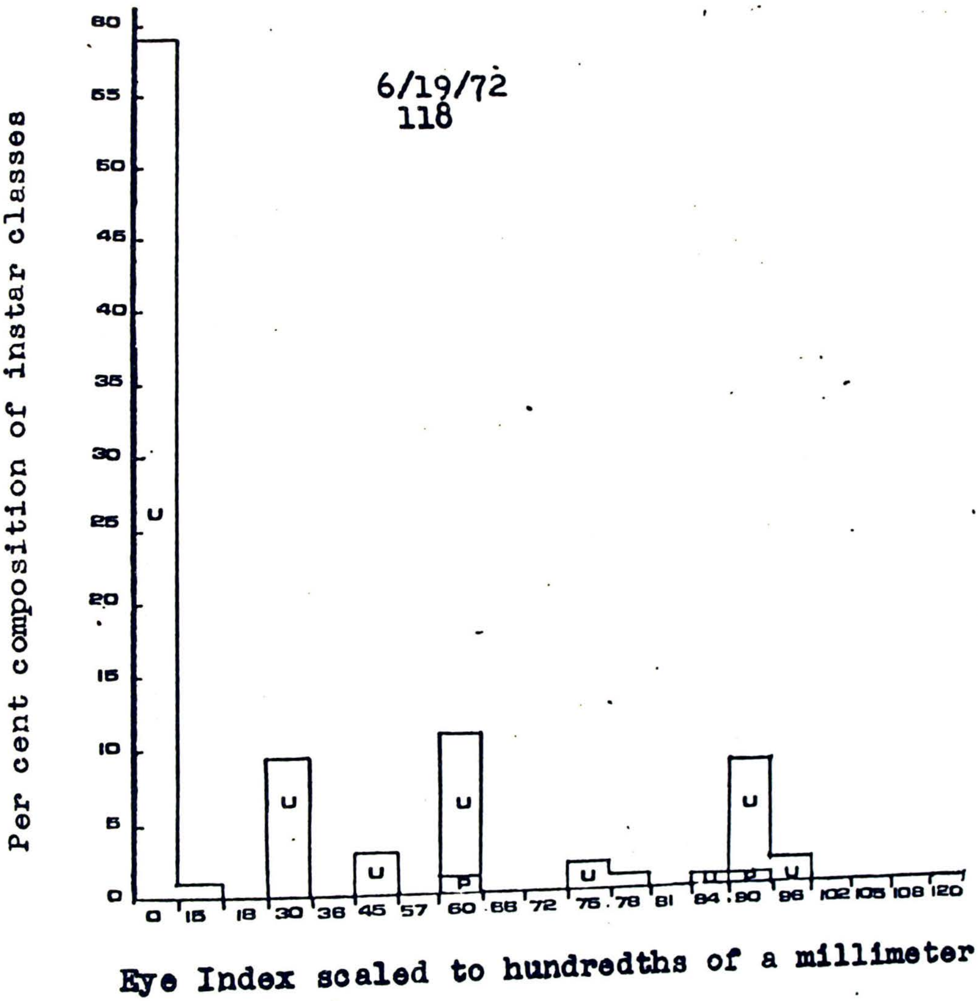


Figure 1. (continued)

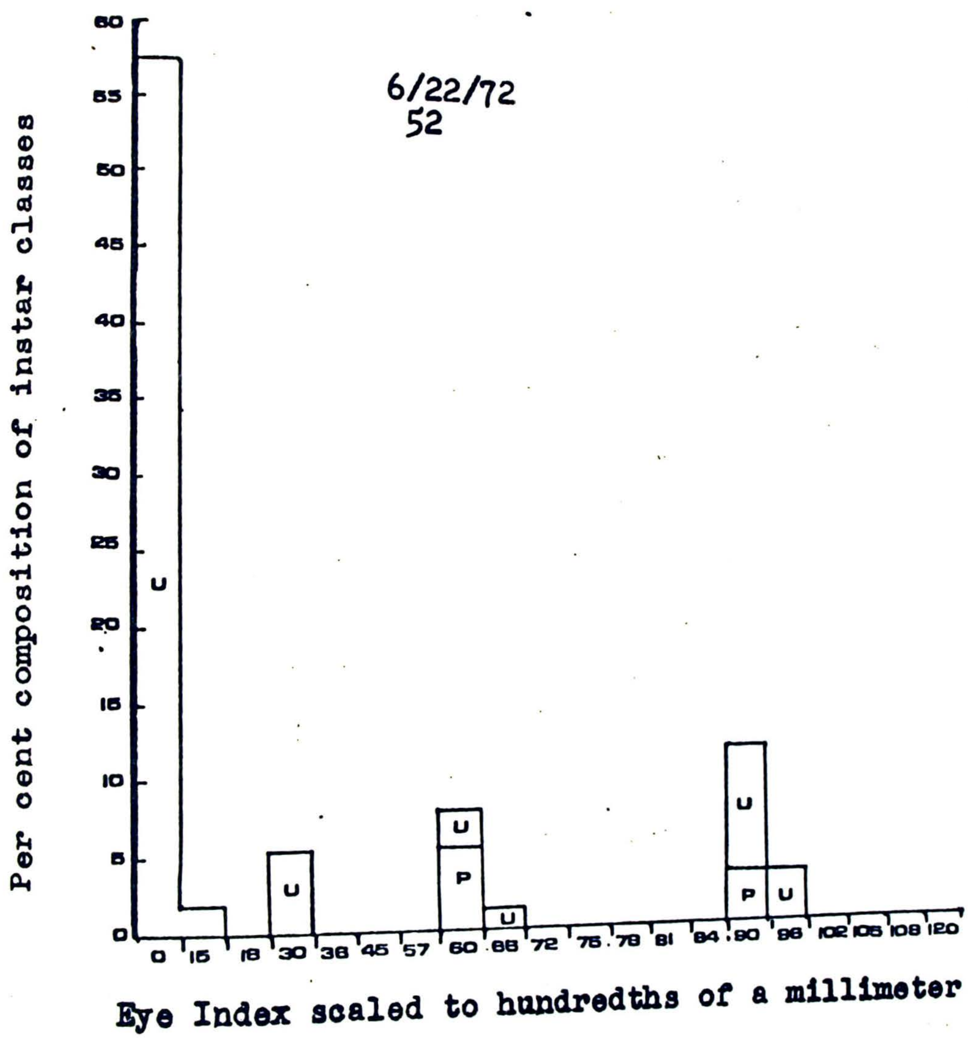
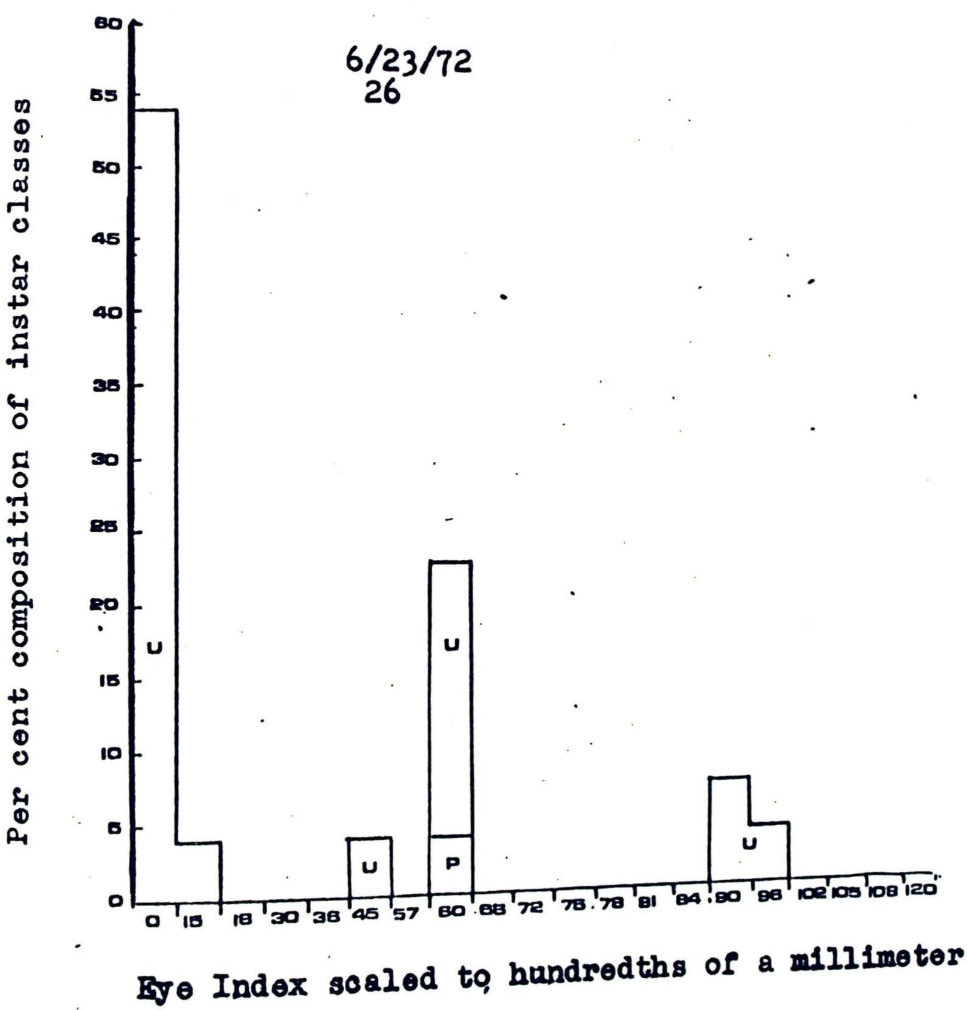


Figure 1. (continued)



On April 12, the first teneral instars appeared in the population (Figure 1.). Tenerals were found to be present in the A-1, Antepenultimate, and Penultimate classes at that time. Tenerals in the Ultimate class did not appear in the population until April 19.

As the water temperature rose to 25 degrees Celsius in May, morphogenesis and ecdysis began to express themselves by the rapid decline and disappearance of nymphs from the instar classes. By May 10 there were no A-2 instars in the population. The A-1 and Antepenultimate classes together comprised less than 20 per cent of the total population. The Penultimate class contained over 55 per cent and the Ultimate class approximately 25 per cent of the population. A major shift had occurred in the population, with the Penultimate class reaching its peak (Figure 2.). The Ultimate class had begun to gain numbers, but at a slow rate.

By May 24 the A-1 class had disappeared from the population with the Antepenultimate class containing less than 1 per cent of the total population. The Penultimate class had declined in numbers to 33 per cent of the population and the Ultimate class dominated with 65 per cent of the total population (Table III).

Progression of instars from the earliest classes to the Ultimate class was best illustrated in Length-frequency histograms (Figure 3.). Percent composition

Figure 2. Seasonal changes in percentage of collection composed of Ultimate, Penultimate, and Antepenultimate instars from January 23, 1972 to June 23, 1972.

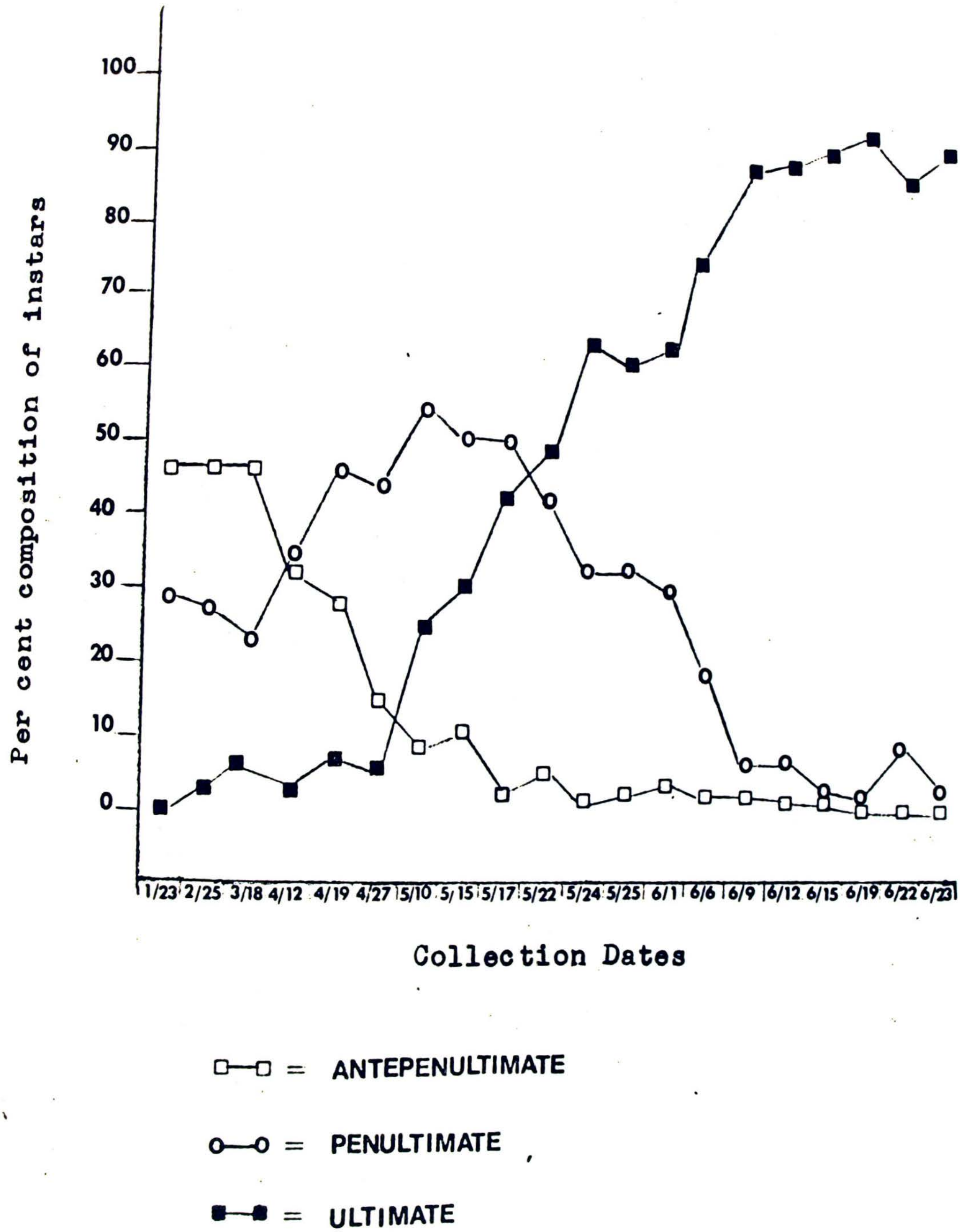


Figure 3. Length-frequency histogram of Pachydiplax longipennis collected in a traditional temporary pond from January 23, 1972 to June 23, 1972.

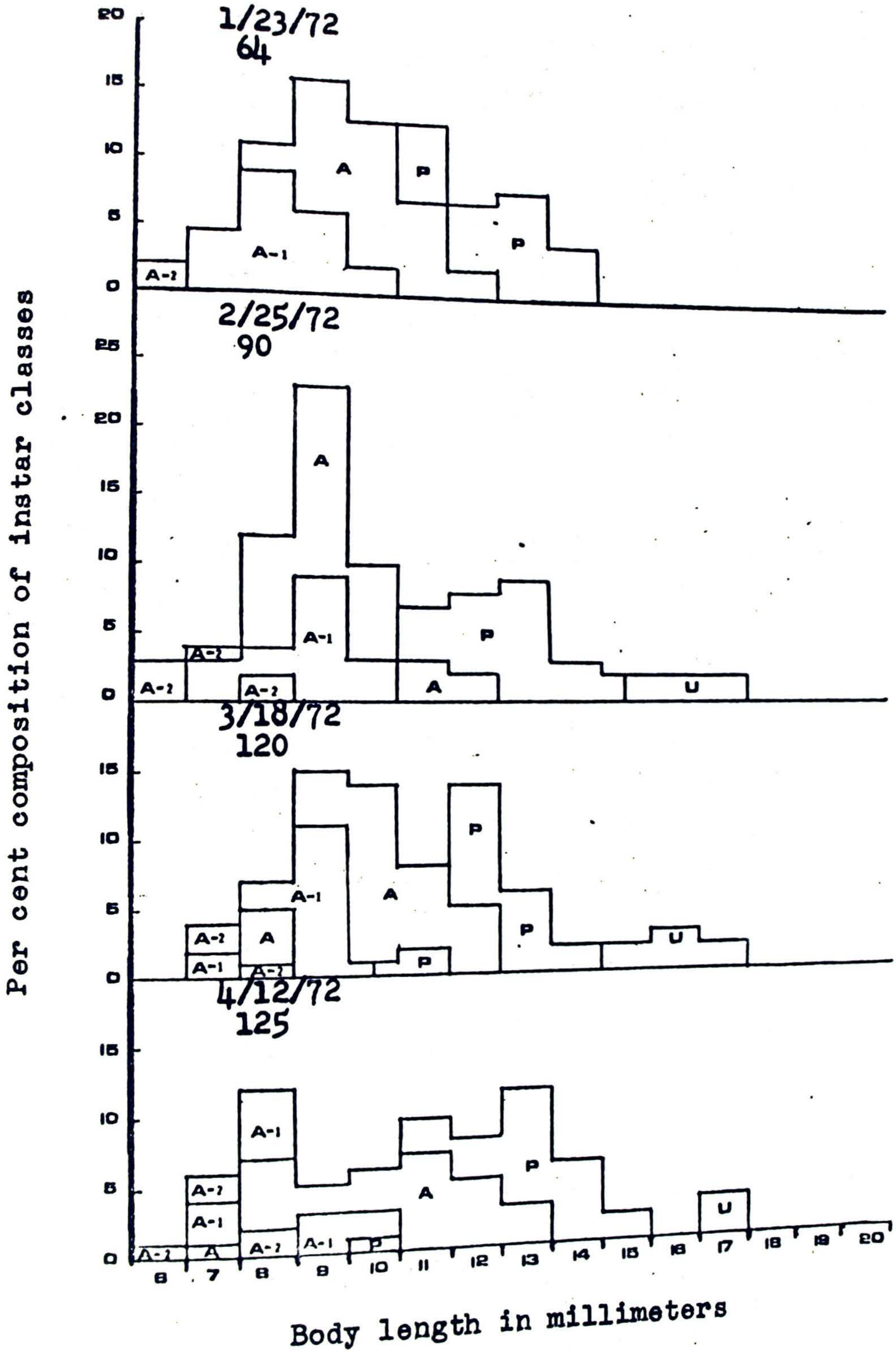


Figure 3. (continued)

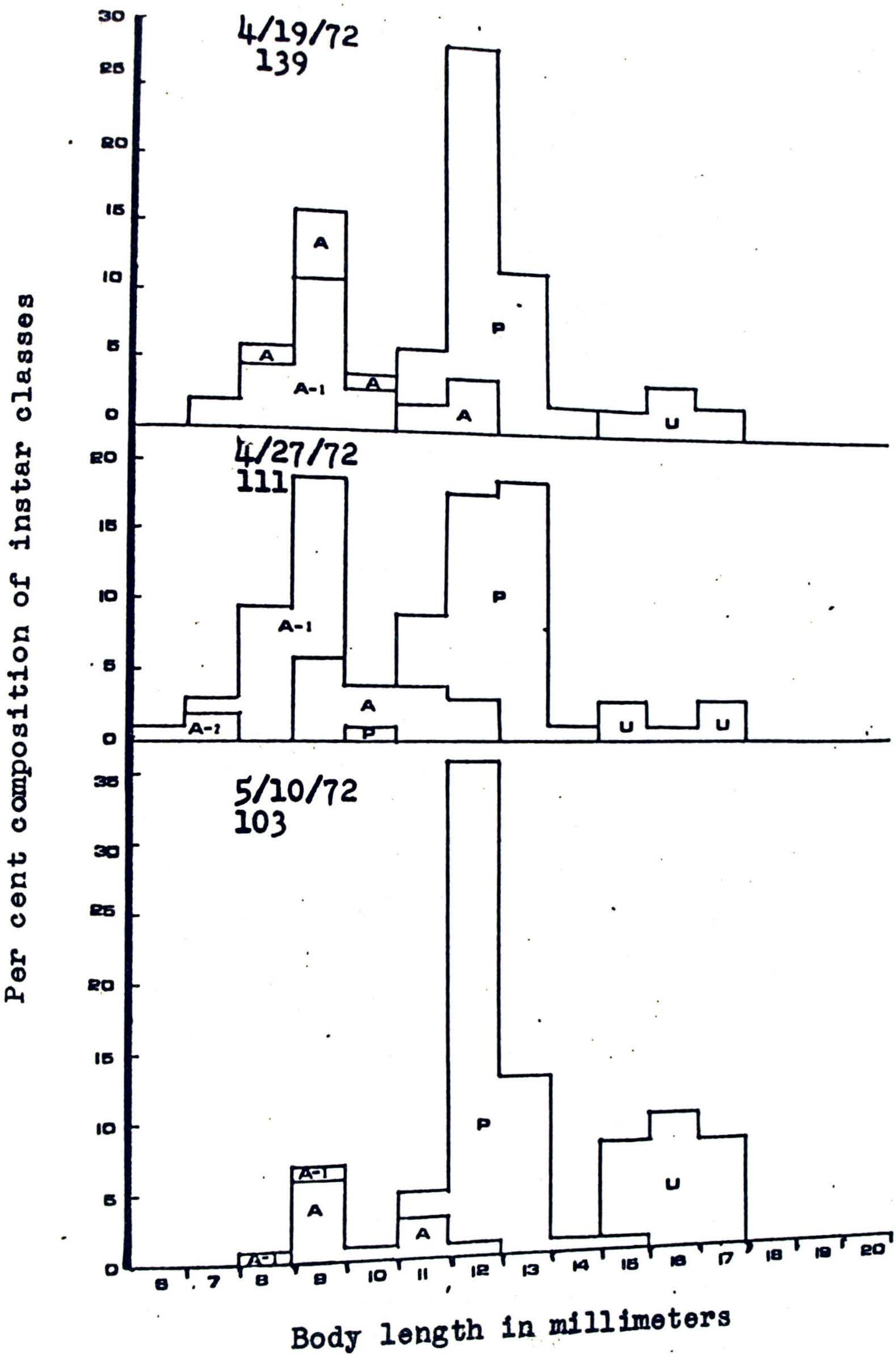


Figure 3. (continued)

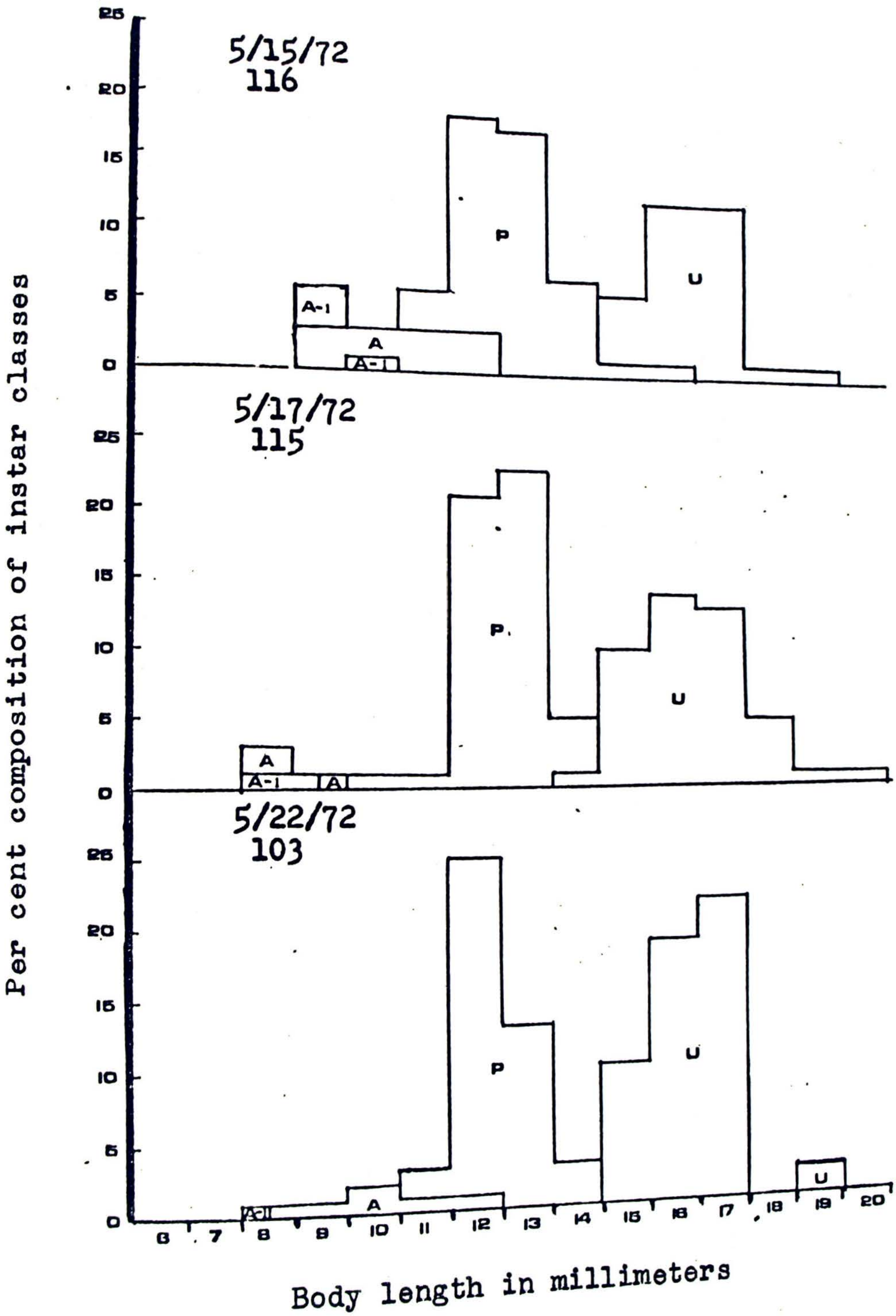


Figure 3. (continued)

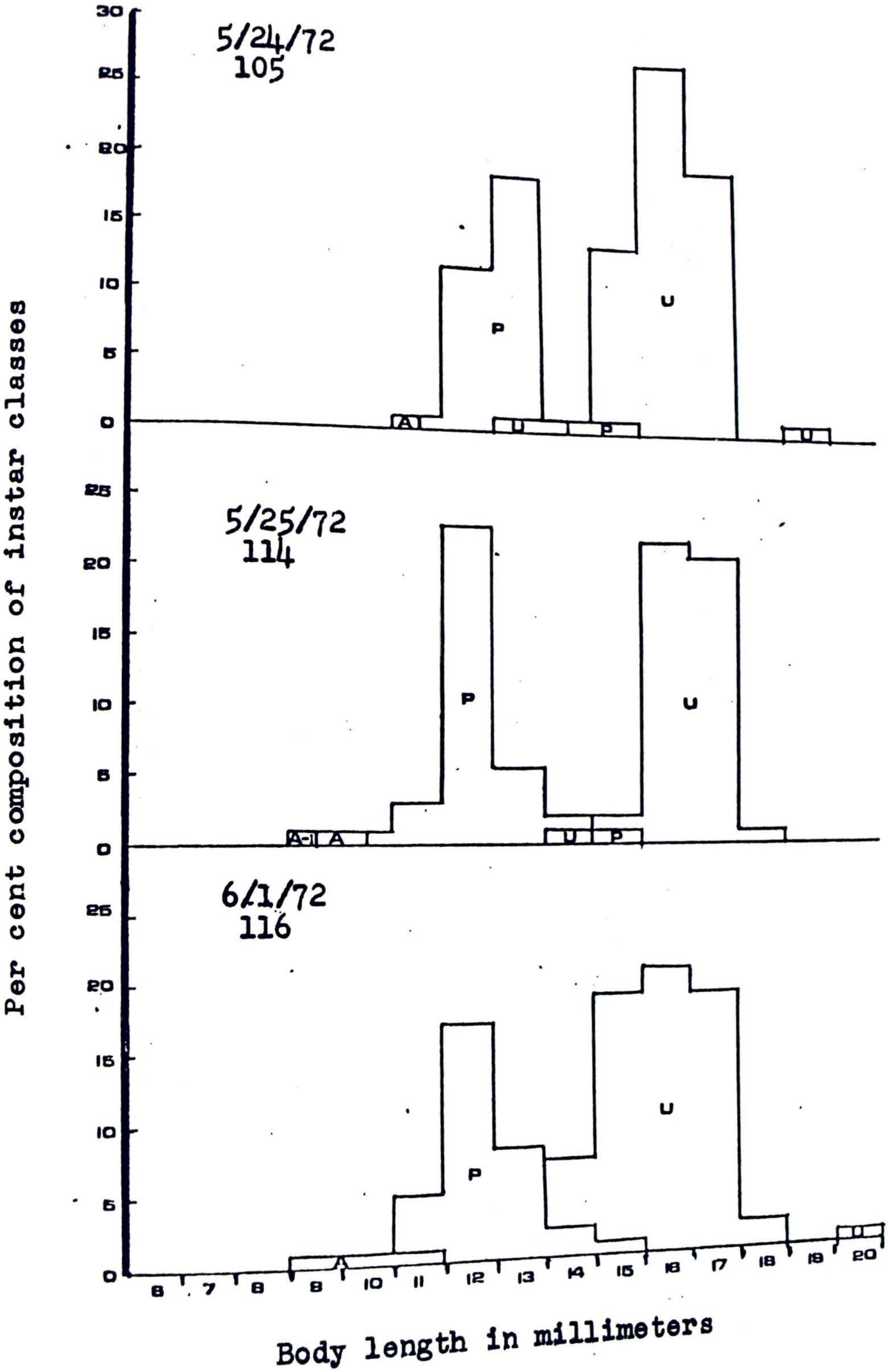


Figure 3. (continued)

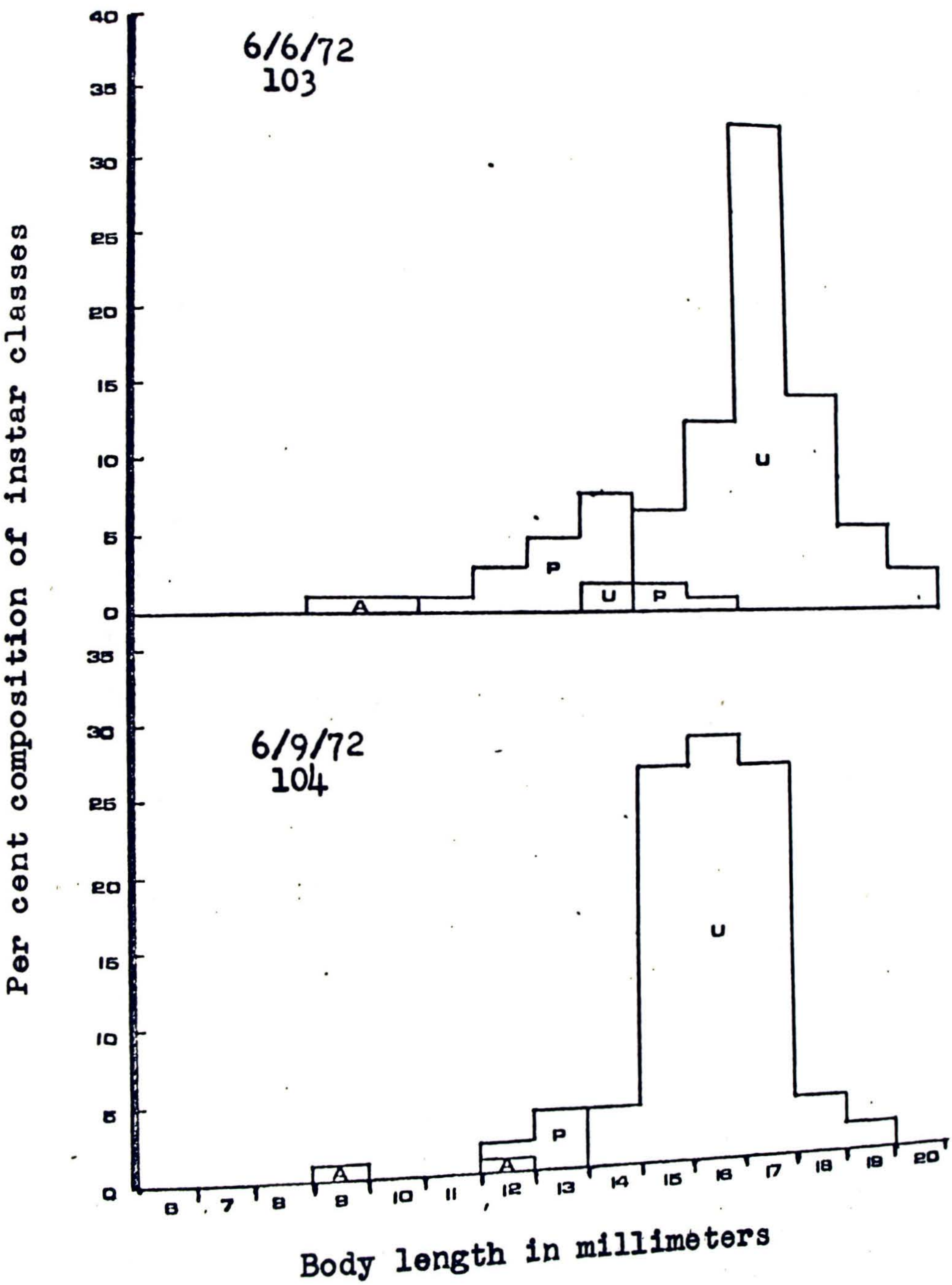


Figure 3. (continued)

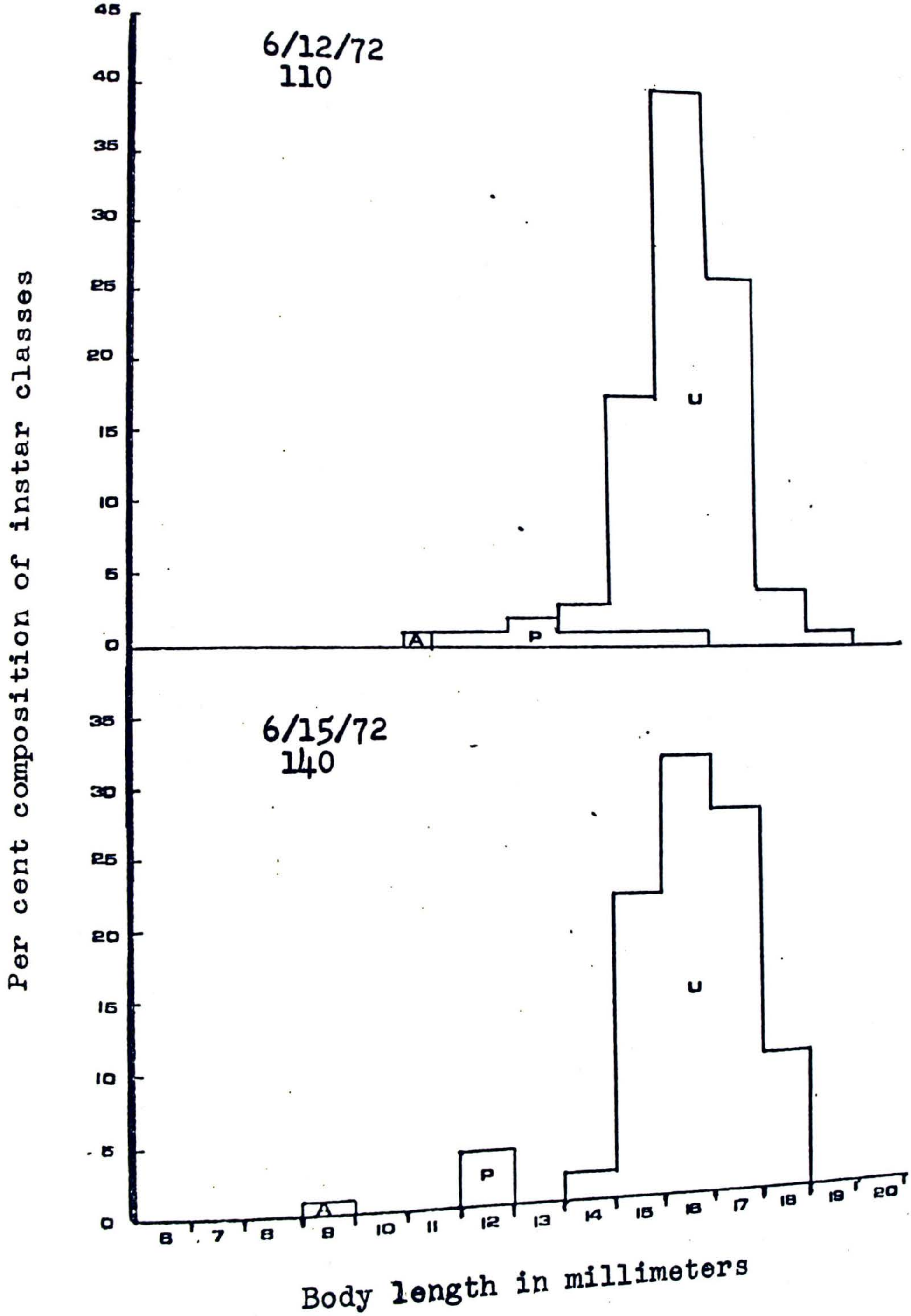


Figure 3. (continued)

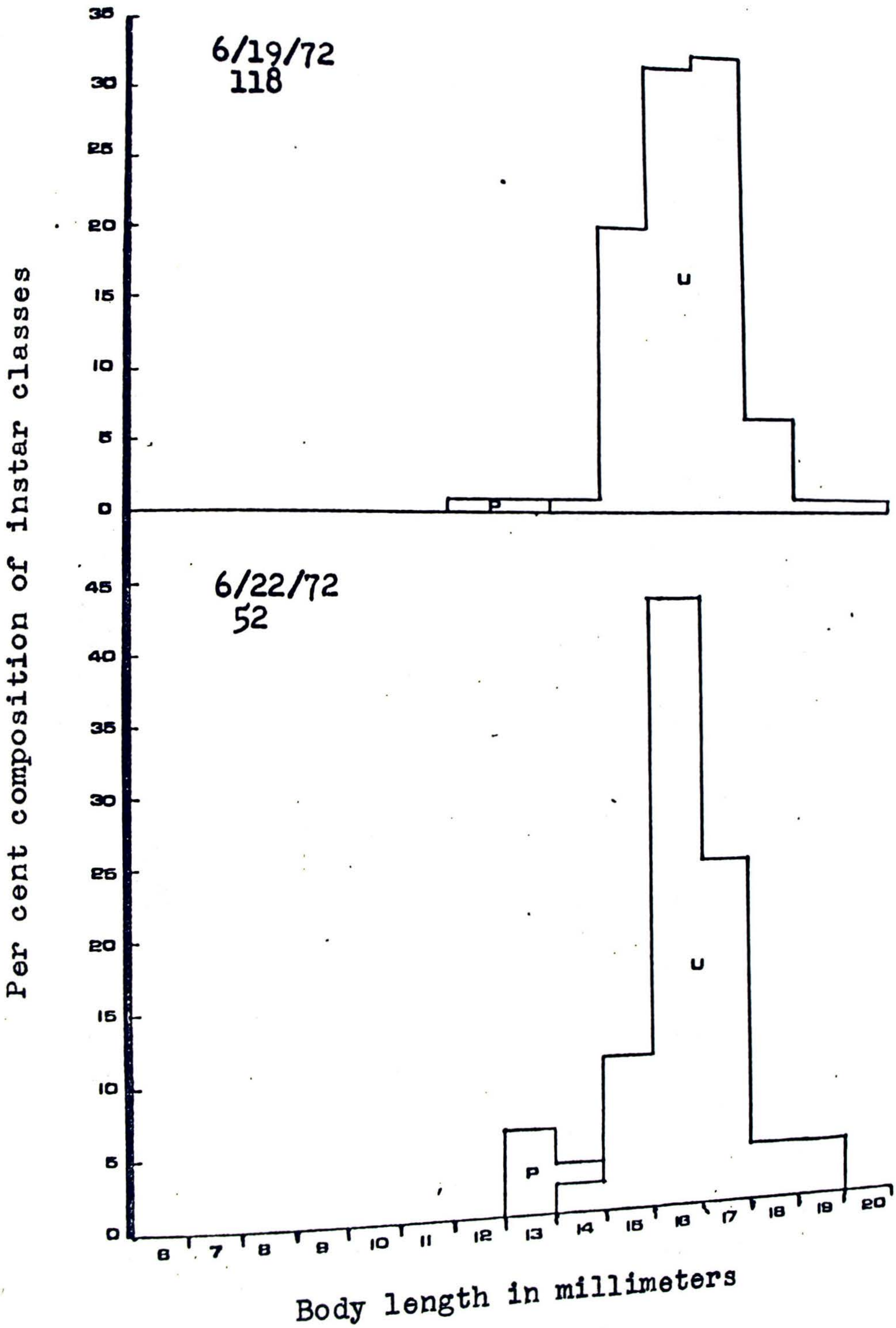
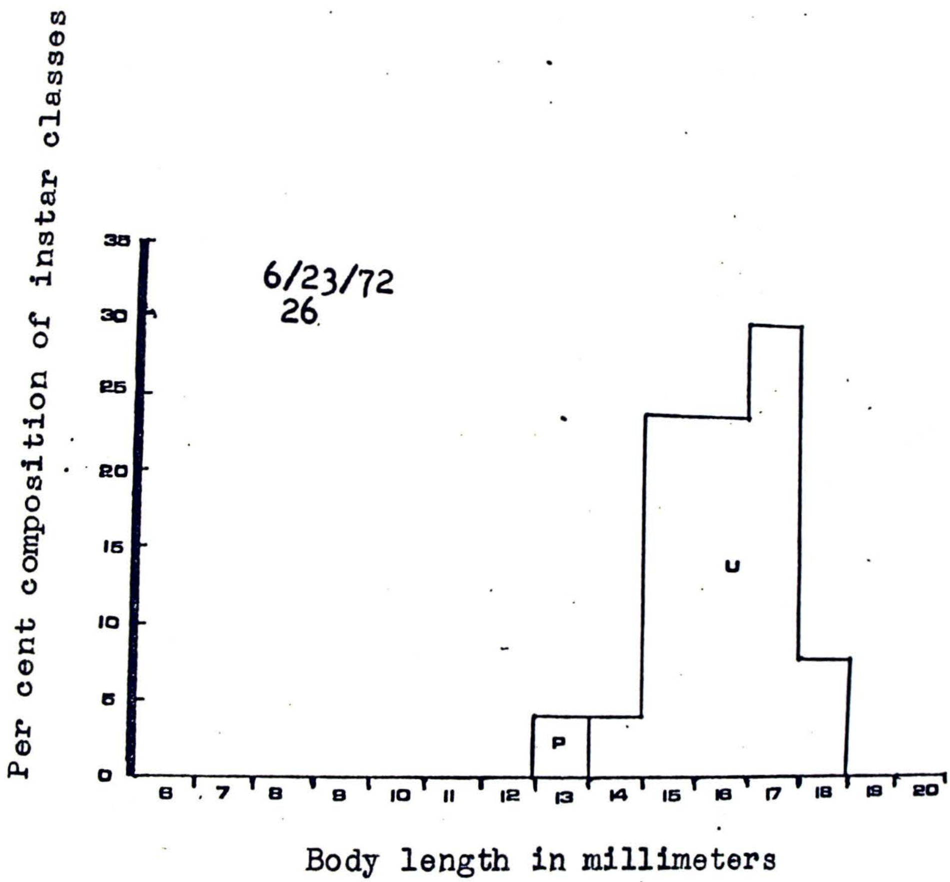


Figure 3. (continued)



of length for each instar class was computed for each collection date. The largest percentage of A-2 instars had a body length of 6-7 millimeters; the A-1 instars, 8-9 millimeters; the Antepenultimate instars, 9-11 millimeters, the Penultimate instars, 12-13 millimeters; and the Ultimate instars, 16-17 millimeters.

Eclosion: Emergence of the first imago occurred on May 25. The date of eclosion was established by collection of exuviae (Figure 4.). The first exuvia was collected on May 25. No other exuviae were shed until June 1. By June 9 the rate of emergence had reached its peak. June 12 through June 19 had become a period of stability in which a plateau was attained. On June 22 the rate of emergence had declined and proceeded with a downward trend.

The population structure of the nymphs remaining in the pond at the time of eclosion was restricted to the final three instar classes (Table IV). The Antepenultimate class comprised 2 per cent of the population; the Penultimate class, 34 per cent; and the Ultimate class, 63 per cent.

The appearance of the first pre-moulting instar with an eye index measurement of 0 occurred on May 15 (Figure 1.). A ten day lag occurred between the first 0 eye index measurement and emergence of the first imago.

The last teneral instar in the Penultimate class was found on June 6. After that date, the remaining

Figure 4. Exuviae collected during eclosion from May 25, 1972 to June 23, 1972.

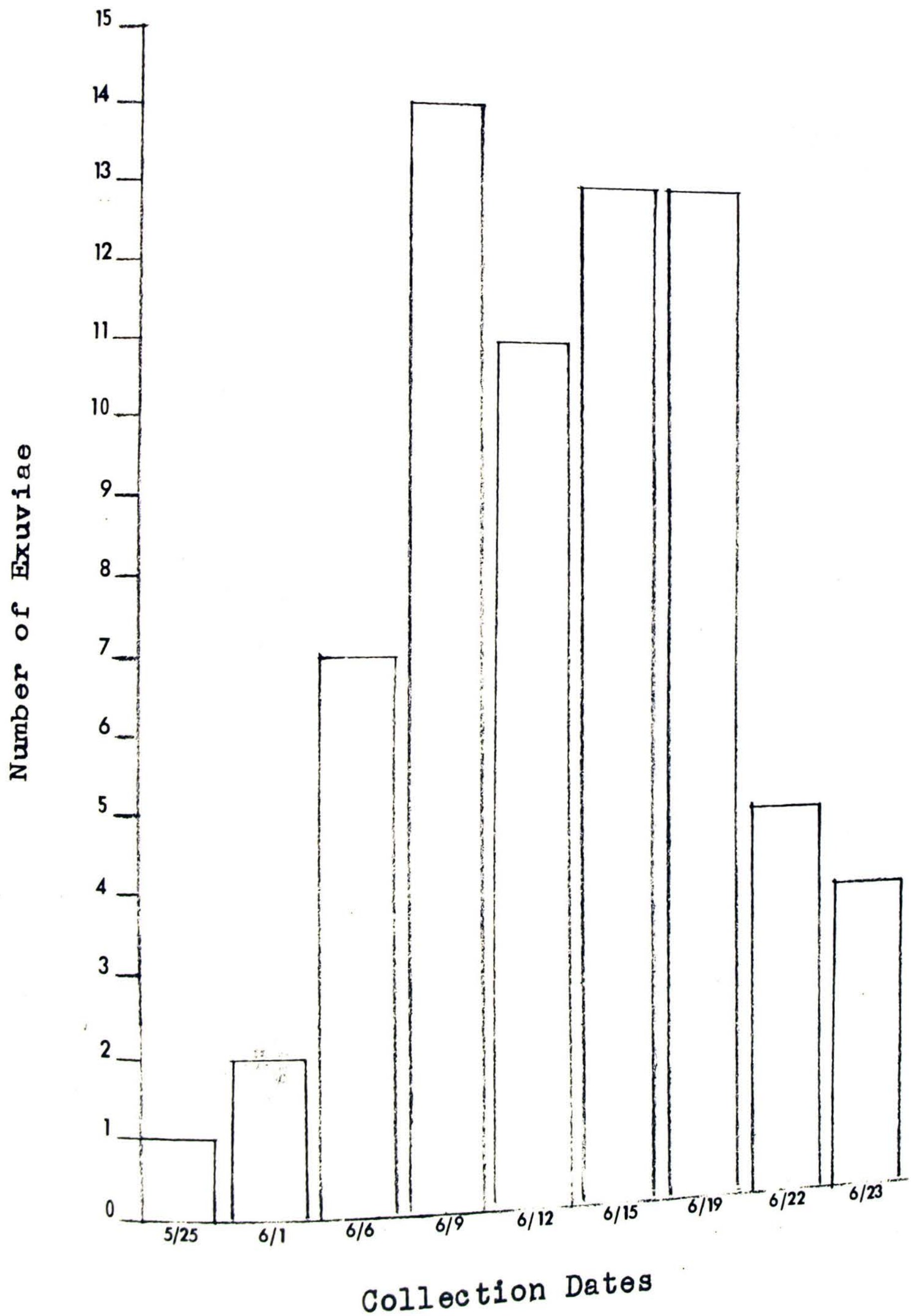


TABLE IV

Per cent composition of instar classes after first date of eclosion from May 25, 1972 to June 23, 1972

N = Number of specimens collected
A-2 = two stages preceding the Antepenultimate
A-1 = one stage preceding the Antepenultimate
A = Antepenultimates
P = Penultimates
U = Ultimates

Date	N	A-2	A-1	A	P	U
May 25	114	0.00	0.88	1.75	34.21	63.16
June 1	116	0.00	0.00	2.59	31.03	66.38
June 6	103	0.00	0.00	1.94	19.42	78.64
June 9	104	0.00	0.00	1.92	5.77	92.31
June 12	110	0.00	0.00	0.91	6.36	92.73
June 15	140	0.00	0.00	0.71	4.28	95.00
June 19	118	0.00	0.00	0.00	1.69	98.31
June 22	52	0.00	0.00	0.00	9.62	90.38
June 23	26	0.00	0.00	0.00	3.85	96.15

tenerals were contained in the Ultimate class (Figure 1.). By June 19 there were only two remaining instar classes in the population; Penultimate and Ultimate classes (Table IV). At that time 60 per cent of the Ultimate instars had an eye index reading of 0 (Figure 1.).

The length-frequency histogram of June 6 denoted a high percentage of the Ultimate class at the 17 millimeter measurement (Figure 3.) The June 19 length-frequency histogram illustrated the great migration of all instar classes into the Ultimate class. The Penultimate class, with a mean body length of 12 millimeters, comprised less than 2 per cent of the total population. The remaining 98 per cent of the population, of which approximately 35 per cent had a mean length of 17 millimeters, were contained in the Ultimate class (Figure 3.).

CHAPTER V

DISCUSSION

<u>The overwintering population:</u> Andrewartha (1952) termed the diapause stage as meaning that stage in the life cycle during which morphogenesis was more or less at a standstill. Physiological development, which occurred during the diapause stage in preparation for the active resumption of morphogenesis, was referred to as diapause development. It was found that morphogenesis would not proceed from certain stages unless exposed to low temperatures within a range which would permit diapause development (5-13 degrees Celsius).

The constant state of the composition of the overwintering population (Table II) was maintained because morphogenesis had come to a standstill. This was attributed to the low temperatures which were in effect at that period of nymphal development.

Five instar classes comprised the overwintering population with the Antepenultimates being the dominant class. The Ultimate class accounted for 3.33 per cent of the total population. The presence of that instar class indicated the possibility of a semivoltine life cycle for this species in a temporary pond. These results agree with study conducted by Eller (1963) in a permanent pond.

The cooler temperatures of autumn slowed morphogenesis in the instar classes. Morphogenesis in the population ceased when the winter temperatures dropped to within a range which would permit diapause development. Low temperatures after diapause prevented morphogenesis of all classes.

Thus the Ultimate instars in the population could not attain the goal of eclosion until the higher temperatures of spring allowed morphogenesis to resume (Figure 1.). This phenomenon has been noted in several life cycles by Corbet et al (1960).

Eller (1963) in his study of seasonal regulation of *Pachydiplax longipennis*, reported that the instar class composition of the nymphal population remained constant from the termination of morphogenesis in the autumn until its resumption in the spring. His results showed that five instar classes, dominated by the Antepenultimate class, comprised the overwintering population. Of the total population, he found that 97-98 per cent of the population displayed a univoltine life cycle while the remaining 2-3 per cent were semivoltine.

Resumption of morphogenesis: Andrewartha (1952) found that high temperatures (17-35 degrees Celsius) permitted the progression of morphogenesis. Morphogenesis in *Pachydiplax longipennis* was found by Eller (1963) to occur most favorably at 22 degrees Celsius.

In the present study, resumption of the morphogenesis was observed at the first part of April. The rise in water temperature to 23 degrees Celsius was considered the chief factor in the progression of morphogenesis and ecdysis. At that time, a shift in the population had occurred with emphasis on the Penultimate class. The high rate at which the population moved into the new classes was regulated by morphogenesis and ecdysis.

The first tenerals or new recruits were observed on April 12 (Figure 1.). The tenerals of the Antepenultimate-minus-one, the Antepenultimate, and the Penultimate classes were delimited by a 1.2 millimeter eye index measurement. The tenerals of the Ultimate class were delimited by a 0.96 millimeter eye index measurement.

By May 10 the Antepenultimate-minus-two instars no longer comprised a class in the population structure. May 24 marked the disappearance of the Antepenultimate-minus-one class from the population. The Antepenultimate class persisted for almost a month after the loss of the former classes; however, on June 19 the Antepenultimate class, too, succumbed to the migratory pressures of morphogenesis and ecdysis.

<u>Eclosion</u>: In the present study, emergence of the first imago was observed on May 25. Eller (1963) found that his populations emerged on May 23. In both instances, the dates of emergence were determined by collection of the exuviae.

The first exuvia was collected on May 25. Because of a stationary cold front in the area, the water temperature was lowered by 9 degrees Celsius. Thus a period of one week passed without emergence of another imago. By June 1 the temperature had risen and imagoes again emerged. Then the appearance of a second stationary cold front delayed emergence until June 6. The peak of emergence was observed on June 9. The emerging population reached a plateau between the dates of June 12 and June 19. By June 22 the rate of emergence had declined rapidly (Figure 4.). This condition was attributed to the depletion of the Ultimate class from the population.

Eller (1963) made a thorough study of a population of _Pachydiplax longipennis_ inhabiting a permanent pond in Chapel Hill, North Carolina. He has suggested that it is a "summer species" with a life cycle similar to that of the "spring species," _Tetragoneuria cynosura_, later studied by Lutz and Jenner (1964). The structure of the overwintering population, the resumption of morphogenesis, and the period of eclosion as observed in the present study were in agreement with the results found by Eller (1963). _Pachydiplax longipennis_ inhabiting a traditional temporary pond situation exhibited a life history simolar to a population of _Pachydiplax longipennis_ inhabiting a permanent pond situation. The differences in longitude between the two populations seemed to have no effect on the life history of _Pachydiplax longipennis_.

CHAPTER VI

SUMMARY

The present investigation was undertaken to determine the pattern of development in Pachydiplax longipennis nymphs in a temporary pond situation in nature: 1) the composition of the instar classes and the dominant instar class in the overwintering population; 2) the resumption of morphogenesis; 3) the period of emergence and the beginning of the flight season.

Instar class composition remained stable throughout the winter months. Five instar classes comprised the overwintering nymphal population with the Antepenultimates being the dominant class.

In the first week of April, a shift in the population structure had taken place with emphasis on the Penultimate class. By May 10 the Antepenultimate-minus-two instars were no longer found in the field collections. After May 24 the Antepenultimate-minus-one class was no longer present in the field collections. By June 19 the Antepneultimate class was no longer found in the field collections. Emergence was first observed on May 25. The peak of emergence apparently occurred around June 9. Emergence became stationary and remained constant through June 19.

After June 22 the rate of emergence declined rapidly. An exhaustive search conducted on June 23 yielded only twenty-six nymphs remaining in the temporary pond.

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