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Observations on the Phenology and Ecology of Amphibia in the Region of Częstochowa

[Pp. 391—460, with 8 text-figs]

Obserwacje nad fenologią i ekologią płazów w okolicach Częstochowy

Исследования по фенологии и экологии земноводных в окрестностях Ченстоховы

Abstract. This paper presents the results of ten-year investigation on the phenology and ecology of 11 amphibian species occurring in the Częstochowa region (51°N, 19°E, altitude — 200—400 m a.s.l.). Identical observations were carried out in five different sites at the same time. The area covered by study was about 50 sq. km. Attention was given to the biological succession of all the main stages of the 11 amphibian species: the beginning of active life, mating season, development of embryos and larvae, active life after the mating season, autumn migrations and hibernation. The dependence of the time of phenological phenomena upon meteorological conditions varying from year to year was also investigated. The optimum temperatures, most favourable to the biological processes of particular species, were determined. Much attention was given to the mating season and to the causes and conditions of spring and autumn migrations. The minimum and maximum periods of hibernation are given in tables. The observation material is illustrated with phenograms, tables and graphs.

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INTRODUCTION

Polish herpetology lacks comprehensive phenological studies which would both cover all the amphibian species of this country and deal with important abiotic factors that influence the ways of life of these animals. This is why Roszkowski (1924) wrote that nearly all that was known of the periodical phenomena in the life of amphibians concerned the regions situated to the west of Poland and that it was necessary to collect phenological materials in various parts of Poland. This still remains a question of the moment. Thus, 40 years later Kowalski and Młynarski (1965) emphasize lack of continuous phenomenological observations concerning the mating season and hibernation in amphibians and reptiles in mountainous regions. "This question is generally poorly known and calls for a modern elaboration".

In Poland only Włodzimierz Juszczyk has been carrying out close studies on the annual rhythm in *Rana temporaria* and the genus *Triturus* for many years. Some of his studies have already been completed and published (Juszczyk, 1938, 1961, 1967a, b). In the paper entitled "The Phenomenon of Annual Rhythm in Amphibians" (1967) he presented ecograms of the amphibian species against the annual cycle of their life, paying attention to essential vital phenomena of these animals.

Out of the other publications contributing many new data to the phenology of amphibians, we must mention atlases of and keys to the vertebrates of Poland (Bayger, 1937; Berger and Michałowski, 1963; Młynarski, 1966) and the studies on biological mechanisms existing in animal organisms and controlling the alternating periods of activity and rest (Emme, 1962; Cena and Wołoszyn, 1966).

Numerous papers by Juszczyk (1938, 1967a, b) and Riabinin (1955, 1961, 1968a, b and others) mention the achievements of the phenologico-ecological investigations carried out in this country and suggest some subjects for study in the near future. Among the most important tasks in the field of animal phenology these authors place the focusing of studies on autonomous scientific problems, the carrying-out of observation on material obtained from natural environments, the relating of the results of studies to the climatic and ecological factors, and the conducting of observation throughout the year so as to cover all the biological phenomena in the life of animals under study.

In 1960—1968 I carried out systematic investigation on the annual rhythm of amphibians in the region of Częstochowa, situated at 51°N and 19°E and at an altitude of somewhat above 200 m a.s.l. I selected environments which contrast with each other and are typical of the given region. The Olsztyński Forest near Kucelinka is a typical coniferous forest, whereas in the Blachownia region there are deciduous and mixed forests. The site at Ostatni Grosz represents vanishing peatbogs and moors and Brzeziny lies in a dry sandy area, resembling a desert in places. Złoty Potok is a nature reserve with numerous weathering limestone island rocks (monadnocks) grown over by deciduous wood.

In my observation I included the biological succession of all fundamental stages of 11 amphibian species: the outset of active life and mating season, the development of embryos and larvae, the active life after the mating season, autumnal migrations and hibernation.

I also investigated the dependence of the time of phenological occurrences upon meteorological-climatic conditions, varying from year to year; this makes it possible to distinguish some regularities and make generalizations.

CHARACTERISTICS OF STUDY AREA

On Romer's map of climatic areas the Częstochowa District is included in the climatic region named the Śląsk—Kraków Uplands. As regards climate and biotopic conditions the character of this region is very varied.

The Kraków—Częstochowa Ridge extends in the southern part of this district. The ridge consists of a number of detached hills, often divided by wide and shallow valleys. The hills average 300—400 m in altitude. They are covered by thick deciduous forests with surprisingly numerous tree species.

A large plain lies south-west and north-east of the Kraków—Częstochowa Jurassic Ridge. No limestone hills can be seen here, for the Jurassic formations are overlain by later glacial deposits. Half the area of the Częstochowa plain is under cultivation and about 25 per cent of it is occupied by mixed forests in which the pine predominates evidently.

The climate of the Częstochowa region is characterized by great variation and remarkable fluctuations in the progress of the seasons in consecutive years. One of the main factors which has a specific effect on the climatic conditions is rainfall. In this region about 40 per cent of the total rainfall falls in the summer months, 16 per cent in the winter months, and the rest in the spring and autumn periods.

According to the data of the Hydrological-Meteorological Station, PIHM, at Częstochowa (261 m a.s.l.), the values of the basic elements of climate are as follows (Table I).

Table I

The data on meteorological factors in the investigation area in 1965

Meteorological factor	Months												year 1965
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	
Mean temperature of month	2,5	1,6	2,1	7,2	13	16	17,8	16,8	13,2	7,9	2,6	0,9	7,6
Rainfall, in mm	40	34	38	54	66	84	102	77	52	49	43	41	680
Number of days with snow cover	16	16	6	1	—	—	—	—	—	—	—	—	39
Number of days with precipitation	14	13	12	14	13	14	14	13	14	13	13	12	159

The annual amplitude is 20·3°C. The vegetation season with mean temperatures above 0°C lasts from 27 March to 17 November (= 236 days) and with mean temperatures above 5°C from 1 May to 4 November (= 218 days).

Taking into consideration the fact that systematic phenological observations were carried out at four selected localities (Kucelinka, Brzeziny, Blachownia, Ostatni Grosz) and sporadically at Złoty Potok, which are marked by specific ecological-biological characteristics and lie a long way from each other, below I give short descriptions of particular environments.

1. Kucelinka

The region of Kucelinka is situated in a partly wooded area of the Kraków—Częstochowa Jurassic Ridge.

The whole area is covered with a thick layer of diluvial sands overlying the primary Jurassic formations, which outcrop at places only and form limestone hills.

The wide valleys that stretch between hills and the plains are overgrown with coniferous and mixed woods and the Jurassic karst island hills with rich deciduous vegetation. The occasional peatbogs and marshes abound in various sorts of quagmires, exploited claypits, seasonally drying-up or lasting puddles. Along the Warta River there are old riverbeds, which are now being overgrown with vegetation.

2. Brzeziny

The village of Brzeziny lies 6 km south of Częstochowa. It is surrounded by woodless area all around, cultivated fields, pastures, fallows and meadows providing habitats for thermophilous species.

The soil is mostly sandy and poor. The region is deficient in water, owing to the permeability of sands. Its part situated between Brzeziny and Częstochowa, 24 hectares in area, resembles a desert to some degree. Barren sands are only partly covered with heather, lichens and wasted flower plants. The most valuable feature of this area are its contrasts. Dry heated sands border upon small swamps and lasting or seasonal water reservoirs left after the exploitation of sandbeds. On account of the great exposure to the sun's rays, the temperature in this region is markedly higher than in the surrounding areas. Here snow thaws earlier and the *Urodela* and *Anura* leave their winter shelters earlier in the spring.

The country lowers considerably south of Brzeziny and is crossed by a small rivulet, the Brzezinka (a tributary of the Konopka), which flows in a wide valley. The river valley abounds in old riverbeds and small pools of still water, providing favourable conditions for the reproduction and life of amphibians.

3. Ostatni Grosz

A vanishing peatbog and moor, about 4 square kilometres in area, lies in the vicinity of Częstochowa, south-west of the town. The deforestation of this area caused far-reaching changes in the climatic and water-soil conditions and contributed to the extinction of many plant and animal species adapted to life in an exclusively marsh environment.

A pond and several smaller water reservoirs occur in the central part of this area. The area of the largest pond is about 500 square metres.

Early in the spring, in the mating season, aggregations of common and field frogs are conspicuous. These animals haunt both in the zone near the banks of the large pond and in inaccessible pools situated in the bogs.

4. Blachownia

Blachownia lies 12 km west of Częstochowa. It is a sort of clearing in the forest. Pine and mixed forests stretch as far west and south as Opole. The area of sandy soil, north-east of Blachownia, is covered with uniform coniferous pine-dominant forest. Areas of clayey soil, situated lower, are grown over by denser and wetter woods. Here grow oaks with an admixture of birches, forming magnificent woods, called "dąbrowy". The peatbogs and marshes are grown over by the dwarfed pine and birch.

In this region there are a few large ponds and more than ten smaller ones, about 50 hectares in area altogether. All the ponds have a long past history and are rich in the flora and fauna. For its proximity to Częstochowa and the beauty of nature the Blachownia region is frequently visited by naturalists and geographers.

5. Złoty Potok

Złoty Potok is situated 28 km east of Częstochowa in the Kraków—Częstochowa Jurassic Ridge. It is characterized by a great variety of its flora and fauna. A long chain of more than 30 fish-ponds, connected with each other by the very rapid Bystrzyca River, extends between two elevations of the Jurassic Ridge. The banks of the ponds are hard and accessible, being covered with deciduous trees and shrubs at places. The ponds are generally shallow, with a sandy or rocky bottom and with clear and always cold water. Gucowski Pond is the most beautiful of them.

High rocky limestone hills rise east and west of the ponds and are covered with oak-beech woods. Streams of extremely cold and clear water well mightily up from under the rocks. This is really a sort of oasis of coolness, dampness and shade.

The park at Złoty Potok and oak-beech woods on the rocky hills beside the ponds have been separated as a National Reserve of Nature.

METHODS

Among the physical factors that exert an influence on the biology of amphibians I number, in the first place, the air, soil and water temperatures, the exposure to the sun's rays, and the humidity of the atmosphere.

I measured air temperature at a standard height of 2 m above the ground twice a day. The maximum air temperatures were recorded between 1 and 2 p.m. and the minimum ones at 1 or 7 a.m.

Soil temperature was measured at a depth of 10 cm in all the five study areas twice daily: at 2—3 p.m. to record the maximum temperatures and at 6—7 a.m. for the minimum temperatures.

In view of the fact that the amplitudes of water temperature are slight, I took temperature at a depth of 10 cm once daily, at 3 p.m. The temperature of the upper layers of water is always higher than that of the lower layers and the difference may reach 2—3°C, but the mating specimens and the embryos and larvae which develop in the following period generally stay in the upper and, consequently, warmer water layers.

The humidity of the air was measured using a hair hygrometer also at 3 p.m. The humidity of the air in early morning hours and late in the evening and, especially, by night is, as a rule, remarkably higher than it is in the daytime, and for this reason the humidity measured at 3 p.m. may be regarded as the lowest.

I determined the weather conditions (insolation, cloudiness, and rainfall) on the basis of my observations made during a day and night. The air and soil temperatures in the open area and the humidity of the air have been compared with the data obtained from the Hydrological-Meteorological Station, P.I.H.M., at Częstochowa. Our records are either very similar or, most frequently, identical.

Phenological observation of amphibians was made at different hours of day and night everyday so as not to fail to observe the most important moments connected with the subject of this study. During the mating season the specimens of particular species were kept under constant observation from early morning till night. In the case of species which mate also in the night observation was continued into the night. I did not move from one site to another until the intensity of the process observed had slackened.

The action of low temperatures as a factor that inhibits life processes was observed during the spells of rapid cooling in the natural habitats of amphibians, whereas the influence of high temperatures, torridity, and low humidity upon various aspects of life manifestations in amphibians, when such weather conditions occurred in the study area. I searched the sand at the bottom of holes and ditches for winter shelters of the spadefoot toad and natterjack, which hibernated there in masses. The winter quarters of the other amphibians are relatively shallow and easier to find.

In the autumn I also observed the migrations of amphibians to their winter shelters and recorded the time of their sinking into winter sleep.

I produced appropriate equipment for catching amphibians and their larvae to make measurements and observations on them.

The results of observations in five study areas were plotted on special phenological charts illustrated by an example given below (Fig. 1). The phenological

Fig. 1. SITE 3 – OSTATNI GROSZ

1967																														
Air temperature /max/	9	6	9	9	9	7	8	12	16	23	17	19	15	15	15	18	19	16	6	12	16	9	8	4	5	6	8	8	14	18
Air temperature /min./	-1	1	0	3	1	4	4	1	4	12	9	4	8	9	5	5	7	4	0	1	6	1	1	1	0	1	1	4	4	5
Soil temperature /max./	3	3	4	4	3	5	6	6	8	16	11	11	11	10	11	15	15	12	3	6	11	7	6	3	3	4	5	6	8	14
Soil temperature /min./	0	0	1	2	2	2	3	3	4	6	6	6	6	6	5	4	6	4	3	5	4	4	3	2	2	3	4	5	5	5
Water temperature	8	7	8	9	9	8	8	9	11	15	14	15	14	13	12	16	17	13	6	8	11	9	7	4	4	5	7	8	11	15
Humidity of air, in %	75	80	85	90	80	100	100	80	100	60	65	65	95	95	65	50	85	75	75	70	80	80	80	95	100	100	100	100	95	50
Date	1 IV	2 IV	3 IV	4 IV	5 IV	6 IV	7 IV	8 IV	9 IV	10 IV	11 IV	12 IV	13 IV	14 IV	15 IV	16 IV	17 IV	18 IV	19 IV	20 IV	21 IV	22 IV	23 IV	24 IV	25 IV	26 IV	27 IV	28 IV	29 IV	30 IV

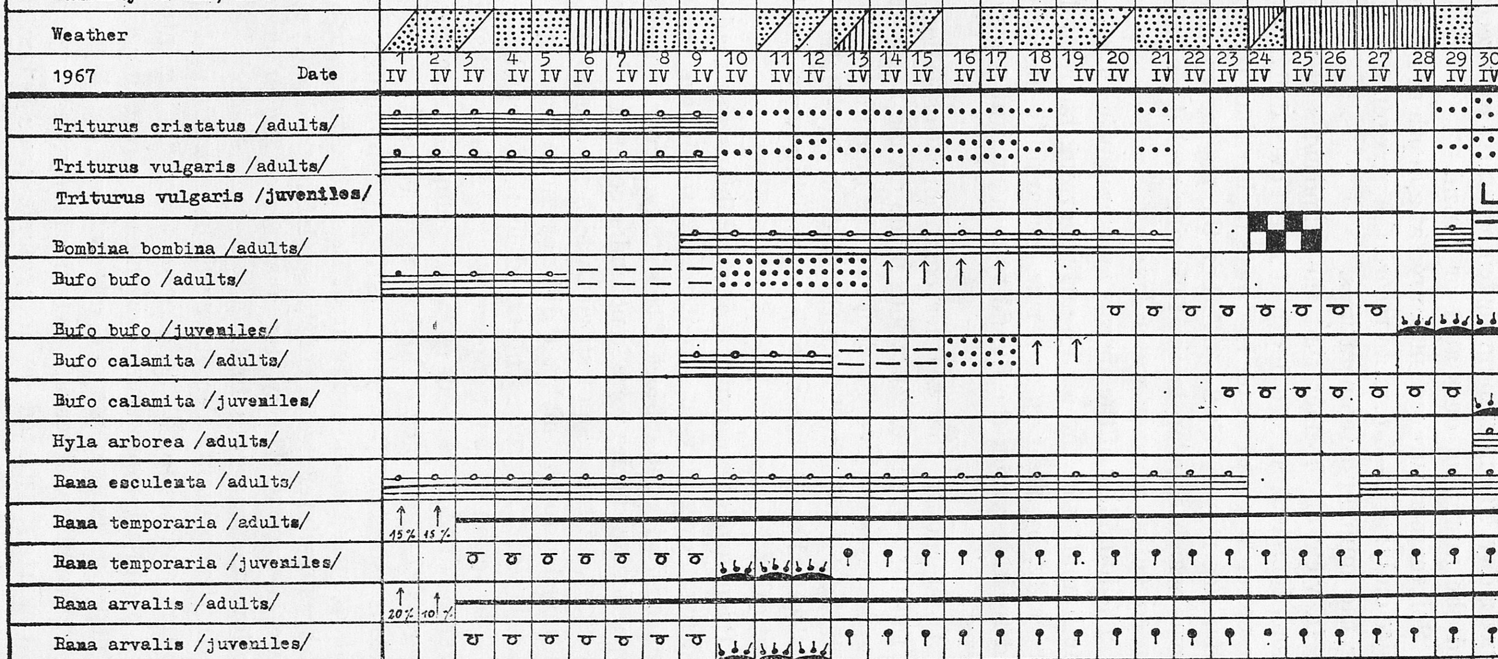
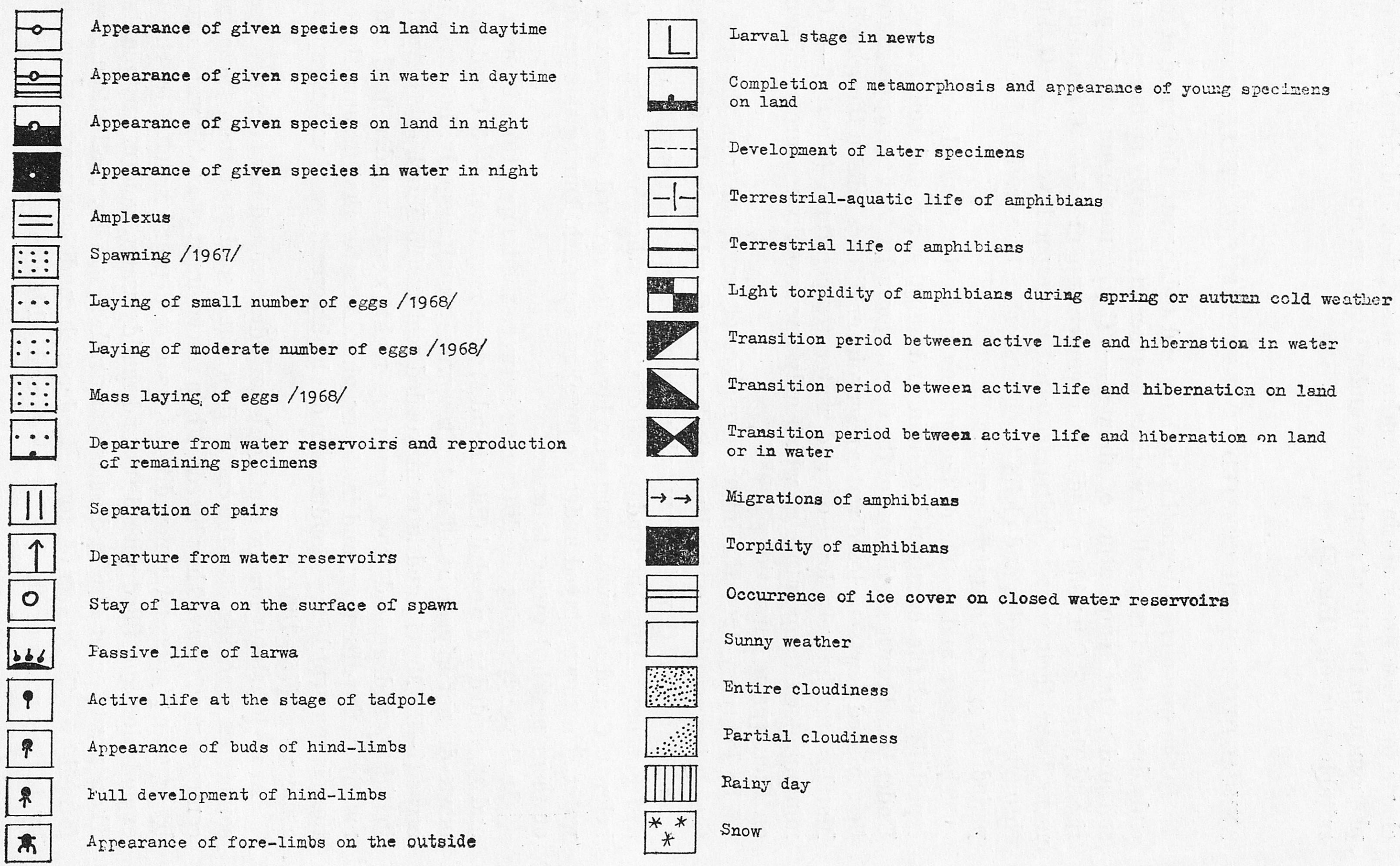


Fig.2. EXPLICATION OF SYMBOLS USED IN THE PHENOLOGICAL CHART



charts for these areas are in the author's possession. Individual processes and phenomena in the life of amphibians under study are represented in the chart by suitable symbols (Fig. 2).

ANNUAL CYCLE OF THE CRESTED NEWT *TRITURUS CRISTATUS* (LAURENTI, 1768)

In the specimens hibernating both on land and in water the period of torpidity ends during the first spell of warmer weather in the early spring, at a diurnal soil and water temperature of about 3—4°C (the maximum air temperatures rise to about 7°C in this period). At a temperature of 4·5—5°C the adult specimens leave their winter shelters situated in deeper layers of earth and pass through various holes and clefts to the superficial layer. This is a preparatory period for active terrestrial-aquatic life.

The outset and course of the mating migration depends on the weather, especially on the occurrence of rain and suitable air and soil temperatures. Under the climatic conditions of the Częstochowa District the appearance of the first crested newts in closed water reservoirs or ditches falls in the second half of March, at relatively low soil and water temperatures (about 5—7°C). The minimum soil temperature at which only few sexually mature specimens start on their spring migrations is 4°C.

In February 1968 the influx of masses of warm air from the west caused the air temperature to rise dramatically to 11°C and the soil and water temperatures to above 5°C, which resulted in the appearance of newts in water as early as 7 February. After the tenday spell of warm weather the temperature dropped below 0°C and a several-centimetre layer of ice covered the reservoirs of still water. The newts stayed under ice for about a month. During this period many of them perished owing to anoxia.

In the early spring the differences between the temperatures in open (Sites 2 and 3), shaded and wooded (Sites 1 and 4) areas may reach 4—5°C and this is why newts do not appear in all water reservoirs simultaneously, but first in open areas (7—15 March) and later in wooded regions (25 March — 10 April). Since in this period ground frost occurs by night, newts wander in the daytime, mostly in the afternoon and in the evening. A factor that favours these migrations is frequent heavy cloudiness and a high percentage of water vapour in the atmosphere (75—100%).

As their habitat for the mating season adult crested newts choose reservoirs, sometimes reaching 80—100 cm in depth and so deeper than those in which common newts stay. They breed both in reservoirs of clear still water overgrown by aquatic plants and in new ditches, pools or depressions left after clay or sand exploitation and filled with dirty and muddy water, void of any plants at all. These newts occur also in ditches along railway tracks, the bottom of which is formed by a thick layer of stones. Under such conditions newts are accompanied by fairly numerous fire-bellied toads and edible frogs.

The pre-mating period — from the appearance of the first specimens till egg-laying — lasts 12—27 days, being dependent on the prevailing weather conditions, and in 1968 it exceptionally lasted from 7 February to 15 April, or as many as 66 days.

Females begin to lay eggs in thick submerged vegetation about 10 April at a water temperature of 10—12°C. The mating season of newts lasts from 10—15 April to mid-June with short breaks caused by drops in water temperature below 9°C. Water temperatures between 15 and 20°C constitute the optimum conditions for egg-laying; such favourable conditions occur mostly in May, when female newts lay the largest numbers of eggs (several eggs daily). In the

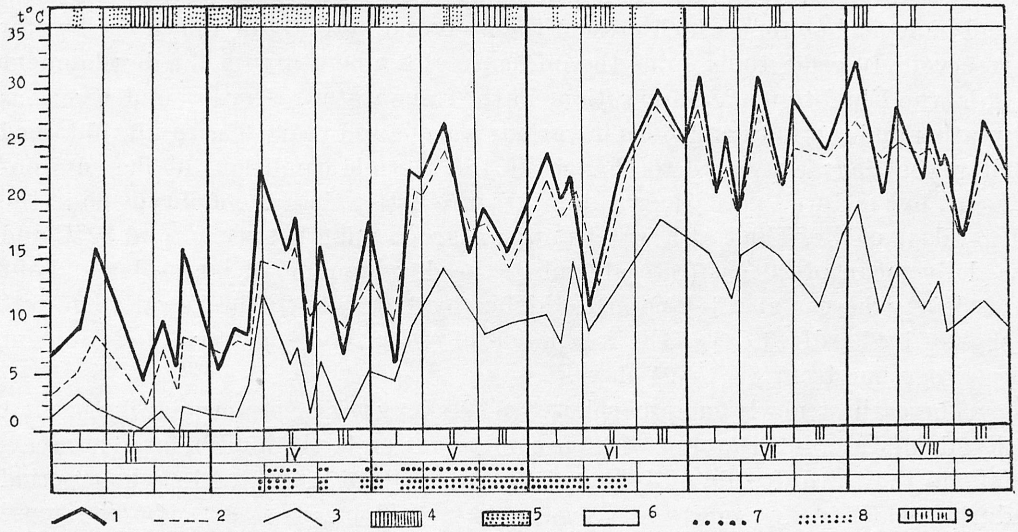


Fig. 3. Mating seasons of the crested newt *Triturus cristatus* (LAUR.) and the common newt *Triturus vulgaris* (L.) against the background of meteorological conditions (Site 1, 1967). Explanation of symbols: 1 maximum air temperatures, 2 maximum water temperatures, 3 minimum air temperatures, 4 rainy, 5 cloudy, 6 sunny, 7 mating season of crested newt, 8 mating season of common newt, 9 decades of month

second half of April the water temperature persists below the optimum values and in June it overtops them, and in these periods females lay at most one egg daily. Within the limits of extreme temperatures (10—27°C) newts mate both on rainy days and during fine sunny weather (at a relative humidity of 28—100%). However, the process of egg-laying is the intensest during rain or soon after it has stopped, since then all the sexually mature specimens participate in mating and the females lay two or, more rarely, three eggs daily.

Development of Embryo and Larva

The embryonic development of the newt, from the fertilization of the egg to the emergence of the larva from the double egg membrane, lasts 10 to 20 days in a natural environment. The length of this period is dependent, above all.

upon the water temperature, for the influence of nutritional, biological, chemical and other factors is here still out of question.

In the pond at Złoty Potok the larvae hatch after 20 days at a water temperature ranging between 4 and 17°C and a daily mean temperature of 10°C. The rise of the mean water temperature by 0·7°C shortens the developmental period by 1 day. At the other sites the mean temperature is considerably higher in April. At a water temperature between 7 and 20°C and a daily mean temperature of 12°C the embryonic stage lasts 17 days. At a water temperature of about 25°C the embryos developing in the eggs laid at Sites 1 and 2 towards the end of May leave the eggs as early as 10 days later (Table III).

The rate of development of larvae depends on a whole complex of ecological and biological factors, which present themselves differently in almost each water reservoir. In order to examine the influence of temperature on the development of larvae I had to make observations in the same water reservoirs under various weather and thermic conditions in various seasons and years. The results obtained show that larvae respond to changes in the thermic conditions of the environment, but endure fluctuations in temperature better than the embryos do in the first days of life. Thus, at a water temperature ranging between 7 and 32°C and a daily mean of 20·5°C (Sites 1 and 2) the development of larvae lasts about 72 days, whereas at a temperature higher by 1°C (Site 2) the larval stage was shorter by hardly 3 days. The full period of embryonic and larval development is altogether from 88 to 91 days.

The earliest newly metamorphosed newts leave water reservoirs in the first decade of July, but the time of their coming out on to the land in large numbers falls in the third decade of July and the first half of August. The whole period during which young newts leave water is fairly long, as it extends over more than 4 months (from the first decade of July to mid-November). A small number of larvae, namely those which develop from the eggs laid latest and fail to metamorphose by the middle of November, hibernate in this state without going through further metamorphosis till the spring of the next year. They hibernate at the bottom, in the bank zone of water reservoirs, amidst a thick growth of the water-thyme (*Elodea canadensis* Rich.), water nimfoil (*Myriaphyllum spicatum* L.), pond-weeds *(Potamogetonaceae)* and other plants, but most of the larvae perish of various causes in the winter-spring season.

Active Life after Mating Season

After the termination of the mating season the adult specimens leave the water environment (3rd decade of July—August) and live on land, especially in shady and damp places. Only a very small number of the specimens stay in fairly deep water reservoirs for a whole year. Terrestrial newts occur in nearly all types of biocenoses of this region, i.e. in forests, meadows and marshes. Their activity begins at twilight and lasts till dawn.

In the autumn characterized by a gradual drop in air, water and soil temperatures and great amplitudes between diurnal and morning temperatures (17—20° C), the agility of newts subsides and in this connection the intensity of food intake decreases considerably. In the first half of October, when the night temperatures drop to 3—5° C, a slight torpidity of these animals is observed; they become vigorous again in the afternoon owing to a remarkable rise in ambient temperature. The temperature at which they sink into torpidity is about 1—2° C. In forest sites with higher soil temperatures in the transitional period newts sink into winter sleep a few days later than the specimens hibernating in open areas do.

Tables II, III, V and VI present the meteorological conditions and the times of appearance, breeding, coming out on to land and sinking into torpidity for the crested newt in the Częstochowa region in 1960—1968.

ANNUAL CYCLE OF THE COMMON NEWT *TRITURUS VULGARIS* (LINNAEUS, 1758)

The waking of newts from torpidity is strictly dependent on the thermic conditions of the terrestrial environment in which they take shelter for winter. In warm and dry areas (Site 2) newts wake from winter sleep in the first decade of March, at a soil temperature of about 3° C. In the wooded area of the Kraków—Częstochowa Jurassic Ridge, characterized by a great variety of configuration,

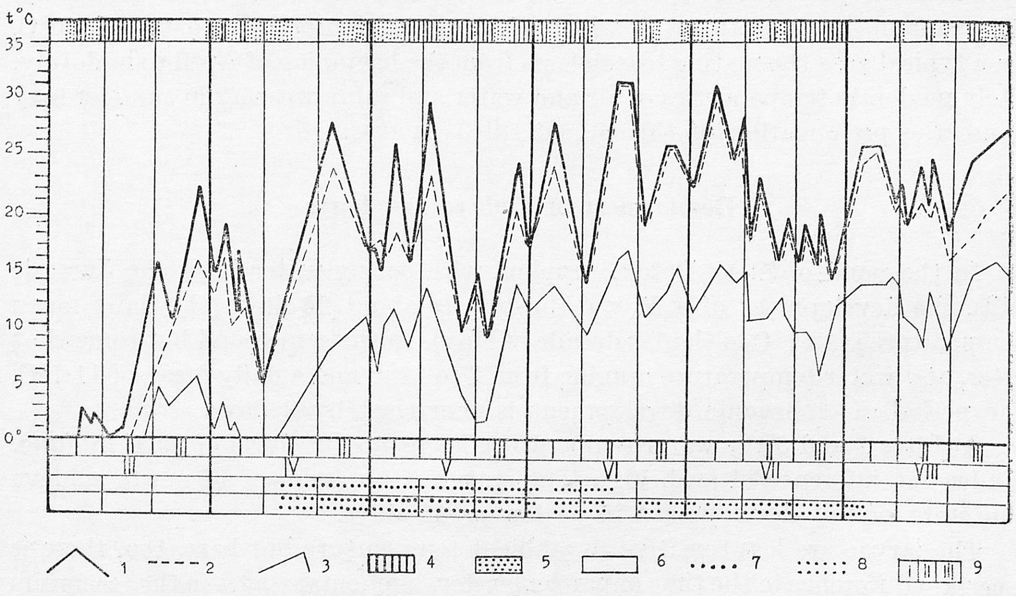


Fig. 4. Mating seasons of the crested newt *Triturus cristatus* (LAUR.) and the common newt *Triturus vulgaris* (L.) against the background of meteorological conditions (Site 1, 1968). Explanation of symbols: 1 maximum air temperatures, 2 maximum water temperatures, 3 minimum air temperatures, 4 rainy, 5 cloudy, 6 sunny, 7 mating season of crested newt, 8 mating season of common newt, 9 decades of month

the interval between the appearance of the first and last specimens in water reaches 20—30 days. The specimens hibernating in valleys, forest clearings, and light pine forests wake up from torpidity earlier and those taking shelter in rock clefts in the northern slopes of the Jurassic elevations, covered with damp deciduous forests, later. Ice and snow cover sometimes linger here up to 15—20 April, which, in turn, delays the moment of awakening of newts from torpidity. Generally speaking, in ill-differentiated woodless areas newts leave their winter shelters and travel towards water reservoirs as early as the 3rd decade of March, whereas in wooded regions they do that in the 2nd and 3rd decades of April. The first specimens appear in water at as low a temperature as 4°C above zero. Mass migrations of newts are observed at an air temperature ranging between 10 and 15°C and at soil and water temperatures above 7°C. Spring migrations of newts from forests to water reservoirs situated out of them occur throughout April.

The common newt is not very sensitive to the pollution of water and fluctuations in temperature; its mating takes place in the reservoirs of warm water and in spring-water ponds (Złoty Potok), in which the temperature keeps within limits of 8—17°C in spring and summer.

The females begin laying single eggs as early as the 1st decade of April, in waters warmed by the sun radiation at least to 9°C. However, mass mating occurs in May at a temperature from 15 to 22°C. At that time all the mature specimens display sexual activity and the females lay as a rule 2 eggs daily. The extreme temperatures at which this species reproduce are 9 and 30°C. In a typical year the mating season lasts from the beginning of April to mid-July. Only moderate temperatures of air and water and rainy weather in summer may cause the prolongation of this period till 3 August.

Development of Embryo and Larva

In the pond of Złoty Potok, supplied with spring water from the Jurassic hills, the development of a May embryo lasts about 20 days (the daily mean temperature is 10·1°C in the 1st decade of May). In the same pond but somewhat later, at a water temperature ranging from 7 to 17°C and a daily mean of 11·7°C, the period of embryonic development is shortened by 2 days.

At Sites 1 and 3 the water temperature keeps up at a level of 25°C in June. Under the influence of such high temperatures the embryos of newts achieve the state of full development in as few as 12 days.

The larvae are less sensitive to ambient temperature but here, too, there is a certain difference in the time of particular developmental stages in the reservoirs observed. At Site 4, for example, at a water temperature fluctuating between 7 and 17·5°C and a mean of 14°C the embryos break the egg membrane, settle on its surface and metamorphose in 78 days. At the same time in Sites 1 and 3 at a mean temperature of 20·1°C the developmental process of the larva, including its metamorphosis, takes only 66 days and at a daily mean of 21—25°C (Site 2) as few as 62 days. It follows that the 8°C difference in temperature causes the shortening of the larval stage by about 16 days.

Comparing the results obtained at the sites mentioned during the period of several years, I found that the time of full development of the embryo and larva is altogehter about 82—98 days in dependence on the environmental thermic conditions.

The earliest young specimens appear on the land about 20—25 June, whereas the period when they leave water in masses is July and the 1st decade of August. Few larvae metamorphose as late as September and October at a temperature above 7°C.

In all the four sites observation on the development of the embryos and larvae was carried out in reservoirs of clean water, open and exposed to the sun's rays, with a silty-sandy or clayey bottom covered with fairly exuberant vegetation. They contained enough vegetable and animal food for the developing young organisms.

Terrestrial Life

After the mating season the first adult specimens leave water in the 3rd decade of June and the last ones in the 3rd decade of August. Thus, the period during which newts leave the water environment after the mating season lasts a fairly long time, on the average about two months.

In the area examined the common newt is a frequent animal occurring in large numbers. It inhabits nearly all biocenoses of this region, taking shelter in shady and damp places and leading a nocturnal and hidden mode of life.

Migrations of newts from retreats unsuitable for wintering to safer shelters, situated deeper underground, are observed in October.

They hibernate in groups, forming clusters of several tens or even hundreds of specimens, often together with members of other amphibian species. Single specimens of the common newt assume a characteristic posture, bending the fore part of body backwards. Newts sink into a light torpidity as early as the 1st half of November at a temperature of 4—5°C, but they achieve the state of full torpidity in the 2nd half of the month, when the temperature drops below 3°C (Tables II, III, V and VI).

ANNUAL CYCLE OF THE FIRE-BELLIED TOAD *BOMBINA BOMBINA* (LINNEUS, 1761)

The specimens hibernating at Sites 1, 2 and 3, in gaps between stones of which the railway embankment is made, as a rule end their torpidity season in the 2nd decade of March, at a soil temperature of 3—4°C. A further rise in soil temperature to 7—8°C incites fire-bellied toad to move from the deeper parts of burrows and clefts of various sorts close to the opening leading to the surface. In the 3rd decade of March and the 1st decade of April, at air and soil temperatu-

Table II

Times of appearance and mating and meteorological conditions accompanying mating seasons of amphibians in the region of Częstochowa

Species	Earliest and latest dates of appearance of first specimens in spring 1960—1968		Mating season										
			Earliest and latest dates of egg-laying	Maximum, minimum and optimum temperatures during mating season								Humidity of air in %	
				Air		Soil		Water					
	Earliest dates	Latest dates		Maximum	Minimum	Maximum	Minimum	Maximum	Minimum	Optimum		Maximum	Minimum
Triturus cristatus (LAUR.)	7·2	25·3	5·4—15·6	28	9	27	9	27	9	15—20		100	28
Triturnus vulgaris (L.)	5·2	21·3	15·3— 3·8	30	9	29	9	27	9	15—20		100	25
Bombina bombina (L.)	21·3	11·4	15·4—10·8	30	14	—	—	30	15	17—26		—	—
Pelobates fuscus (LAUR.)	8·3	6·4	26·3—29.4	28	13	28	9	26	12	13—16		98	27
Bufo bufo (L.)	9·3	11·4	27·3—20·4	26	5	21	4	22	6	13—17		100	27
Bufo viridis LAUR.	28·3	6·4	30·3— 5·7	30	14	29	12	28	14	15—24		100	27
Bufo calamita LAUR.	10·4	26·4	10·4—14·7	25	7	25	8	25	14	18—22		100	42
Hyla arborea (L.)	6·4	30·4	18·4— 4·7	30	16	29	12	27	14	20—26		100	27
Rana esculenta L.	11·3	24·4	20·4—11·8	32	15	29	14	31	14	17—27		100	28
Rana temporaria L.	5·2	21·3	11·3—18·4	22	7	19	4	17	7	11—15		100	37
Rana arvalis NILS.	4·2	21·3	11·3—18·4	22	7	20	4	19	7	10—15		100	37

res of 15 and 11°C respectively, the fire-bellied toads leave their winter shelters on the land and start on a migration to a water environment. They enter water warmed by the sun's rays to at least 11°C. In the region of Kucelinka and Brzeziny the earliest appearance of *Bombina* in the 9 years of my investigation fell on 21 March 1968.

Males appear earlier and begin to utter mating calls, at first weak and so audible at a distance of hardly some dozen metres. As the temperature rises, more and more new specimens of both sexes occur in water; they hibernated in shady places or places covered with a thick layer of snow, where a relatively low soil temperature persisted for a fairly long time. This is why at Site 4 the specimens wintering under tree trunks in the forest appear in water 2—3 weeks later than the ones which hibernated in open areas, well exposed to the sun's rays. We may assume that the lowest temperature at which *Bombina* appears — both on land and in water — approximates to 11°C. On account of different thermic conditions at Sites 1—4, the spring migration season lasts on the average for about a month. They leave their winter hiding-places in the daytime during warm and sunny weather or in a spell of rains. Recurrences of cool spring weather and drizzle make fire-bellied toads take shelter in burrows of mammals, gaps under stones, or even they return to winter retreats, if these are situated near the water reservoir.

In observing *Bombina*'s life, I came to the conclusion that this animal is not very particular about the water environment in which it mates. It occurs in all water reservoirs, large or small, clean or dirty, sometimes even in current waters into which the sewers of the steelworks and different factories of Częstochowa open. In the Blachownia region mating takes place in ponds polluted with sewage and at Kucelinka in ditches receiving sewage from the municipal refuse heap. Specimens of *Bombina* are encountered both in permanent and in seasonal water reservoirs. After several-day heavy rains they stay in masses in flooded meadows and spawn, attaching their eggs to submerged plants. In my opinion, fire-bellied toads mate in all water reservoirs, both permanent and seasonal, in which they find plants suitable for attaching packets of eggs to, close to the water surface.

In *Bombina* the pre-mating season may last from 8 to 41 days according to the thermic conditions of the environment. Pairing occurs at a water temperature exceeding 15°C, but the largest number of pairs mate in water warmed to 20°C and somewhat above.

Females of this species lay spawn most often on aquatic plants at a depth of 15—30 cm in the zone well exposed to the sun's rays and oxygenated. A female lays on the average 100 brown eggs, dividing them into several packets and attaching them mostly to the tops of submerged plants. The highest and lowest temperatures of water, at which only a small number of females lay eggs, are 14 and 30°C, whereas the optimum conditions for spawning exist at a water temperature between 17 and 27°C. A rise in water temperature to above 30°C accompanied by long-lasting sunny weather compells the fire-bellied toads to leave water and take shelter on land. For this purpose they use not only burrows, depressions under stones and trunks, and all sorts of clefts in earth but also thick waterside thickets, where the soil temperature is lower than the water temperature by several degrees. After the period of dry and sunny weather the specimens of both sexes return to water and resume mating (they also retreat on to the land when the water and air temperatures drop below 12°C). I am convinced that within the limits of extreme temperatures the mating of fire-bellied toads proceeds normally both at the time of dry sunny weather (at a humidity of 27—35%) and on cloudy and rainy days. However, in warmer years with more abundant rains the mating season is considerably prolonged as compared with its length in the years marked by lower temperatures and a light rainfall. Thus, e.g. in 1964, 1966 and 1968 the total rainfall of the spring-summer months (April-August) was 400—600 mm; these years were warm but wet and had a prolonged mating season of *Bombina*, from the end of April to 8—10 August. In the spring-summer periods of 1962, 1963 and 1967 the dry and sunny weather with a light rainfall (300—350 mm) prevailed, and for this reason the sexual activity was given up by *Bombina* as early as 12—15 July. It should also be emphasized that the highest number of eggs is laid in June, that is, in the month characterized by both an increased rainfall and the occurrence of optimum water temperatures.

In the Częstochowa region the mating season of the fire-bellied toad begins as a rule towards the end of April or at the beginning of May and lasts till the end of July, its maximum range being from 15 April to 10 August.

Development of Embryo and Larva

At Sites 1 and 3 larvae hatch as early as the third day at a mean daily water temperature of 20°C. Under similar conditions the larva stays on the surface of the mother spawn for another three days.

At temperatures ranging from 9 to 30°C with a daily mean of 21°C the development of the larva, including its metamorphosis, takes 90 days and at a mean daily water temperature of 22·5°C it is reduced to 75 days. Thus, the total time of development of the embryo and larva, from the moment of the laying of eggs to that when the young freshly metamorphosed specimens leave water, is 78 to 93 days.

The first juveniles appear on the banks of the water reservoirs (or on islets) in the second half of July, whereas mass metamorphosis occurs in August.

Under favourable environmental conditions females of *Bombina* may lay eggs as late as the 1st decade of August (1960, 1964, 1968) and the larvae derived from these eggs do not leave water before the end of October and some tadpoles hibernate without metamorphosing.

Post-mating Season

In the mating season adult specimens stay close to the banks of the reservoir or in isolated groups in shallows at any distance from the bank. After mating they move to deeper water reservoirs, where they live both in water and on the bank among exuberant gramineous plants. The favourite summer habitat of *Bombina* are tiny wet islets grown over with rich marsh vegetation.

Having metamorphosed young specimens form aggregations in shallows near the banks or stay on the banks of reservoirs, hiding in water while in danger.

During a dramatic cooling of the atmosphere and water in summer fire-bellied toads take shelter in burrows, under stones, and also in different clefts and depressions in the ground, but when the warmer weather comes again they leave their shelters on land and return to their previous habitats.

Fire-bellied toads leave summer habitats relatively early, in the 1st and 2nd decades of September. The main factors that determine the time of commencement of their autumnal migrations to winter shelters are, in my opinion, an increase in the diurnal ranges of temperatures to 10—19°C and the systematic lowering of the daily temperatures of air, soil and water (from 22 to 15°C) and, above all, nocturnal temperatures from 12 to 2·5°C. The transitional period of *Bombina* (from the time when they leave their summer habitats to that of their becoming torpid) last more than two months. In this period they are active and agile. When the air and soil temperatures rise, they often come close to the surface through chinks in the earth and a small number of juveniles even come out on to the surface, whereas when the temperature falls below 5—6°C and at night they hide in the chinks at a considerable depth.

At Sites 1, 2 and 3 the fire-bellied toads hibernate in gaps between stones of the railway embankment and at Site 4 in burrows, under tree roots and under stones. All their generations spend this passive period of life together, forming big aggregations of several hundred individuals in exceptionally favourable places. In the Kucelinka region I counted as many as 318 fire-bellied toads of various age in the chinks in a dump of furnace slag (6 cum.m in volume), accompanied by 11 common newts and 9 crested newts.

Fire-bellied toads as a rule take shelter for winter in crevices at a depth of 2—4 m from the surface. Occasional specimens hibernate singly or in small groups in the burrows of mammals and in other holes, buried at a depth of several tens of centimetres, and also under stones, tree trunks and heaps of dry branches. The temperature at which they fall into torpidity is 2—3°C (Tables II, III, V and VI).

ANNUAL CYCLE OF THE COMMON SPADEFOOT *PELOBATES FUSCUS* (LAURENTI, 1768)

At Site 2 the members of this species hibernate in sand at a depth of about 90—120 cm and in plains with sandy-clayey soil (Sites 1 and 4) I found hibernating spadefoot toads remarkably shallower (at a depth of 60—90).

Adult toads wake from torpidity towards the end of March, more rarely at the beginning of April, at a soil temperature of 3·5—4°C. They scramble out on to the surface in a few following days and then head for the nearest isolated water reservoir to mate. Spadefoot toads start on spring migrations at a relatively low temperature (air — 7°C, soil — 3°C, water — 4°C).

The mating season is closely dependent on the intensity of rainfall in the spring-summer period. Only in early spring, at a relatively poor insolation and high air humidity, a few mating individuals may be seen in water during a spell of sunny weather. In the course of my nine-year investigation I counted 120 days of mating yearly in the case of the spadefoot, of which 65% were rainy days, 30% cloudy days and hardly 5% sunny days.

The mating season of the spadefoot consists of 4—5 stages of 5—7 days each according to the weather conditions in spring and summer. The particular stages begin during rainy weather at a water temperature between 12 and 26°C. Soon after entering water the animals pair and the females lay spawn in it. Both these processes as a rule occur at night. Water temperatures between 13 and 16°C constitute the optimum conditions for the spadefoot to reproduce; the wide range of temperatures favouring the process of spawning indicates that this animal can breed both in early spring and in a hot period in summer.

During long-lasting rainy weather new specimens of both sexes may appear every now and again and, consequently, cause the illusion that the mating season of the spadefoot may last even about 20—25 days. Individual specimens stay in water for hardly 5—6 days and so shorter than the other amphibians living in Poland. The beginning of the first stage of mating in the spadefoot coincides with the subsidence of sexual activity in the common frog and field frog.

In the mating season the spadefoot pairs also with members of other species of the tailless amphibians; the most commonly encountered mixed pairs consisted of a female spadefoot and a male common or field frog. Spadefoot toads pair also with proper toads. I have never met with hybrids between these species under their natural environmental conditions.

The spadefoot is not particular about water in which it lays eggs. It can reproduce even in water reservoirs which receive the sewage of a town.

Table II gives the times and meteorological conditions of the appearance and reproduction of this species in 1960—1968.

Development of Embryo and Larva

Under natural conditions the spadefoot tadpoles metamorphose in 81—150 days in the Częstochowa region. The rate of development of the embryo and larva depends upon a whole complex of factors, of which water temperature is the most important. For example, at a water temperature fluctuating between 5 and 15°C and a daily mean of 8·5°C the embryos leave their jelly casings after

14 days, and at a considerably higher water temperature, 14—16° C, the development of the embryo in the egg takes only 7 days.

The time the larval spadefoot stays on the surface of the spawn is also dependent on water temperature. It is as many as 10 days at a temperature of 4—13° C and a daily mean of 7·5° C and hardly 4 days at 13—17° C with a daily mean of 15° C.

In water reservoirs with temperature fluctuating between 4 and 32° C (daily mean 18·5° C) the metamorphosis is completed after 84 days and at a temperature of 8—32° C and a daily mean of 19·8° C (typical thermic conditions of the study area) the metamorphosis of the larvae is accomplished after 81 days.

The full embryonic and larval development of one-season specimens takes 91—95 days altogether.

In a typical summer with average temperatures the first juveniles appear on land at the beginning of the 2nd decade of July and they leave water in masses in August and in the 1st half of September. In the years with a reduced autumnal period and unfavourable thermal balance the larvae complete their metamorphoses as late as April of the next year (e.g. 1965, 1966 and 1968).

Terrestrial Life

After mating the adult specimens live a decidedly nocturnal life. They leave their hiding-places at twilight and wander foraging in the fields, moors, and various sorts of waste land. They are also met with in pine forests, juniper growth, gardens and parks, and even in town greens and flower-beds. Before dawn they bury themselves in sandy or clayey soil, enter the burrows of mammals, and squeeze into crevices washed away in ditches and pools. In summer the spadefoot may be found in soil at various depths, but always in damp layers protecting their delicate skin from drying and making skin respiration possible. In summer it buries itself deeper than in spring or early autumn and keeps changing the place of hiding.

In the 1st half of October, when the soil temperature falls to 3—4° C at night, the spadefoot does not leave its hiding-place but stays in its upper layers, at a depth of a few tens of centimetres. It buries itself deeper, to 1—1·5 m under the surface, only in the 2nd half of the month (when the first ground frost occurs). I repeatedly found that at diurnal air and soil temperatures above 8° C some specimens deepened their winter shelters as late as the 1st half of November. Young specimens bury themselves in earth to a depth of 70—100 cm and therefore not so deep as the adult ones.

Both adult and young animals bury themselves backwards, rapidly stretching their hind legs alternately to the sides and making their ways at an acute angle to the horizontal plane. The spadefoot hibernates in a sitting possition, its body swollen and limbs pressed tightly to the trunk. They fall into deep torpidity at a soil temperature of 2—3° C, i.e. generally in the 2nd half of November or at the beginning of December (Tables II, III, V and VI).

ANNUAL CYCLE OF THE COMMON TOAD *BUFO BUFO* (LINNAEUS, 1758)

This species occurs nearly all over the Częstochowa District not excluding the town area. It shows preference for deciduous forests, gardens and fields. The hill-sides of the Kraków—Częstochowa Jurassic Ridge particularly abound in these animals.

They hibernate both in open areas and in forests of all types. The time when common toads wake from torpidity in various biocenoses depends upon their thermic conditions. In treeless areas, sufficiently well exposed to the sun's rays, the common toad wakes from its winter sleep generally in the 2nd and 3rd

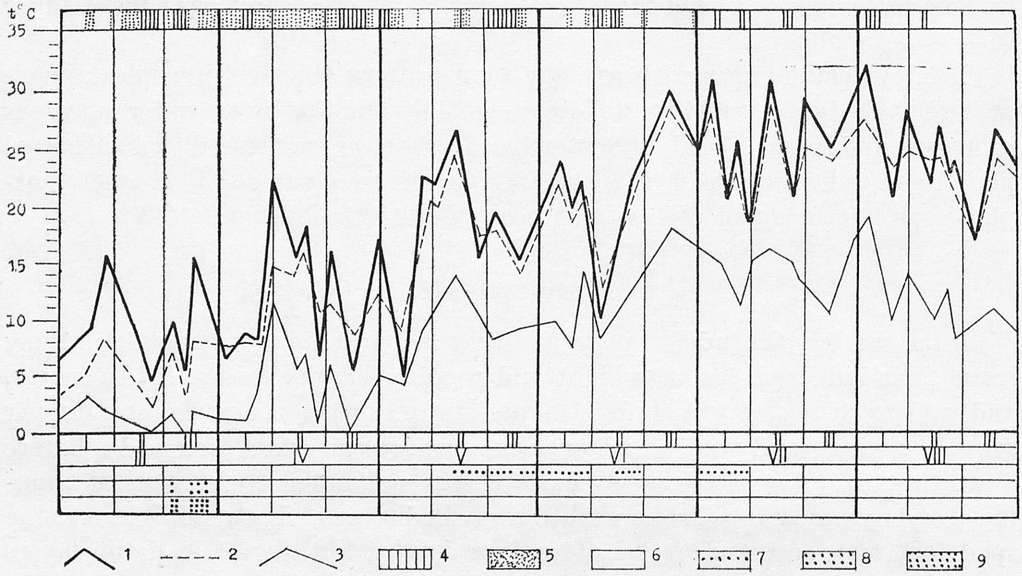


Fig. 5. Mating seasons of the common toad *Bufo bufo* (L.), the variable toad *Bufo viridis* LAUR. and the natterjack *Bufo calamita* LAUR. against the background of meteorological conditions at Site 1 (region of Częstochowa) in 1967. Explanation of symbols: 1 maximum air temperatures, 2 maximum water temperatures, 3 minimum air temperatures, 4 rainy, 5 cloudy, 6 sunny, 7 decades of month, 8 spawning of common toad, 9 spawning of variable toad, 10 spawning of natterjack

decades of March, at a soil temperature of 3—4° C. In forests of all types snow thawing proceeds much more slowly than it does in open areas because of the ununiform and relatively poor exposure to the sun's rays, and this is why the common toads from forests arrive in local water reservoirs 2—3 weeks later. Common toads are resistant to cold, as they start on their daily spring migrations to water at a soil temperature higher than the thermic minimum by hardly 2° C. Wandering common toads are met with all day long in early spring, regardless of weather. Males appear in water earlier and females join them in a few following days.

In mating season male common toads display intense activity, their number being twice or four times as large as that of females. As a result, two to six males attach to one female very frequently. I also observed some common toads mating with green toads, and with edible, common and field frogs.

In the Częstochowa region common toads mate in old riverbeds, large and small ponds, clay- and sand-pits, and more rarely in ditches, puddles and marshes. This shows that they choose rather deep water reservoirs in which they keep close to the banks. The breeding females attach their spawn to submerged plants. In shallow seasonal water reservoirs with scanty ground-vegetation, the females wind their spawn round sticks or hang it between submerged stones. Having found no support at all, they stretch it on the bottom. At the edge of the forests at Blachownia common toads mate also in thickets by fairly rapid rivers and streams, which have a relatively low water temperature (10—11°C). At this locality common toads spawned also in a sewage sump.

The pre-mating season may last from several to more than 30 days according to weather. The beginning of mating as a rule falls in the first and second decades of April, more rarely in the 3rd decade of March. The extreme temperatures of reproduction of this species are 6 and 22°C. During nine years' investigation I observed only one example of spawning at the lowest temperature mentioned above; it proceeded very slowly from early morning hours till evening.

The optimum temperature for sexual activity of this species ranges between 11 and 17°C and the duration of the mating season is dependent on weather. Under optimum conditions common toads stay in water for 6—8 days, but they take no more than 3—4 days to lay eggs. Under unfavourable conditions the reproductive process may be prolonged to 16—20 days and it consists of two or three stages.

The common toad requires a somewhat higher temperature for mating than the common and field frogs do, but within the limits of suitable temperatures it is little pervious to weather and thus it pairs and spawns both on sunny days and on cloudy and rainy days. It is also little sensitive to wind and wind-induced waving of water. It spawns both in the daytime and at night. The process attains the highest intensity in warm and windless evenings and nights, at a water temperature of 14—16°C. At the time of spawning common toads are little sensitive to stimuli coming from outside their environment. They generally lay 3000—6000 eggs and the number of females that lay more or fewer eggs is very small.

Soon after laying eggs the females leave water and start on their terrestrial migrations mostly at night. The males stay in water for another several or some dozen days and next come on to the bank to begin their life on land.

Development of Embryo and Larva

In the natural environment of the Złoty Potok region the development of the embryo within the egg membranes takes 10 days at a water temperature of 7—9°C and 9 days at 7—15°C (1st decade of May) and a daily mean of 10°C. At the other localities the embryo leaves the egg in water warmed to a mean temperature of 15°C as early as the seventh day.

The temperature of water exerts also a great influence on the rate of development of tadpoles and their metamorphosis. Thus, e.g. at temperatures ranging between 9 and 27°C and a mean of 19°C the metamorphosis of larvae occurs after 56 days and at temperatures within limits approaching the extreme temperatures but at a somewhat lower mean (16·5°C) the tadpoles of the common toad complete their metamorphosis after 65 days, whereas in much cooler waters (ponds at Złoty Potok, rivers and streams in the Blachownia region) at a temperature not exceeding 17·5°C and a daily mean of 13·5°C the metamorphosis of these larvae lasts relatively long, namely, as many as 74 days.

Consequently, the development of the embryo and larva may take from 65 to 84 days altogether. The rate of development is directly proportional to the increase in water temperature: the higher the temperature of water the shorter the developmental period of the young amphibian organism is.

Under favourable environmental conditions the first juveniles appear on land as early as 13—14 June; in the 2nd half of the month they leave water in masses and form big colonies of several hundred or even several thousand specimens at the waterside. Soon they disperse and gradually pass from diurnal to nocturnal ways of life. In reservoirs of relatively warm water (Sites 2 and 3) the period of the metamorphosis and departure from water of the whole young generation lasts for about 13—18 days, whereas in reservoirs having considerably lower water temperatures (ponds and rivers at Złoty Potok and Blachownia) this process is prolonged, as a rule, to about 25—30 days. Backward specimens leave water about 20—22 July.

Terrestrial Life

After mating the common toad leads a nocturnal life on the land. At the beginning of autumn, in connection with a gradual drop in the nocturnal temperatures of air and soil, it becomes more and more languid and more and more rarely forages on the surface of earth. At the setting-in of autumnal cool weather with air and soil night temperatures around 4—5°C the toad does not leave its shelter and at 2—3°C falls into torpidity, which lasts until the spring of the next year (Tables II, III, V and VI).

ANNUAL CYCLE OF THE VARIABLE TOAD *BUFO VIRIDIS* LAURENTI, 1768

The variable toad wakes from winter sleep in the 2nd decade of March at a soil temperature of about 4°C but it does not leave its winter shelter, which is at a considerable depth in burrows, crevices or in the soil before the 3rd decade of March or at the beginning of April at a soil temperature above 7°C. On leaving the winter shelters the adult specimens migrate to shallow water reservoirs, but before entering water they stay among waterside grasses and bushes for several hours or days. Males appear in water before females and taking up their positions facing the bank they wait for their arrival uttering characteristic mating calls, the intensity of which increases towards evening. The mating period of the variable toad is not connected with definite temperatures of the environment or calendar dates, although it is influenced by rainfall to a high degree. Thus, for instance, in 1961, 1966 and 1967 the first specimens appeared in water at comparatively very low ambient temperatures (air — 8—10°C,

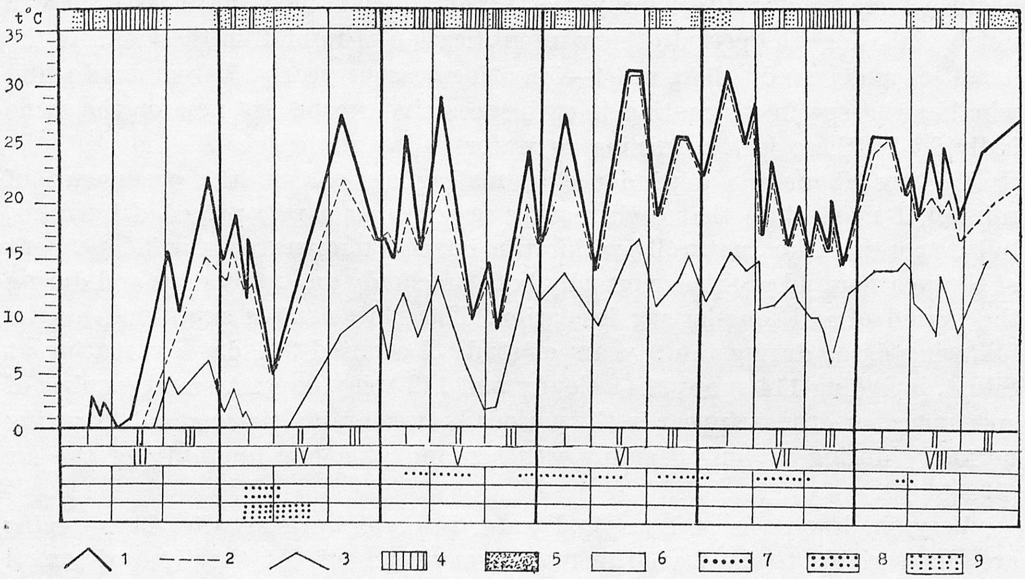


Fig. 6. Mating seasons of the common toad *Bufo bufo* (L.), the variable toad *Bufo viridis* Laur. and the natterjack *Bufo calamita* Laur. against the background of meteorological conditions at Site 1 (region of Częstochowa) in 1968. Explanation of symbols: 1 maximum air temperatures, 2 maximum water temperatures, 3 minimum air temperatures, 4 rainy, 5 cloudy, 6 sunny, 7 decades of month, 8 spawning of common toad, 9 spawning of variable toad, 10 spawning of natterjack

soil — 7—9°C, water — 8—9°C) and in 1960, 1965 and 1968 at twice as high temperatures. In all the years mentioned except 1968 the first mating season began during a spell of heavy rains or soon after their subsidence.

Pairing occurs nearly immediately after the meeting of specimens of opposite sexes in water. Male variable toads attack also the females of the common toad, edible frog and spadefoot toad and form mixed pairs with them, sporadically met with under natural conditions. Particularly importunately they attack edible frogs, which making use of their power of quick swimming try to avoid that. Nevertheless, crossing pairs consisting of members of these species are fairly often encountered. Occasionally there occur aggregations in which male variable toads are 2—4 times as many as female edible frogs. Female variable toads mate with male common toads, natterjacks and spadefoot toads. Toads form pairs both in the daytime and at night. As early as the same day or on the next day the females in amplexus begin to lay eggs. This process lasts for 1·5—3 hours, according to the temperature of water. Variable toads show the intensest sexual behaviour at temperatures between 14 and 27°C. At temperatures within limits of 17 and 24°C they lay about 95% of their eggs. This species is characterized by the greatest reproductive power of the amphibians of this country; each female lays as a rule over 10000 eggs.

Soon after spawning the toads of both sexes leave the water reservoirs and begin a terrestrial and, generally, nocturnal life. The next mating season will not begin before the period of new intensification of rainfall in the area. At the localities under study there are 4—5 mating seasons yearly. It remains to find whether the specimens mating in each successive season are new or the same individuals (these last, returning to water to lay more eggs).

Writing about the dependence of mating seasons on the occurrence of rainfall, I must state that each mating season is as a rule preceded by rains, but its continuation, naturally within the extreme temperatures, is independent of the weather and proceeds normally both on cloudy and rainy days and during the period of full long-lasting insolation. This statement is supported by the following data: during the 9 years of study I counted 397 days of mating at Site 4, including 114 sunny, 141 cloudy and 142 rainy days. A small number of specimens sometimes appear in the periods between rains, pairing and spawning normally during prolonged sunny weather and at a low humidity of the air (30—50%).

Very shallow pools and seasonal water reservoirs arising after heavy rains are the variable toad's favourite mating environment. At the time of sexual activity the toad occurs also in ponds and in clay- and sand-pits, but only in the shallows near the bank. In general, variable toads make little demands as to the nature of reservoirs in which they are to do their short mating and lay eggs. They appear in large numbers, e.g., in liquid manure pits and settling ponds, laying spawn in the form of 3—4-metre double strings on the bottom. They can mate in the presence of the members of all the lowland amphibian species occurring in the study area.

The mating season of the variable toad lasts intermittently from the 1st decade of April throughout June. It may be exceptionally prolonged till 4—5 July if the weather is warm and the rains heavier than usual.

Development of Embryo and Larva

Embryos develop from the eggs laid in shallow pools and pits at relatively high temperatures of 23—26°C even after 2—3 days and at a somewhat lower temperature (22°C) after 4 days.

I observed the development of the variable toad embryos in the water environment cooled to 10—16°C, at a daily mean of 14°C. Under these unfavourable thermal conditions the embryos left the double egg membrane only after 9 days. The period of the stay of the larvae on the surface of the spawn also depends on water temperature and may last from 2 to 8 days.

I dependence on the weather in the spring-summer period the metamorphosis of variable toad tadpoles occurs after 44—70 days. At a relatively high water temperature, ranging within limits of 16—35°C, and a daily mean of 25·2°C the metamorphosis is completed as early as 44 days. Within the close extreme temperatures but at a considerably lower daily mean (20·8°C) the process of metamorphosis takes 58 days, whereas at a still lower mean daily water temperature (18·4°C) the period of development and metamorphosis into a land form lasts up to 70 days.

Having gone through metamorphosis, the first young specimens appear on land in the first decade of June and they occur in large numbers in July. Since the mating season of the variable toad is protracted very much, the juveniles take 2—2·5 months (25 June — 8 September) to leave water.

Terrestrial Life

On leaving water the adult forms as a rule have nocturnal ways of life, but they can also often be met with in the daytime, whereas the freshly metamorphosed juveniles are more active in the daytime than at night. The transition period during which the juveniles adapt themselves to the nocturnal ways of life lasts for about a month and in the case of some specimens even considerably longer.

This species endures the action of the sun's rays and drought relatively well. Its favourite habitats are fields and barren lands of sand soil, ravine sides and rocky hills of the Kraków—Częstochowa Jurassic Ridge. It lives, as the only member of the Amphibia, on high and dry woodless hills.

In October, at a night soil temperature of about 5—6°C the toads bury themselves in the burrows of rodents, passages of moles, in cellars and pigsties, hide under heaps of refuse or manure, and there spend the winter in torpidity. The specimens in the first year of life are less sensitive to low air and soil temperatures than the older ones are and so they may be encountered as late as the 3rd decade of October and even in the 1st decade of November at a night temperature below 5°C (Tables II, III, V and VI).

ANNUAL CYCLE OF THE NATTERJACK *BUFO CALAMITA* LAURENTI, 1768

I have published a study on this subject in the Przegląd Zoologiczny XIII, 2, 1969 and now I shall confine myself to several observations made later.

I have found the occurrence of the natterjack nearly all over the lowlands of the Częstochowa District. In the spring-summer period this amphibian is present both in sandy areas, barren lands, pastures and tilled fields and in low mires, peat-bogs and moors. In the Olsztyn region (14 km east of Częstochowa)

Development of embryo and larvae of am

Species	Development of embryo in egg				Time spent by larvae on the surface of spawn, in days			
		Daily water temperatures				Daily water temperatures		
	No of days	Maximum	Minimum	Mean		Maximum	Minimum	Mean
Triturus cristatus (LAUR.)	20	18	4	10,2	—	—	—	—
	19	19	6	10·8	—	—	—	—
Triturus vulgaris (L.)	20	16	4	10·1	—	—	—	—
	18	19	6	11·7	—	—	—	—
Bombina bombina (L.)	4	21	18	20·0	3	23	21	21·7
	3	26	20	23·3	4	21	17	18·7
Pelobates fuscus (LAUR.)	7	16	14	14·8	10	13	4	7·5
	14	15	5	8·5	4	17	13	15·0
	4	23	21	28·0	4	18	13	15·5
	2—3	28	23	25·5	2	27	25	26·0
Bufo bufo (L.)	7	16	14	14·8	10	13	4	7·5
	9	15	6	9·9	3	20	19	19·6
	10	9	7	8·0	8	9	7	8·0
Bufo viridis LAUR.	4	26	20	22·2	3	24	20	21·6
	9	16	10	13·9	8	13	7	8
	2—3	26	25	25·5	2	26	24	25·0
Bufo calamita LAUR.	7	16	10	12·8	6	8	5	6·3
	3	26	22	24·0	3	21	17	19·3
	2	28	25	26·5	1	26	26	26·0
Hyla araborea (L.)	3	23	20	21·0	3	22	21	21·7
	3	24	21	22·6	3	22	19	20·3
	5	22	14	17·5	5	18	15	17·0
Rana esculenta L .	4	25	18	22·0	3	18	16	17·0
	4·8	22	14	17·5	2	25	23	24·0
	3	25	23	24·0	2	25	23	24·0
Rana temporaria L.	10	11	4	8·6	8	11	6	8·1
	7	19	14	15·8	6	15	6	9·0
Rana arvalis NILS.	11	10	3	7·4	6	9	8	8·5
	8	16	13	14·3	9	15	5	8·1

fields of winter and spring corn and papilionaceous plants are a favourite summer habitat of the natterjack.

In the 1st decade of April the sexually mature specimens gradually approach water reservoirs, gathering round them and hiding in waterside thickets and

Table III

phibians under defined climatic conditions

Passive life of larvae, in days	Daily water temperatures			Development of limbs			Development of larva from its hatching from egg				Total time of development of embryo and larva
	Maximum	Minimum	Mean	Buds of hind-limbs	Hind-limbs	Fore-limbs	No of days	Maximum	Minimum	Daily water temperatures	
6	21	11	18·0	29	47		71	32	7	21·3	91
7	20	15	17·3	30	48		72	32	8	20·5	91
8	18	5	12·6	22	40		62	32	6	21·5	82
5	23	17	19·6	25	43		66	35	11	20·1	84
3	25	24	24·3	35	48	64	75	32	12	22·5	78
4	20	16	18·0	44	59	82	90	30	9	21·3	93
4	17	8	13·0	40	50	69	84	32	4	18·5	91
3	21	18	19·3	39	51	66	81	32	8	19·8	95
3	21	18	19·2	40	52	67	82	32	9	20·2	86
2	27	25	26·0	36	48	63	78	32	14	14·4	80
4	17	8	13·0	25	44	58	65	25	4	16·5	72
2	22	22	22·0	20	35	49	56	27	9	19·0	65
6	9	7	8·0	32	52	67	74	17·5	7	13·5	84
3	20	17	18·0	27	43	54	58	35	12	20·8	62
4	17	8	12·7	31	53	65	70	32	5	18·4	79
1—2	27	25	26·0	22	33	41	44	35	16	25·2	46—47
3	17	11	14·3	26	38	52	56	27	5	17·2	63
3	20	17	18·0	25	37	50	53	32	12	19·3	56
2	24	19	22·0	20	32	38	40	35	17	25·3	42
3	27	25	26·3	28	43	59	63	32	7	24·0	66
4	20	16	17·2	29	44	60	65	32	9	22·6	68
4	20	16	17·2	33	59	79	85	32	7	18·p	90
2	19	18	18·5	28	36	52	71	32	12	21·8	75
2	22	20	21·0	24	32	48	67	32	9	22·3	71
2	22	20	21·0	30	60	90	111	24	7	13·0	114
2	15	11	13·0	40	49	69	75	27	5	15·5	85
7	11	6	8·1	32	40	60	64	27	6	16·8	71
3	15	11	13·3	34	45	66	73	25	3	15·2	84
6	16	7	10·5	31	42	63	67	25	5	16·6	75

nearby agricultural crops. In a rain or soon after it has stopped the specimens wandering to mate form pairs. This happens both on the surface of the earth and in the burrows of mammals. At the time of pairing natterjacks give "concerts" in the afternoon and eveoing hours, the interval between the first and the second "concert" being about 40 minutes. As the night comes, the intervals between particular "concerts" become shorter. About 6 p.m. the natterjacks joined in pairs and a few single specimens migrate to water in large numbers. The procession of mating natterjacks generally occurs in the evening and in the early night hours. As early as several hours later some females begin spawning. After they have laid eggs, the pairs split and the specimens of both sexes leave water.

The time of the next mating season depends on the occurrence of rain and suitable temperature of the environment, for the natterjack reproduces at a water temperature ranging between 14 and 25°C. This process is the intensest in water at 18—22°C.

In the region of Częstochowa the first mating season begins generally on 10—15 April and the last one ends in the 3rd decade of June. The maximum span of the mating seasons of the natterjack reaches from 10 April till 15 July.

During my 9-year study of mating seasons in the natterjack I counted 205 days of mating (on which females actually laid eggs), including 52 sunny, 68 cloudy and 85 rainy days. These data suggest that natterjacks pair and spawn chiefly on cloudy and rainy days, but continue the once started process of spawning in sunny weather, at a low humidity of the air (about 42—45%).

Mature specimens mate most frequently in the company of the variable toad, fire-bellied toad, edible frog, spadefoot toad, tree toad and common newt; still earlier the common frog, field frog and common toad lay eggs in the same water reservoirs.

In these last five years I have investigated the number of eggs laid by a single female at one egg-laying. Thus, in a hundred sets of eggs counted

17 females laid 2800—3000 eggs
32 females laid 3000—3500 eggs
41 females laid 3500—4000 eggs
3 females laid 4000—4100 eggs

While counting the eggs, I also found that larger females lay, as a rule, more eggs than the smaller ones do.

Development of Embryo and Larva

As can be seen from the investigation carried out, the developing specimens are very sensitive to the action of weather factors, especially in the early stages of their development. For instance, at a mean daily water temperature of 26·5°C the development of the embryo in an egg takes hardly 2 days, at 24°C 3 days and at 12·8°C as many as about 7 days.

The rate of development of particular larval stages also depends on the changes in water temperature during 3—5 phenological seasons (Table III). At a temperature ranging between 17 and 35°C and a daily mean of 25·3°C the development of the larva lasts only 40 days, at a daily mean of 19·3°C 53 days and at a still lower water temperature — changing within limits of 5 and 27°C at a mean of 17·2°C — the metamorphosis of tadpoles occurs after as many as 56 days (Table III). The first metamorphosed small toads can be seen on the banks of water reservoirs as early as the first decade of June, whereas the latest ones leave water in the 2nd decade of September. The period in which young toads come out on to the land lasts very long, about 100 days. This is, above all, due to the presence of several mating seasons in adult specimens and also to the slowing down of larval development caused by the regular shortening of the daytime and a drop in water temperature in August and September.

Terrestrial Life

After leaving water, natterjacks generally have nocturnal ways of life. However, I sporadically met with adolescent and adult specimens in the morning (till 10 a.m.); they wandered about in sunny weather and at a relatively high air temperature (up to 23°C).

Towards the end of September and at the beginning of October adult natterjacks bury themselves in damp sand to a depth of 60—120 cm and there they fall into torpidity. Young natterjacks bury themselves in sand somewhat less deep and about 10 days later than the adults do. They become thoroughly torpid at a temperature below 3°C (Tables II, III, V and VI).

ANNUAL CYCLE OF THE TREE FROG *HYLA ARBOREA* (LINNAEUS, 1758)

The tree frog is a highly thermophilous amphibian. It wakes from winter sleep generally in the 2nd half of April, exceptionally in May, and leaves its terrestrial or aquatic winter shelter at about 17°C. Specimens that hibernate on land appear in water warmed at least to 14°C. At lower air and water temperatures tree toads hide on the banks of water reservoirs, among rushes *(Juncaceae)* and peatmosses (orders *Sphagnales* and *Bryales*) or under decaying leaves in osier-beds (*Salix cinerea* L.). Males appear in water before females. At a water temperature above 17°C the males utter mating calls and form pairs with females (the males still on land and bound for the mating-ground answer the sonorous calls of the males mating in water). The pairing of tree toads in water reservoirs lasts scarcely 1—2 days. They sometimes pair with natterjacks and spadefoot toads.

The mating females soon begin laying eggs. The first mating season falls in the 3rd decade of April or the 1st decade of May. In May and June the tree toads spawn another three or four times. In the Częstochowa District they begin breeding activities relatively late, for only the edible frog commences its mating season at the same time or somewhat later, whereas all the other species under study start mating considerably earlier.

The occurrence of the mating season of the tree frog depends upon rainfall; the period of egg-laying, as a rule, begins during or after a spell of heavy rains, only in the dry spring and summer tree frogs are forced to mate during rainless weather. The individual mating seasons last about 3—7 days each at a water temperature of 14—17° C, the largest numbers of eggs being laid by females at 20—26° C. The intervals between particular mating stages coincide with drought or a marked cooling of the environment and last from 3 to 20 days.

Each females lays 750—1065 eggs, dividing them into 2—6 small bundles and placing them on the bottom of the water reservoir. A hundred sets of eggs laid by individual females at Sites 1 and 2 in May were examined and showed that

	5	females	laid	750—800	eggs
	37	"	"	800—850	"
	35	"	"	850—900	"
	14	"	"	900—950	"
	8	"	"	950—1000	"
and	3	"	"	1000—1065	"

The data listed above show that the groups with 800—950 eggs include most of the females and only a small number of them lay more or fewer eggs than that.

Permanent or seasonal water reservoirs surrounded with thick waterside plants and bushes make a favourite habitat of the tree toad, which avoids new ditches and ponds, clay-pits and other reservoirs void of marsh and water vegetation.

During my long investigation I found that in some years (1962, 1965 and 1968) a relatively small number of specimens of both sexes appeared in water to mate and the characteristic mating "concerts" were hardly audible, whereas in other years the tree frogs arrived in large numbers and the calls of the males resounded intermittently from the beginning of May throughout June. I cannot, as yet, explain the cause of this phenomenon. It seems, however, that the reduction in the number of adult specimens occurs during the severe winters with little snow, which usually precede the summers with a decreased number of mating toads.

Development of Embryo and Larva

The tree frog lays eggs in shallow open water reservoirs and, as a result, the embryos and larvae develop at relatively high water temperatures. At Site 2 at 21—22·8° C the development of the embryo in the egg takes only 3 days, whereas in a clay-pit (Site 1) at a considerably lower temperature (17·5° C) about 5 days.

At temperatures ranging from 7 to 32° C and a daily mean of about 18° C the tadpoles complete metamorphosis after 85 days, but at a much higher temperature (exceeding 22·6° C) the metamorphosis of the larvae takes only about 65 days. Thus, the total period of development of the embryo and larva covers 68 to 90 days and at a water temperature above 24° C only 66 days.

Early juveniles leave water in the 1st decade of July. The duration of metamorphosis of all young specimens depends closely on two factors: on the number of mating seasons and their distribution in the whole period and on the weather conditions in the given year, above all, the total amount of heat throughout the period of development of the embryos and larvae (May—September). Generally, the latest tadpoles complete their metamorphosis at mid-August, this process being prolonged till 8—10 September only under less favourable conditions. In the years when the autumn is short or cool these larvae are forced to spend winter in water. Thus, e.g., in 1962 and 1966 the tadpoles hibernated in the ponds of Blachownia.

Terrestrial Life

After a short stay in water in the mating season the tree frogs live on broad-leaved plants in the vicinity of water reservoirs. Their active life terminates at the end of September or in the 1st decade of October. Main factors determining the time when they leave the trees and look for winter shelters are the increasing amplitudes between nocturnal and diurnal temperatures, reaching 15—20° C, and the systematic fall in air temperature from 22 to 13° C in the daytime and particularly in nocturnal temperature from 12 to 2—3° C.

ANNUAL CYCLE OF THE EDIBLE FROG *RANA ESCULENTA* LINNAEUS, 1758

At Site 1 adult edible frogs hibernate in the tributaries of the River Warta and at Site 4 in the upper course of the River Stradomnia and in streams flowing into it. Only very few — mostly injured or ill — specimens spend winter on the bottom of ponds.

They begin active life in flowing water at its temperature of 3° C in March. A rise in temperature by 1—2° C considerably enhances the living activities of these animals in water. They scramble out of sand and silt in the bottom of smaller rivers and streams and oftenest make for the growths of the water-thyme (*Elodea canadensis* RICH.), water nimfoil (*Myriophyllum spicatum* L.), *Batrachium aquatile* (L.) and plants of the family *Potamogetonaceae*. Owing to the strong and well co-ordinated movements of their hind-legs edible frogs are able to oppose the fast currents of water and in danger to hide in chinks in the under-mined banks of rivers, among submerged plants, under decaying plants or in bottom silt.

At a temperature between 5 and 7° C the frogs come out on to the bank of the reservoir and, facing the water, bask in the spring sunshine.

Soon the frogs start on their early-spring migration to deeper water reservoirs, like lakes, ponds, old riverbeds, clay- and sand-pits, deep ditches, etc. The lowest soil temperature that makes these spring migrations possible is 4° C. The first specimens appear in closed reservoirs generally in the 2nd half of March, exceptionally in the 1st decade of this month. The spring migrations from flowing waters to stagnant waters last for about a month and the number of these amphibians in particular reservoirs increases systematically. From mid-April to May the frogs live on the banks of deeper water reservoirs covered by exuberant gramineous plants. In the 3rd decade of April or at the beginning of May, at air and soil temperatures above 20°C, they make mating migrations from the deeper to shallower reservoirs, in which the females lay eggs in water. During their sexual activities they form colonies numbering several tens or hundreds of

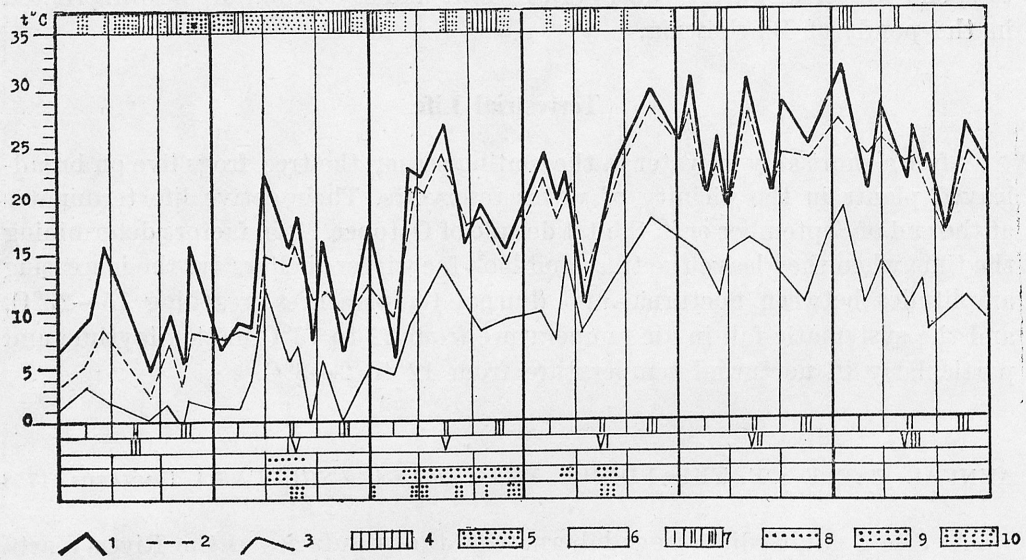


Fig. 7. Mating seasons of the edible frog *Rana esculenta* L., the common frog *Rana temporaria* L. and the field frog *Rana arvalis* NILS. against the background of meteorological conditions at Site 1 (region of Częstochowa) in 1967. Explanation of symbols: 1 maximum air temperatures, 2 maximum water temperatures, 3 minimum air temperatures, 4 rainy, 5 cloudy, 6 sunny, 7 mating season of edible frog, 8 mating season of common frog, 9 mating season of field frog

mating specimens of both sexes. The pairing of frogs in a colony lasts for about 3—6 days, mostly in afternoon and evening hours, at the minimum water temperature of 17°C.

A four-phase 24-hour activity cycle can be distinguished in the mating season of the edible frog in connection with changes in the thermic conditions of air, soil and water:

1. 8—10 a.m. Frogs show very poor sexual activity, only few females begin spawning; agility of amphibians restricted by relatively low water temperature.

2. 10 a.m. — 2 p.m. Frogs brisk up; about 15% of females lay eggs in water.

3. 3—9 p.m. Maximum sexual activity of frogs; at that time about 80% of specimens of both sexes pair and females begin spawning, in which they are accompanied with much commotion and croaking of males.

4. At 10—11 p.m. frogs sink to the bottom of the reservoir, where they spend night in the bottom silt or in the dense water vegetation. The optimum temperatures of reproduction of this species lie within limits of 17 and 27°C. The mating season of one colony lasts from 4 to 11 days. Soon the colony breaks up and its members leave the mating ground in large numbers and return to the banks of the previously chosen water reservoir. Here the edible frog leads an active terrestrial-aquatic mode of life until it goes on the next mating migration, the time of which depends in a great measure on thermic conditions. Egg-laying — differently from what is observed in most of the remaining amphibians of this country — occurs several times a year.

During my 9-year investigation I counted 410 days on which the female edible frogs spawned and which included 117 sunny, 141 cloudy and 152 rainy days. These data and the phenograms of 1960—1968 show that rainfall (and at that the high humidity of the air, reaching 85—100%) is the factor that hastens the commencement of mating but exerts no evident influence upon the further course of this process, which is continued (within extreme temperatures) independently of weather.

The mating females lay eggs at a water temperature ranging from 14 to 32°C. So wide a range of temperatures makes it possible for this species to reproduce nearly continuously from May throughout August. There are however intervals between particular mating seasons and they are the longer, the rarer are the rainy periods in the area under consideration.

The foregoing would suggest that female edible frogs spawn five or six times a year, but fairly long observations of adult frogs do not support that. In the proximity of a mating colony I often observed single sexually mature specimens which did not participate in mating, although they were within the range of audibility of the croaking of the mating males. These observations allow the statement that the total number of mating seasons in the given area always exceeds the number of mating seasons of individual frogs.

Edible frogs keep migrating from the moment they wake from torpidity up to the end of mating. The first migration, from rivers and streams to closed and deeper reservoirs, occur in the 2nd half of March. In the 2nd or 3rd decade of April they migrate to shallow water reservoirs to fulfil their first mating and after that return to sluggish rivers and streams, lakes, ponds, old riverbeds, clay-pits and the like. In the period of three months (May — July) they make several such migrations; it should be emphasized that each time each colony mates in another place from that in the previous mating season. My observations suggest that sexually mature frogs perform not fewer than 7—9 migrations in either direction in the spring-summer period.

In the study area edible frogs generally lay eggs from May throughout July. Under exceptionally favourable thermic and humidity conditions they mated from 20 April till 11 August (1962, 1968).

Larval development of 11 amphibian species in Czechoslovakia,
The figures indicate number of

Species	ŠTĚPÁNEK 1949	SCHREIBER E. 1912	STERNFELD R. 1913	RAMNER W. 1956	FREYTAG G. E. 1966
	Czechoslovakia	Germany	Germany	Germany	Germany
Triturus cristatus (LAUR.)		90—120		90—120	
Triturus vulgaris (L.)	90	90—120		90	
Bombina bombina (L.)	90				
Pelobates fuscus (LAUR.)	90—120	90	2/2·3—4	100	
Bufo bufo (L.)	60—90		1/2·3—1/2·5		60—90
Bufo viridis LAUR.	60—90		1/2·5—1/2·7		
Bufo calamita LAUR.					
Hyla arborea (L.)	90		1/2·4—8	90	3—7
Rana esculenta L.			90		
Rana temporaria L.	70—90	90	1/2·3—1/2·5	4—7	60—90
Rana arvalis NILS.	70—90		1/2·3—1/2·5		60—90

Development of Embryo and Larva

I carried out observations on the development of embryos and larvae of the edible frog in three sites (1, 3 and 4), which are marked by different topographical, ecological and, in part, biological conditions.

The edible frog lays eggs towards the end of the spring and in the summer and, consequently, its embryos and larvae develop at a relatively high water temperature (above 20°C). It can be seen from the phenograms constructed during a few years that even slight fluctuations in temperature cause the acceleration or inhibition of the developmental process of the embryo and larva. Thus, e.g., at a mean daily temperature of 22°C the embryo attains a full development in 4 days, a rise in water temperature by 2°C shortens this stage

Table IV

Germany, Poland and U.S.S.R., according to different authors
days or season (dates or months)

Juszczyk W. & Szarski H. 1950	Berger L. & Michałowski J. 1963	Młynarski M. 1966	Juszczyk W. 1937, 1967	Terentiew P. V. & Chernov S. A. 1949	Bannikov A. G. & Denisova M. N. 1956	Tarashchuk V. J 1959
Poland	Poland	Poland	Poland	U.S.S.R.	U.S.S.R.	U.S.S.R.
5—	90	90	2/2·6 4— 11	±90		±90
5— 6—	60— 90		1/2·6 4— 9		60— 70	±90
5— 6—	90	±90	2/2·6 1/2·8	90	60— 90	90
5—8—9 6—9—10	90—150	90—150	2/2·6 2/2·7	120—140	90—100	120—135
2/2·3—2/2·6	90	±42	2/2·4—2/2·6	77— 91	43	
	60— 90		2/2·4—7	60— 91	39— 45	60— 90
5— 6—	40— 50			42— 49		42— 49
	90	±90	2/2·4—2/2·7	90	60— 90	±90
5— 6—8 7—	72—214	72—214	1/2 —8	133	70— 75	90—120
2/2·3—	50—180		2/2·3—2/2·6	50— 90	50— 60	50— 90
2/2·3—	50—120	50—120	2/2·4—	51—120	60— 65	75— 90

by 1 day. If the mating season of frogs is followed by a rapid cooling of water to 17°C, the development of the embryo is prolonged to 5 days, and at 15°C even to 7—8 days.

The influence of environmental factors is also reflected in the rate of larval development. At Site 1, at a mean daily temperature of 22·3°C, the larva accomplishes its full metamorphosis in 67 days, at Site 3, at a mean of 21·8°C, in 71 days, and in the pond at Złoty Potok, at a considerably lower temperature (mean — 13°), in 111 days (Table III).

Young specimens derived from the eggs laid at the beginning of May metamorphose in the 3rd decade of July but they appear in large numbers on the banks of water reservoirs in the 1st and 2nd decades of August. The larvae hatched from the eggs laid in the 1st decade of August do not metamorphose until the April of the next year.

Post-mating Life

After mating the adult frogs stay on the banks of natural and man-made ponds, lakes, ditches, old riverbeds and slow-flowing streams. They are most active in the afternoon and for the night bury themselves in the silt at the bottom of the reservoirs or hide amidst the aquatic vegetation.

At the end of August, at a relatively high water temperature (about 20° C), the first adult specimens start on a migration from closed water reservoirs to small slow-flowing rivers and streams. Mass migrations occur in the 2nd half of September, when the air, soil and water temperatures fall rapidly from 20—22° C to 11—13° C. The sick and injured specimens, which have lost a limb under various circumstances, leave the summer habitats latest. Many of them perish on the way to the winter quarters, which are sometimes at a distance of 3—5 km from the summer grounds.

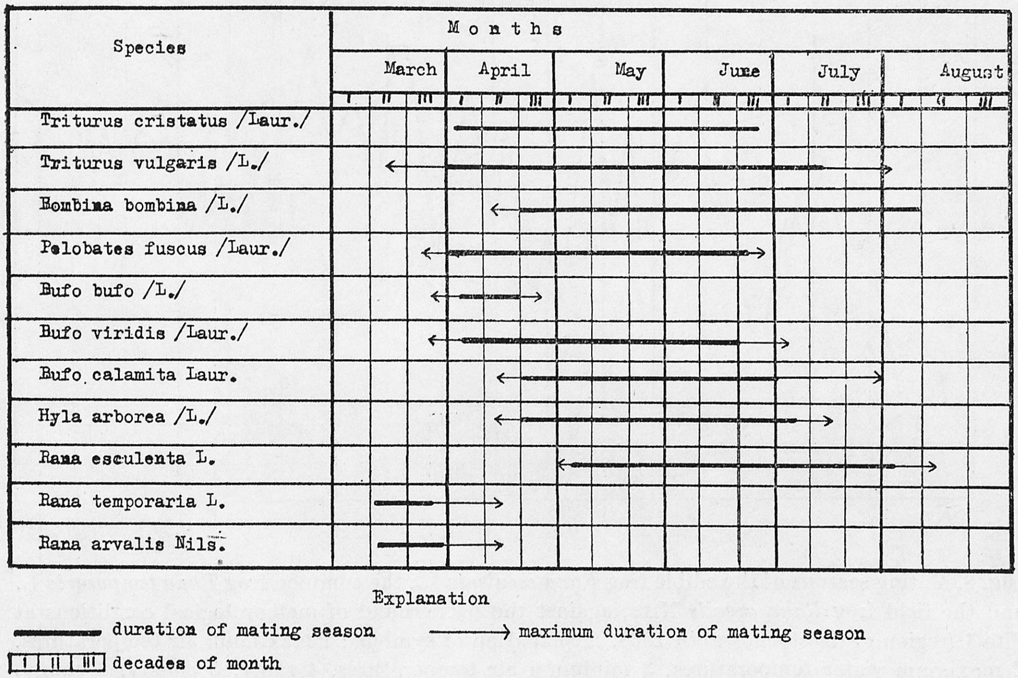
Having arrived in their winter grounds, the edible frogs lead an aquatic-terrestrial life throughout October and the 1st decade of November. On sunny and windless days they come out in large numbers on to the banks of streams and bask in the autumnal sunshine, whereas in the periods of cool and gusty winds and drizzle they hide among water plants or in crevices in the undermined banks of small rivers and streams. At an air temperature of about 8° C a few specimens are still met with on the banks when the sun culminates. In general, the frogs appear on land as long as the daily air and soil temperatures keep higher than the water temperature in streams. In the first decade of November, when the water temperature keeps at a level of 9—10° C and the air and soil temperatures fall to 4—5° C, the edible frogs hide among submerged plants, bury themselves in the silt or sand at the bottom or under decaying plants, squeeze into crevices in the undermined banks and under stones, where they fall into partial torpidity together with common frogs. Owing to the fact that the temperature of water in the streams keeps within limits of 3·5 and 7° C throughout the winter the frogs do not lose their capability of motion and that of reception of external stimuli by means of skin receptors even in their sleep. Only in an exceptionally severe winter with long-lasting periods of frost, when the streams become covered by ice and the water temperature falls below 2—3° C, the frogs pass into the state of complete torpidity and lose their capability of moving and receiving any stimuli.

A small number of adult specimens get under tree roots, into chinks between stones and into burrows of mammals and hibernate, this time, with fire-bellied toads and newts.

The specimens in the first year of life wander about the area or keep to the waterside until the outset of frost. They most frequently take shelter on the riverside — in the growths of bushes and grasses, in burrows and holes under stones and tree roots, and under decaying fragments of plants, etc. They oftenest hibernate with field frogs (Tables II, III, V and VI).

MATING SEASONS OF AMPHIBIANS IN THE REGION OF CZĘSTOCHOWA

Table V



ANNUAL CYCLE OF THE COMMON FROG *RANA TEMPORARIA* LINNAEUS, 1758

Under the climatic conditions of the Częstochowa District the common frog wakes from the winter sleep on the bottom of streams and small rivers in the 1st decade of March (phenologically prevernal period) at a water temperature of about 3—4°C. Exceptionally, an inflow of masses of warm air from the south-west in the 1st half of February 1968 caused a rapid rise in soil and water temperatures to 4—6°C and, as a result, some specimens of this species interrupted their winter sleep as early as 5—6 February (at a water temperature of about 4°C). The ten-day warm, typically early spring weather was followed by a period of low temperatures, when the woken frogs fell again into a state of deep torpidity.

During the typically spring period, in the 2nd and 3rd decades of March, the temperature of water in streams and rivers rises to 5—6°C. Under these thermic conditions the frogs begin copulation. The first single specimens and few pairs leave flowing waters and migrate in search of closed water reservoirs to mate. As the water temperature rises to 7—8°C, the number of pairs increases.

Both single specimens and those in amplexus leave streams and rivers in large numbers and at a suitable temperature but regardless of weather and humidity of the air wander to the mating grounds. Directed by their sexual instinct, they make for shallow reservoirs at a speed of 100—160 m (pairs) or about 300—400 m (single frogs) per hour. The males of wandering pairs co-operate

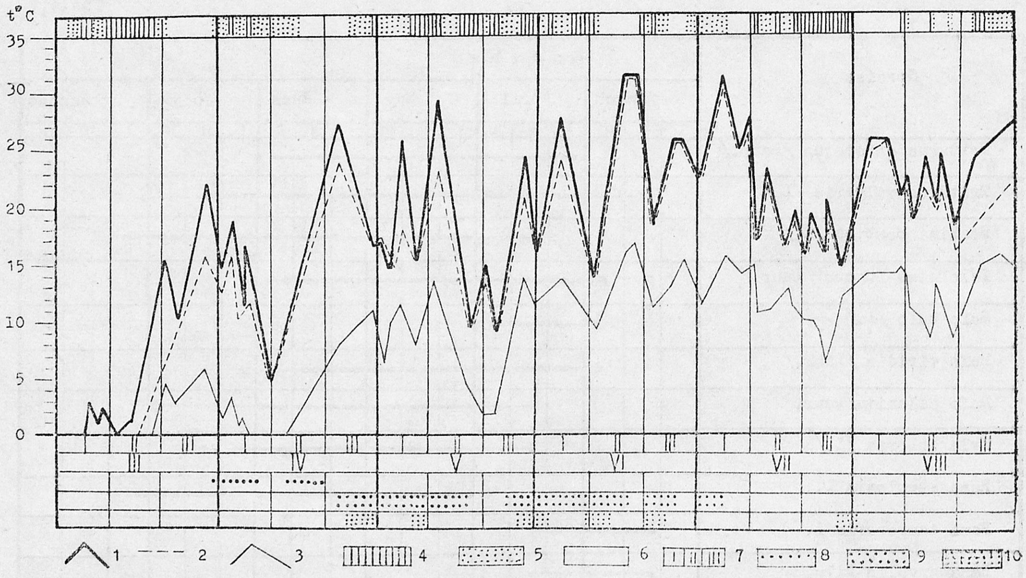


Fig. 8. Mating seasons of the edible frog *Rana esculenta* L., the common frog *Rana temporaria* L. and the field frog *Rana arvalis* Nils. against the background of meteorological conditions at Site 1 (region of Częstochowa) in 1968. Explanation of symbols: 1 maximum air temperatures, 2 maximum water temperatures, 3 minimum air temperatures, 4 rainy, 5 cloudy, 6 sunny, 7 mating season of edible frog, 8 mating season of common frog, 9 mating season of field frog

with the females, using their hind-limbs for this purpose, while they clasp the females with the fore-limbs. The pairing of the specimens which hibernated on land begins when they are still on the way to closed reservoirs, but about 90% of specimens form pairs in stagnant water in the proximity of or just in the place of mating. The length of the period in which the frogs form pairs is entirely dependent upon the thermic conditions of the environment. At 8—12°C in the daytime this process lasts for hardly 1—2 days, if however the temperature drops below the thermic minimum (7°C), it may be prolonged even to 2 weeks and at as low a temperature as 4—5°C some pairs may split.

At the time of mating, at optimum water temperatures within limits of 11—15°C, male common frogs are very active. The increase in their activity is directly proportional to the rise in water temperature and is particularly well seen in the afternoon and in the evening, because it is then that about 60% of adult specimens form pairs to breed.

In addition to normal pairs, aggregations of two, three, four and exceptionally up to 9 males attached to one female are met with. The males show such a strong sex-drive that they do not let go of the females even if these have been stifled or when in amplexus they are carried by the rapid river current for a distance of several kilometres, and every now and again the male strikes its back on the river bank or on some plants and objects that occur in water.

A common biological phenomenon is the occurrence of mixed pairs, consisting of male common frogs and females of other amphibian species, mostly, the common toad, edible frog, field frog and spadefoot toad.

A four-phase 24-hour activity cycle can be distinguished in the breeding season of the common frog in connection with changes in the thermic and environmental conditions:

1. From early morning to 10 a.m. Frogs show very slight sexual activity, only few females begin spawning; agility of amphibians restricted by relatively low water temperature.

2. 10 a.m. — 2 p.m. Frogs brisk up; about 20% of females lay eggs in water.

3. 3—7 p.m. Maximum sexual activity of frogs; about 80% of specimens form pairs and females begin spawning, in which they are accompanied with a great commotion and croaking of males, especially single ones, seeking females to mate with.

4. At 10 p.m. frogs drop to the bottom of the reservoir, where they remain in the state of complete inertia till the morning. Fluctuations in air humidity between 30 and 100% exert no evident influence on the activeness of amphibians during their stay in water.

In the study area the breeding season generally falls in the 2nd and 3rd decades of March, more rarely in the 1st half of April, when the water temperature reaches 7°C in shallow reservoirs. In the period of steady weather the mating season lasts for hardly 7—8 days; a fall in temperature below 7°C has an inhibitory effect on the process of egg-laying and may cause its prolongation to about 20 days. Under optimum thermic conditions (10—15°C) common frogs have a peak of sexual activity on the 2nd and 3rd days of the mating season, when the females lay about 70—75% of spawn.

The common frog is not very particular about the water environment in which it spawns. It is encountered in all kinds of permanent or seasonal closed shallow reservoirs and also in fairly fast-flowing rivers and streams, in which spawn is placed among aquatic plants near the bank or in shallow river creeks. In isolated ponds and pools the female oftenest lays eggs in shallows with remains of plants of the previous year, situated near the bank. The very process of laying spawn takes 10—13 minutes (at a temperature of 12—15°C), after which the male immediately lets go of the female and puts out its head above the water surface in order to provide its organism with atmospheric air. After a 10—15-minute rest the female behaves in a similar way.

Having laid eggs, the females leave the water reservoirs on the same day and start on lonely migrations on land, whereas the males come out on to the bank one or two days later.

At a suitable water temperature the frogs may spawn both on sunny and cloudy or rainy days, even a fairly strong wind, bringing about the undulation of water, does not prevent them from laying eggs. At the time of their sexual activity common frogs gather into large aggregations, which sometimes number several hundred specimens. In such large colonies a special mating atmosphere arises, owing to which the females lay eggs at a relatively low water temperature (about 7—8°). On the other hand, if the copulating pairs are scattered all over the reservoir, the females do not lay spawn even under optimum ecological-thermic conditions. This suggests that the emotional factor, which through the nervous system incites the hormonal and genital systems to intense activity, plays an important role. The colonies of common frogs sometimes include also field frogs, which however most frequently form separate colonies in the same or other water reservoirs. The members of the other species hurriedly leave the breeding grounds of these frogs and seek after more favourable conditions to mate.

Development of Embryo and Larva

The embryos of the common frog begin to develop at the end of March or at the beginning of April at a relatively low water temperature fluct tuating between 4.
and 11°C and a daily mean of about 8—9°C. Under such thermic conditions the embryos leave the interior of jelly shells and settle down on the surface of the spawn after about 10 days. The embryos developing from the eggs laid in the period of rapid warming up, at a temperature of 14—19°C and a daily mean of 15·8°C, hatch after 7 days.

A similar dependence is shown by the larvae during their passive life. At a mean daily temperature of 8—9°C their stay on the surface of spawn lasts for about 6—8 days, whereas at a temperature 3—4° higher only for 4—5 days.

The further development of the tadpole proceeds at a considerably higher temperature, ranging from 6 to 27—30°C in the spring-summer period. Within these extreme temperatures, at a daily mean of 16·8°C, young frogs leave the reservoir after 64 days, whereas the larvae developing at a mean daily water temperature of 15·5°C complete their metamorphosis after 75 days.

Under typical summer conditions the first young specimens appear on the land as early as the 1st decade of June and they leave water in large numbers in the 2nd and 3rd decades of June. Under less favourable conditions all these terms may be postponed by several or some dozen days. The metamorphosis of the members of the young generation lasts as a rule till 5 August, and only in few cases ends later.

Terrestrial Life

After mating common frogs stay in forests, marshes, damp meadows, cultivated fields and gardens.

As early as the 2nd half of September they appear in large numbers in the proximity of their winter quarters. In this period there occurs a systematic fall in air and soil temperatures (maximum temperatures from 24° to 13°C and minimum ones from 13° to 2—4°C) and, on the other hand, the amplitudes between early-morning and daily temperatures increase rapidly and reach the highest values (from 15 to 17°C and in places exposed to the sun's rays even to 20°C).

Frogs wander, as a rule in the daytime, in ditches and valleys along rivers and streams, avoiding dry open areas void of any vegetation. Heading instinctively for their winter quarters, they cover an average way of 1—3 kilometres on land or in water within a few days. In water they move at a speed of 2—10 m per minute and on land at about 200—300 m per hour. Before entering water they form groups in the places situated near their future winter shelters. They leave the terrestrial environment for the water one when the air and soil temperatures drop below 10°C in the daytime and to about 2—3°C by night, whereas the water temperature keeps at the level of 10°C. Single frogs are exceptionally encountered at the waterside in the first half of November, at a daily air temperature of about 5°C.

Young frogs usually hide for winter 10—14 days later than the adults do. They are still met with in November, at daily air and soil temperatures as low as about 1—2°C.

Common frogs hibernate in streams with a sandy or gravel bottom, in small unfreezing rivers, peat ditches, more rarely in ponds and lakes (Złoty Potok, Blachownia). They do not bury themselves in sand or silt in the bottom but squeeze into crevices in the undermined banks or gaps between stones, hide among submerged plants or simply lie on the bottom of the reservoir. They hibernate in groups, numbering several tens or hundreds of specimens. They are never entirely torpid, as they are able to change the place of hibernation in the cases of the freezing of the water, its poisoning and lack of oxygen.

Only few specimens hibernate on land, under heaps of decaying leaves or dry twigs, in rotten trunks, under tree roots, in moss, holes and burrows (Tables II, III, V and VI).

ANNUAL CYCLE OF THE FIELD FROG *RANA ARVALIS* Nilsson, 1842

The field frog belongs to the amphibians which leave their land and water winter shelters very early, when the temperature reaches 3°C. Under normal winter and spring conditions the first males as a rule appear in water in the first decade of March. Exceptionally early or late spring may hasten or retard the awakening of the frogs from winter sleep. For example, in 1968 the field frogs appeared in water at Sites 1 and 2 at a temperature of hardly about 3°C on 4 February. During the following 8 days the temperature of water rose gradually to 5—7°C. The male field frogs revealed a remarkable activeness and their bodies showed distinct dimorphic characters: the back was covered with a blue-purple coat and the skin was swollen owing to the accumulation of a considerable amount of fluid in the lymph sacs.

When the temperature fell below 0°C (16 February — 16 March) and all the reservoirs of stagnant water were covered with a relatively thick layer of ice, the field frogs fell again into complete torpidity, but this time in the water environment. Some specimens persisted in this state till the spring, but most of them perished; they either fell victims to leeches or suffocated under the ice cover.

Large numbers of frogs appear in water warmed to 4—6°C, the males arriving 1—2 days earlier than the females. Soon they form pairs, which under favourable conditions takes a very short time. Both single frogs and their pairs, scattered in the bank zone of shallow reservoirs, gather together into large accumulations, at times numbering several tens or even hundreds of specimens in an area of some dozen square metres.

During the breeding season male field frogs outnumber the females and besides they show an intense sexual activity. This is why a common occurrence is a group of two to six males attached to one female. Interspecific mixed pairs are also fairly often encountered. During steady weather with water temperatures ranging from 7 to 18°C, spawning lasts hardly 6—8 days, but it becomes inhibited or interrupted when the temperature falls below the lower limit or rises above the upper one. The optimum water temperature, at which the females lay about 80% of spawn lies between 10 and 15°C. At lower water temperatures (7—9°C) they are most active in the afternoon and in the evening, but under optimum conditions females begin spawning at 10 a.m. and continue it until late evening hours, sometimes even into the night. Females lay eggs on the bottom of a shallow water reservoir and this process takes about 8—12 minutes, after which the pair splits, the male swims to the surface of water to oxygenate its organism with atmospheric air, in which it is followed by the female after a 10—15-minute rest at the place of egg-laying.

The volume of spawn, just after its being laid, is about 8—15 cu. cm and it contains 1000—2000 tiny eggs. The animal pole of the egg is dark brown in colour, but there are sometimes eggs which are light coloured: yellow, pink and even red.

Soon after laying spawn the females leave water in large numbers and move on to the land, whereas the males stay in water for another day or two, gradually scatter in shallows near the banks, which is accompanied by the subsidence of sexual behaviour and sometimes by the disappearance of dimorphic characters.

Periods of the rapid cooling of air, soil and water to 1—3°C occur in the 2nd half of March or in the 1st half of April every several years. Amphibians, present in water at that time, hide chiefly in waterside thickets. Single specimens and copulating pairs come out on to the bank where they bury themselves in heaps of dry twigs or decaying plants, squeeze into depressions in the ground, under pieces of bark or wood, enter the burrows of mammals, etc. Then the co-ordination of their movements and the balance of body become unsettled, the orientation in the surroundings very poor and the response to external stimuli slight. In the period of spring cool weather a considerable number of common frogs, field frogs and common toads fall victims to horse-leeches *(Haemopis sanguisuga)*, which easily get attached to the then little sensitive skin of these amphibians and suck blood out of them.

Development of Embryo and Larva

The embryos hatch from the egg shells after 11 days at a water temperature of 3—10° C and a daily mean of 7·4° C and after 8 days if the temperature is much higher (13—16° C). The newly hatched larvae remain on the surface of the maternal spawn for 6 to 9 days in dependence on the prevailing thermic conditions.

At a water temperature fluctuating between 5 and 25° C and a mean of 16·6° C the metamorphosis of tadpoles takes 67 days, whereas within the same limit temperatures but at a lower mean (15·2° C) it lasts 73 days. The full development of the embryo and larva lasts 75 to 84 days.

The earliest young specimens come out on to the land as early as the 1st half of June and they appear in large numbers in the 2nd half of this month. Only the metamorphoses of backward specimens continue into the 1st decade of August.

Terrestrial Life

After the breeding season the field frogs are most frequently encountered in meadows, peatbogs, marshes and at the edge of forests. They are more resistant to the dryness of air and soil than the common frog is, but at the same time more sensitive to the falls in temperature, which quite agrees with the prevalence of the diurnal way of life in them over the nocturnal one. They fall into winter sleep on the land at a soil temperature below 2·5° C (Tables II, III, V and VI).

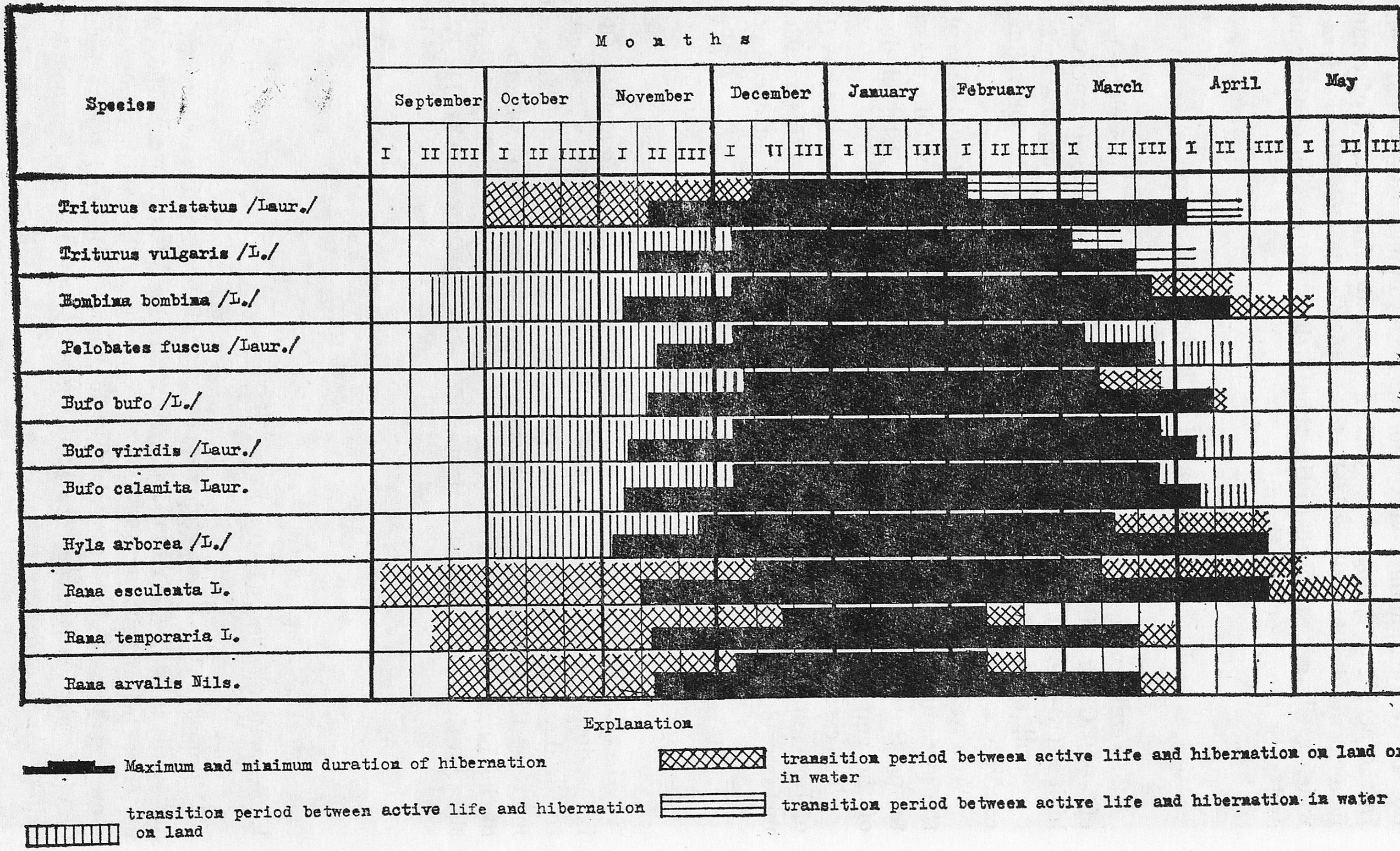
DISCUSSION

1. *Triturus cristatus* (Laurenti, 1768)

Numerous Polish herpetologists claim that the breeding season of the crested newt falls in May (Bayger, 1937; Berger and Michałowski, 1963, and other writers). Only Juszczyk (1967), in the ecogram of the Polish amphibian species, shows against the background of their annual cycles and taking into account their life phenomena that the breeding season of this species includes the 2nd half of April and May.

MAXIMUM AND MINIMUM DURATION OF HIBERNATION OF AMPHIBIANS IN THE REGION OF CZĘSTOCHOWA IN 1960 - 1968

Table VI



In the study area the mating season of newts lasts from 10—15 April to mid-June.

According to Juszczyk (1967a), under normal conditions newts lay one or only rarely two eggs a day, whereas Bannikov and Denisova (1956) write that they lay several eggs daily for 2—2·5 months.

My observations show that the process of reproduction is intensest at warm rainy weather or soon after the rain stops, for then all sexually mature specimens partake in mating, and the females lay mostly two or, more rarely, three eggs daily. In April and June newts as a rule lay one egg a day.

For the neighbouring countries, which differ in climatic conditions, different dates of the appearance of this species and its mating season are given. E.g., according to Schreiber (1912) and Freytag (1966), in Germany the crested newt stays in water from February till late in the summer and lays eggs in April and May.

In the Ukraine newts wander to water very early, often when snow is still lying in the fields, in the 2nd and 3rd decades of March. In the Kherson region they appear in masses in water as early as 11 March, whereas near Kiev in the 2nd half of March. Not long later they start courtship and lay single eggs in April or at the beginning of May (Tarashchuk, 1959).

In Central Russia crested newts reproduce somewhat later than common and field frogs do (April-May), and their mating season lasts for about 50 days (Terentyev and Chernov, 1949; Bannikov and Denisova, 1956).

It follows that in the temperate climate with fairly high rainfall (Poland, Germany) the breeding season of the crested newt is longer than in the dry climate of the Ukraine, where the thermic conditions in the spring and summer are much more favourable than in Central and Western Europe.

In the Polish investigators' opinion (Table IV) in the lowlands the metamorphosis of the larval crested newt is completed after about 90 days. According to Juszczyk (1967b) the larvae begin their metamorphosis at the end of June and the beginning of July and they metamorphose in masses in July and at the beginning of August. However, even in the lowlands metamorphosing larvae can still be met with in November. In the mountainous area the time of metamorphosis comes later and is continued into the late autumn.

In the study area at a daily mean of 20·5°C the development of the larva takes about 72 days, and the full development of the embryo and larva 91 days. The first young newts leave water in the 1st decade of July, in large numbers they come out on to land in the 3rd decade of July and in the 1st half of August. A small number of larvae hibernate. The phenomenon of compulsory hibernation of larvae is well known (Ramner, 1956; Sembrat and Nowakówna, 1959; Berger and Michałowski, 1963; Juszczyk, 1967b, etc.), and Bannikov and Denisova (1956) write that in the north and in the mountains the metamorphosis of larvae often occurs in the second or even third season.

The German authors state that in their territory the development of the larvae of the crested newt lasts 90—120 days (among others Schreiber, 1912;

morphose after about 90 days (Terentyev and Chernov, 1949; Tarashchuk, 1959).

The foregoing data show that in the continental climate of Central and Eastern Europe the metamorphosis of larval crested newts occurs much earlier than in the damp climate of Western Europe.

Newts are characterized by a tendency to form aggregations, especially in the places favourable to their hibernation. The gregarious hibernation of newts is mentioned by many authors (among others Fudakowski, 1953; Tarashchuk, 1959, Berger and Michałowski, 1963; Młynarski, 1966, Juszczyk, 1967b). Braunier (1923), for instance, reports that in the Kherson region 70 crested newts were found under a lying tree trunk in September, where they gathered to stay through the winter.

At Site 1 I fairly often saw large aggregations of hibernating newts, e.g., in the gaps in a heap of slag, 2 cu.m in volume, I counted 317 common newts and 19 crested newts.

2. *Triturus vulgaris* (Linnaeus, 1758)

The Polish herpetologists agree that in the lowlands common newts appear in the early spring, in the 3rd decade of March (among other authors Berger and Michałowski, 1963; Młynarski, 1966). In the Polish literature there is no mention of the active life of newts in the winter, it was, however, observed in February 1968. A flow of a mass of warm air from the west caused a rapid rise in air temperature to 11°C and in water and soil temperature to 5—6°C. I observed the first mature newts in water warmed to 4°C on 5 February, and at 6°C they appeared in many shallow reservoirs in fairly large numbers. When the still waters were again covered with a layer of ice, the newts fell into torpidity. As regards the mating season of the common newt the opinions expressed in literature are extremely different. According to Berger and Michałowski (1963), the female lays eggs in May and June and in Bayger's (1937) opinion, it happens in May and the 1st half of June. In the ecogram of the Polish amphibian species against the background of the annual cycle of their life in the Kraków region Juszczyk (1967a) shows that the period of mass egg-laying lasts from mid-April till mid-June, and its maximum range is from mid-March to about 10 July.

In the course of my own investigation I found that the mating season of the common newt lasts from the beginning of April to mid-July. Only moderate air and water temperatures and rainy weather in summer may cause its prolongation to 3 August.

In Western Europe under favourable thermic conditions and at high humidity both the awakening of newts from torpidity and the mating season occur much earlier than in this country.

Under the natural conditions of the Częstochowa District the adult specimens

In Germany at favourable weather common newts appear in water as early as January or Febraury and the mating season goes on from March to May, sometimes July (WERMUTH, 1957; FROMMHOLD, 1959).

In the Ukraine adult newts start on their migration from terrestrial winter shelters to water reservoirs to mate in April and, in the case of early spring, at the end of March (TARASHCHUK, 1959). The breeding season falls in the 2nd half of April and May (NIKOLSKIY, 1918).

In the region of Moscow this species reproduces in April and May (TERENTYEV, 1961). According to BANNIKOV and DENISOVA (1956), female newts lay eggs, several daily, for 2—2·5 months and in the breeding season stay in water for about 75 days.

In the light of the foregoing in Germany and Poland, which have a temperate climate and higher rainfall of the spring-summer period, the mating season of the common newt is twice as long as it is in the dry and hot Ukraine steppes.

Most authors, in this country and out of it, estimate the length of the larval life of the common newt at about 90 days (ŠTĚPÁNEK, 1949; RAMNER, 1956; TARASHCHUK, 1959; JUSZCZYK, 1967b, and others). A small group of investigators give considerably shorter developmental periods of these larvae, e.g. according to BANNIKOV and DENISOVA (1956) the embryonic stage lasts 14—20 days and the larval stage 60—70 days, and BERGER and MICHAŁOWSKI (1963) are of opinion that the larvae metamorphose after 60—90 days.

In the study area the period of the full development of the embryo and larva is 82—84 days. The first young specimens appear on land about 20—25 June and in large masses they leave water in July and in the 1st decade of August.

3. *Bombina bombina* (LINNAEUS, 1761)

Many authors emphasize the coincidence of the mating season of the fire-bellied toad with rainy weather. In my opinion, within the limit temperatures these animals mate both at the time of dry and sunny weather and on cloudy and rainy days. Only the gusty wind, which causes the heavy undulation of water, may make amphibians interrupt mating for some time and hide in the waterside thickets. It should, however, be stressed that the laying of eggs proceeds more intensely during the rain and soon after it stops and that the maximum amount of spawn is laid in June, the month in which both the rainfall increases and there occur optimum water temperatures.

On the basis of rich material, MADEJ (1966, 1973) states that the males prevail in number (54% of all the specimens of *Bombina bombina*). At Site 1 the males outnumber the females by 5% and, as a result, I observed amplexus of fire-bellied toads in which 2, 3 and even 4 males were attached to a female, on both its dorsal and ventral side. Generally, males embrace females with their fore-limbs at the base of the hind-limbs. Fairly often, however, they face each other in amplexus. Male fire-bellied toads sometimes hold on to a hind- or fore-limb of another amphibian.

The Polish herpetologists differ in opinion as regards the time of egg-laying and the maximum duration of the breeding season of *Bombina*.

Udziela (1910) writes that the mating of fire-bellied toads occurs in the 1st half of May. According to Bayger (1937) and Berger and Michałowski (1963), it falls in May and June, and Juszczyk (1937) thinks that the breeding season of this amphibian is not associated with an exact calendar period, but undergoes great fluctuations, ranging within the period of four months (from mid-April to mid-August; Juszczyk, 1967a).

In the study area the period of mass laying of eggs lasts from 20 April to 20 July, the maximum span of the breeding season reaching from 15 April to 10 August. The beginning of the mating of the fire-bellied toad coincides with the first stage of mating in the variable toad, natterjack and tree-toad. In my opinion, the above-mentioned species have nearly identical ecological-thermic demands in the mating season and differ, as a rule, in the fact that fire-bellied toads mate in both shallow and deeper water reservoirs, whereas the members of the other species breed usually in small and shallow ones, more rarely near the banks in large water reservoirs.

On account of different climatic conditions, in the countries neighbouring on Poland the times of appearance and reproduction of amphibians are also different. Thus, in the Ukraine the fire-bellied toad becomes active in the 2nd half of April (in the post-war years the earliest appearance of this toad was recorded near Kiev on 23 March and in the Luganskiy steppe on 30 March) and mates at the end of April and in May (Nikolskiy, 1918; Tarashchuk, 1959), whereas in the region of Moscow it reproduces in May and June (Terentyev, 1961).

In Germany, in a milder climate than that in the central region of the U.S.S.R. and with heavier rainfall, the mating season of the fire-bellied toad lasts from the 1st decade of April throughout June, being sometimes prolonged into the summer, but the main period of spawning falls in May and June (Frommhold, 1959).

The foregoing data indicate the coincidence of the breeding season of the fire-bellied toad in southern Poland and Germany, these countries resembling each other closely in climate.

A few authors state that this species reproduces several times a year (Wermuth, 1957; Fuhn, 1960). Most investigators, however, do not take into account the occurrence of several mating seasons in the year, but write about one season without mentioning that it contains several mating stages.

In my opinion, in the mating of the fire-bellied toad there are irregular breaks, caused by the sometimes considerable changes in temperature, reaching beyond the limit temperatures of the breeding season of this species (below 14° and above 30°C).

In the unanimous opinion of various authors, the development of the larval fire-bellied toad lasts for about 90 days (Table IV). Only Bannikov and Denisova (1956) give a considerably shorter larval stage, namely, 60—90 days.

In the study area the development of the embryo and larva, from the moment of egg-laying to that of the departure of newly metamorphosed specimens from water covers the period of 78—93 days.

Fire-bellied toads mostly hibernate gregariously. TARASHCHUK quotes SHCHERBAK (1957), who numbered 70 specimens in one aggregation in the Ukraine. I found a winter shelter of the fire-bellied toads (Kucelinka), where in the gaps of a heap of slag (6 cu. m in volume) there were as many as 298 specimens of various age. They were accompanied there by 117 common newts and 9 crested newts.

4. *Pelobates fuscus* (LAURENTI, 1768)

Numerous herpetologists regard the spadefoot toad as an early-spring species (among other authors, BAYGER, 1937; TARASHCHUK, 1959; JUSZCZYK, 1967a).

My observations in this respect quite agree with the results of the authors above. Digging the sand in the bottom of pits and ditches early in the spring, where spadefoot toads were hidden for winter, I found that they woke from torpidity in the 2nd half of March, at a soil temperature of 3·5—4°C.

Adult specimens of both sexes start on mating migrations at dusk or in the night, at an air and soil temperature of about 4—5°C, which indicates a great resistance of this species to low ambient temperatures.

Most herpetologists think that the spadefoot toad's breeding season is not connected with a closely defined calendar period but dependent on the intensity of rains (TERENTYEV, 1961; BERGER and MICHAŁOWSKI, 1963; MŁYNARSKI, 1966).

On the basis of the observations made so far I, too, have arrived at the conclusion that rainfall has a decisive effect on the outset of mating of the spadefoot toad.

So far as the time and duration of the breeding season is concerned, the authors differ in opinion. UDZIELA (1910) states that these toads pair and lay eggs only in April. According to SZARSKI (1939), their mating season was observed from the beginning of April throughout July. BERGER and MICHAŁOWSKI (1963) write that the mating season lasts from March to May, and in BAYGER'S (1937) opinion it falls in the 2nd half of March and in the 1st half of April.

In the study area the breeding season of the spadefoot toad lasts interruptedly — according to the weather — from the end of March to the end of June.

In the Ukraine members of this species appear in the 2nd and 3rd decades of March. Soon after leaving their winter shelters on the land they start a migration to water reservoirs. In order to reach water they must often wander for long distances, which makes the impression that they migrate in search of new living areas. The mating season covers the end of March and April (in the vicinity of Kiev the earliest copulation was seen on 26 March; TARASHCHUK, 1959).

According to OLIGER (1955) and BANNIKOV and DENISOVA (1956), under the more severe climatic conditions of the region of Moscow, copulation and egg-laying begin at the beginning of May and their stay in water lasts for 20—25 days.

In the zone of mild climate in the German territory the mating season of the spadefoot toad begins very early, at the end of February and continues to the end of May, although FREYTAG (1966) mentions only two months, April and May.

These facts show that in the maritime climate of Western and Central Europe the mating season of the spadefoot toad is much longer than it is in the continental climate of the U.S.S.R. It proves, in addition, that the sexual activeness of the members of this species is not connected with a defined calendar time or temperatures of the environment, but it depends on the occurrence of rain.

The data in literature show that the metamorphosis of spadefoot tadpoles occurs after 90—150 days (Table IV). Cases of hibernation of larvae are also known (TARASHCHUK, 1959; BERGER and MICHAŁOWSKI, 1963; FUHN, 1960; FREYTAG, 1966; MŁYNARSKI, 1966).

In my investigation I found that under natural conditions spadefoot tadpoles metamorphose after 81—150 days in the region of Częstochowa. The development rate of the embryo and larva depends on the whole set of factors, of which the temperature of water plays a decisive role. In water reservoirs, which have identical light conditions and similar phytosociological and microclimatic conditions, and only slightly differ in their maximum, minimum and, consequently, mean temperatures, there occur differences in the length of the developmental stages of larvae. Thus, in one reservoir, at a daily mean temperature of 19·8°C, the metamorphosis of the spadefoot larvae is completed in 81 days, whereas in another one, at a daily mean of 18·5°C, its completion occurs after 84 days. The number of specimens included in the analysis in either reservoir comes to about 1400. The full embryonic and larval development of one-season specimens takes, as a rule, 91—95 days. Under typical summer conditions the first young specimens leave water at the beginning of the 2nd decade of July and metamorphose in large numbers in August and the 1st half of September. On the other hand, in the years with a shortened period of autumn weather and unfavourable thermic balance the larvae do not complete their metamorphoses until the April of the next year (1965, 1966 and 1968).

My observations on the enforced hibernation of the spadefoot larvae agree with the data in literature.

5. *Bufo bufo* (LINNAEUS, 1758)

Numerous authors consider the common toad to be an early-spring form with a remarkably short period of egg-laying (TARASHCHUK, 1959; FUHN, 1960; JUSZCZYK, 1967a, and others). Also my observations suggest that the sexually mature specimens generally wake from winter sleep as early as the 2nd and 3rd decades of March at a soil temperature of 3—4°C. In water warmed to 10°C the breeding season takes hardly 8—10 days.

The dependence of the time of awakening from torpidity and the mating season of the common toad upon the thermic conditions of natural environment is evidenced by the following facts: in Germany and Czechoslovakia this species reproduces in March and April, in the belt of deciduous forests in the European republics of the U.S.S.R. towards the end of April, and in Sakhalin in June (WERNER, 1932; FROMMHOLD, 1959; ŠTĚPÁNEK, 1949; CHARLEMAGNE, 1923; TERENTYEV and CHERNOV, 1949). In the mountains, where spring begins nearly a month and a half later than in the lowlands, the mating season of this toad, usually occurring in the lowlands in March and April, is also retarded, which is evidenced by the fact of finding its spawn on 30 April 1964 in a pond at Krościenko in the Pieniny Mts. (KOWALSKI and MŁYNARSKI, 1965).

In herpetological literature there are no data on the limit and optimum temperatures of the breeding season of the common toad. In the Częstochowa District mass pairing and laying eggs occurs at a water temperature between 11 and 17°C, extreme temperatures of breeding being 6 and 22°C.

In FUHN'S (1960) opinion, male common toads are more numerous than females. In the natural environment of the study area the number of males is 2—4 times as large as the number of females. Consequently, we fairly often meet with an aggregation of toads in which 2—8 males are attached to one female.

There are fairly great divergencies in the opinions on the duration of the embryonic and larval stages in the common toad.

MŁYNARSKI (1966) states that the period of metamorphosis lasts about 6 weeks, after which small toads leave water in masses. JUSZCZYK (1954) confines the time of the metamorphosis of larvae to two months: June and July (Annual cycle of the common toad in Poland). On the other hand, UDZIELA (1910), BAYGER (1937) and BERGER and MICHAŁOWSKI (1963) hold the opinion that metamorphosis occurs after three months, usually in June.

According to the German herpetologists (FROMMHOLD, 1959; FREYTAG, 1966), the larval development of this species takes 2—3 months.

In different geographical regions of the U.S.S.R. tadpoles of the common toad take 43 to 91 days to complete their development. The coming out of young specimens on to the land is observed in the Kiev region at the beginning of August and in the Carpathians (Stryysk) as late as the 2nd half of September (TARASHCHUK, 1959; BANNIKOV and DENISOVA, 1956; TERENTYEV and CHERNOV, 1949).

In the water reservoirs of the four sites under comparison the period of development and metamorphosis of the larval common toad lasts for 56—74 days. The juxtaposition of the results obtained by me with the data given by the authors quoted above shows that in the study area the developmental period of the larva comes in this respect nearest to that found by MŁYNARSKI (1966).

6. *Bufo viridis* LAURENTI, 1768

More than 30 years ago JUSZCZYK (1937) wrote that the breeding season of the variable toad is not connected with a closely determined calendar period, but undergoes fluctuations and may cover a space of about 3 months, being dependent upon the intensity of rainfall. KOWALSKI and MŁYNARSKI (1965), too, explain the long period of spawning in the Pieniny Mts. by the occurrence of heavy rains in the summer months.

In the study area mating, as a rule, followed rainy weather, but, if started, it proceeded at temperatures within limits of 14 and 27°C irrespective of the weather, i.e., both on cloudy or rainy days and during periods of full and lasting insolation. Few specimens appear in water in a dry period, at a relative humidity of 30—50%; nevertheless, they pair and spawn normally under such conditions.

Herpetologists differ in opinion as regards the time of egg-laying. According to BAYGER (1937) and BERGER and MICHAŁOWSKI (1963), the breeding season of the variable toad falls in April and the beginning of May, or even later. In SEMBRAT'S (1953) opinion, this species breeds in the 2nd half of April and in May, sometimes as late as June. In the ecogram of the Polish amphibians JUSZCZYK (1967a) demonstrates that the period of mass egg-laying lasts from the beginning of May to 20 June and the maximum range of the mating season reaches from the 2nd decade of April to the 1st decade of July. KOWALSKI and MŁYNARSKI (1965) state that in the Pieniny Mts. the variable toads lay spawn from the end of April to the end of June and in 1964 their characteristic voice was heard even in September.

In the Częstochowa District this species reproduces from the 1st decade of April throughout June; in exceptionally warm summers with increased rainfall the period is prolonged till 4—5 July.

In the countries bordering on Poland the occurrence of the mating season of this species depends on the climate of the given region. Thus, e.g. in the relatively warm and damp climate of Germany variable toads mate from April to June, sometimes even to August (FROMMHOLD, 1959; FREYTAG, 1966), whereas in the central region of the European territory of the U.S.S.R., in the continental climate with considerable fluctuations of both daily and annual temperatures, egg-laying begins as late as the end of April or in May but lasts only to the end of August. On the other hand, in the Ukraine, which has a lower humidity but considerably higher annual quantity of light and heat, the mating season begins much earlier. In the spring the first specimens appear in water as early as the end of March and spawn in April. Mating generally goes on till mid-May, and so it lasts much shorter than in damper areas (TERENTYEV and CHERNOV, 1949; BANNIKOV and DENISOVA, 1959).

According to different authors the development of the tadpole variable toad may take from 39 to 91 days. The great differences in the duration of development in this species indicate its great plasticity and adaptibility to different environments. E.g., in the Ukraine, with its relatively dry and hot summer, the process of metamorphosis lasts hardly 39 days (BANNIKOV and DENISOVA, 1956), and in the areas situated close to the northern range of this species the larvae metamorphose into small toads in 91 days (TERENTYEV and CHERNOV, 1949).

In the study area the metamorphosis of tadpoles of the variable toad is completed after 44—70 days, being dependent on the weather of the spring-summer period.

According to TARASHCHUK (1959), the development of the embryo lasts for about a week, but the author does not give any data concerning the environmental conditions in which the study was made.

The larval stage is also dependent on the weather conditions in particular years, for weather is responsible for such factors as the lighting of water reservoirs and their temperature. Detailed data in this respect will be seen in Table III. The data concerning the duration of the larval developmental stage in different European countries, derived from various sources, and the results of my investigation quite agree with each other. In the north the larval stage lasts for about 91 days, in the south for 39 days, and in the study area for 40—70 days. The mean length of the developmental larval stage in the Częstochowa District corresponds with the situation of this area in Central Europe.

In October, at a nocturnal soil temperature of about 5—6° C, the toads bury themselves in the burrows of rodents, passages of moles, cellars and pigsties or hide under the heaps of refuse or manure and there they hibernate in the state of torpidity. The specimens in the first year of life are less sensitive to low air and soil temperatures than the older specimens and, consequently, they can be met with as late as the 3rd decade of October and even in the 1st decade of November, at a night temperature below 5°C.

BANNIKOV (1940) writes about the resistance of the young specimens, as follows: "While under experimental conditions the adult specimens do not endure the cooling of their bodies below —0·4 — —0·8°C, the young ones, in the first year of life, resist the cooling to —1 or —1·1°C".

7. *Bufo calamita* LAURENTI, 1768

As can be seen from literature, neither the distribution nor biology of the natterjack is sufficiently well known.

I have already published some observations on the natterjack (KOWALEWSKI, 1967, 1969), in which among other data I gave the terms of the successive developmental stages of this species against the background of the thermic conditions of water. I shall compare the later observations, chiefly concerning the mating season of the natterjack, with the data from literature.

There are no data at all as regards the thermic conditions of the appearance of the natterjack. RZEPECKI (1965) reports only that he never met with the members of this species during cool nights when the temperature fell below 12°C. RAMNER, 1956). In the European territory of the U.S.S.R. the larvae metascramble out on to the surface of the ground at a temperature of 8—10°C and enter water when the temperature is above 13°C.

No data concerning the extreme temperatures and optimum conditions of reproduction are given for this species in literature. Only Rzepecki (1965) states that egg-laying becomes a mass process at water temperatures from 18 to 20°C.

In the regions of Kucelinka and Brzeziny natterjacks carry on mating in 5 or 6 stages at water temperatures between 14 and 25°C. The optimum water temperatures of mating lie within limits of 18 and 22°C.

Polish herpetologists disagree as to the time and duration of the breeding season of the natterjack. According to Sembrat (1953), the natterjack spawns in May and June. Bayger (1937) claims that egg-laying begins in May and lasts till mid-June, and Berger and Michałowski (1963) report that the mating season falls in May. In Młynarski's opinion (1966), spawning is sometimes protracted throughout the summer.

In the region of Częstochowa the first mating season begins, for the most part, on 10—15 April and the last one ends about 20 June. The maximum span of the mating season of natterjacks is from 10 April to 15 July. Thus, my observations in this respect most resemble the data given by Sembrat and Młynarski.

In the countries neighbouring upon Poland the terms of breeding of the natterjack, given by different authors, are also different, owing to various weather conditions. Thus, in Germany, where the climate is temperature, mostly mild, under the influence of the masses of air from above the ocean, the breeding season of the natterjack occurs in April and May (somewhat earlier than in Poland) and only exceptionally is prolonged to July (Freytag, 1966). In the western Ukraine and Byelorussia (climate resembling that of this country) the natterjack breeds from April to September (Terentyev and Chernov, 1949; Tarashchuk, 1959) and in the north-western part of the European territory of the U.S.S.R., where the climate is more severe than in the German Lowlands or in the Ukraine, its breeding season begins as late as May but includes also the summer months (Bannikov and Denisova, 1956).

Numerous herpetologists consider the natterjack to be a Central or West European amphibian, which inhabits, above all, the areas whose climate shows influences of the sea. However, the occurrence of natterjacks has been reported from the western Ukraine, where the climate is rather continental than maritime. This fact suggests that this species moves gradually to the east and thus extends its distribution area.

During my investigation carried out for many years in the region of Częstochowa I succeeded in observing the appearance of natterjacks in new areas of both light sandy soils and heavy sand-yclayey ones. I also found the presence of mating specimens in more and more new water reservoirs and at that in increasing numbers. This proves the extension of natterjacks over new woodless areas (barrens, cultivated fields, pastures, parks and gardens).

During my systematic observations of the life of toads living in this country I arrived at the conclusion that the natterjack has many hereditary characters which allow it to predominate over the other toad species. These characters are as follows:

1. the natterjack is smaller and more agile, it can hide against its enemies more easily;

2. it has a more effective protective coloration than the other toad species;

3. it secretes venom of great toxicity, which is effective in defending it against predators;

4. it is marked by great fertility (for it lays eggs by stages for 3—4 months);

5. it is very indiscriminative as regards the selection of environment to mate in. It lays eggs in different sorts of both permanent and seasonal small water reservoirs;

6. it attains sexual maturity a year earlier than the remaining species of toads;

7. its larvae develop so quickly (40—45 days) that they can complete their metamorphosis in seasonal water reservoirs before they have dried up;

8. it hides for winter more effectively than the members of the other toad species, for it buries itself in earth to a depth of a metre or even deeper;

9. it is more intelligent and careful than the common toad and variable toad;

10. occurs in the vicinity of factories and therefore is not very sensitive to their obnoxious fumes, which spread both in the atmosphere and in water.

The foregoing survey suggests the conclusion that, owing to its plasticity and capability of prompt adaptation to its environment, which in our times changes at a very great rate, the natterjack may become the commonest species, dominant over the other toads living in Poland.

The scanty foreign literature on the length of the developmental stage of the larva indicates that in other areas characterized by different climatic conditions the development of the tadpole of this species also proceeds promptly and lasts for hardly 42—49 days (Terentyev and Chernov, 1949; Tarashchuk, 1959).

8. *Hyla arborea* (Linnaeus, 1758)

Many Polish authors write that the tree frog appears as early as April (Berger and Michałowski, 1963; Młynarski, 1966; Juszczyk, 1967a), but they differ in opinion as to the time of the mating season. According to Udziela (1910) mating begins at mid-April and lasts throughout May. Bayger (1937), Berger and Michałowski (1963) and Młynarski (1966) are of opinion that the mating season of the tree toad falls in May, whereas Szarski (1949) and Juszczyk (1967a) think that it is not connected with an exact calendar time, but undergoes great fluctuations which span over a period of four months (from mid-April to 2nd decade of July).

In the region of Częstochowa this species starts breeding relatively late. The first mating season occurs in the 3rd decade of April or the 1st decade of May.

During May, June and part of July the tree toad lays spawn three or four times. The occurrence of the mating season in the tree frog is dependent on rainy weather; the period of egg-laying generally begins during or soon after heavy rains.

In connection with the various climatic conditions in different regions of Europe the difference in time between the mating seasons of tree frogs is up to about 3 months. In the mild and warm climate of the German Lowlands the tree toad mates from March to June (Frommhold, 1959; Freytag, 1966) and in Czechoslovakia, which has a temperate and, for the most part, warm climate, it appears and begins spawning in April (Štěpánek, 1949). In the Ukraine, where the climate is continental, the mating season includes April and May (Nikolskiy, 1918; Tarashchuk, 1959). In the regions of Bryansk and Voronezh mating begins in the 2nd half of April, while in the mountains (Carpathians, Caucasus — up to 1500 m a.s.l.) in the 1st or 2nd half of May (Terentyev, 1961; Bannikov and Denisova, 1956; Tarashchuk, 1959).

In many authors' opinion, the metamorphosis of larvae into adult tree frogs occurs after about 90 days (Table IV). My investigation shows that the larval stage may range from 65 to 85 days according to the thermic conditions prevailing in the water environment.

Quite a few authors recorded the cases of hibernation of larvae and their metamorphosis in the next season (Terentyev and Chernov, 1949; Berger and Michałowski, 1963; Tarashchuk, 1959; Młynarski, 1966). In the study area I observed this phenomenon very rarely (Site 1 and Złoty Potok, 1962 and 1966).

Investigators differ in opinion as regards the tree frog's winter shelters. Berger and Michałowski (1963) state that most specimens winter in silt in the bottom of water reservoirs and only few ones remain on land, burying themselves in different sorts of depressions, whereas Bannikov and Denisova (1956) write that only a small number of tree toads hibernate in water and most of these animals spend winter on land, in gaps between stones, in the litter of dead leaves, in moss, at the foot of trees, under stones and in burrows and tree-holes; finally, according to Freytag (1966), tree toads hibernate exclusively on land.

In my opinion, Bannikov and Denisova are nearest the truth, for in many years' investigation I observed specimens hibernating both on land and in water. In water they hide chiefly in silt and in the thick growth of plants, on land in forest litter and in rock crevices (Kraków—Częstochowa Jurassic Ridge). More rarely, they are met with in deep pits, under stones, in holes in the ground and in burrows of mammals.

9. *Rana esculenta* Linnaeus, 1758

The opinions on the thermic conditions and time of the appearance of the edible frog in the spring and the length of its breeding season expressed in herpetological literature differ markedly.

Numerous authors think that this frog is a thermophilous species and that it wakes from winter sleep in the late spring (STERNFELD, 1913; FREYTAG, 1959). NIKOLSKIY (1918) and CHARLEMAGNE (1917) hold a different view, i.e. that during mild winters in the Crimea they do not fall into torpidity at all and in the steppe region of the Ukraine appear relatively early in the spring.

In the study area (Sites 1 and 4) the edible frogs begin active life in March, at a water temperature above 3°C. At temperatures ranging between 5 and 7°C they begin a spring migration to closed water reservoirs, like ponds, lakes, old riverbeds, deep ditches, etc. There are different opinions on the time and course of the edible frog's breeding season. UDZIELA (1910) thinks that this species breeds from mid-May to mid-June, and JUSZCZYK and SZARSKI (1950) are of opinion that edible frogs mate from May throughout July, being chiefly dependent in this respect upon rainfall and temperature. JUSZCZYK (1937) writes that he found new-laid eggs of the edible frog even in the 1st decade of August. On the other hand, according to BAYGER (1937) and BERGER and MICHAŁOWSKI (1963), the mating season of this species falls in May.

In the sites (1, 3 and 4) examined in the region of Częstochowa the frogs in colonies begin to form pairs at the end of April or in the 1st decade of May, at a minimum water temperature of 14°C. BANNIKOV and DENISOVA (1956) write that these animals mate at a water temperature between 16 and 31°C.

Unlike common and field frogs, they lay eggs several times a year. There are 4—6 mating seasons at each site in the period from the 1st decade of May throughout July, and exceptionally till 5—11 August, the spring mating seasons being considerably longer than the summer ones. Each separate mating season begins during or soon after a spell of heavy rain and is not connected with a closely determined calendar time. It should however be emphasized here that although there are 4—6 mating seasons in a year, their total number in the case of particular specimens is smaller than that observed for the whole population.

JUSZCZYK (1937), BANNIKOV and DENISOVA (1956) and some other authors observed several mating seasons (2—3) in the edible frog, but most of the investigators do not distinguish separate stages or mating seasons of the edible frog and only mention that the beginning of mating occurs in the spring and its end at mid-summer.

In Romania, Czechoslovakia and Germany the mating of this species falls in the 2nd half of May and in June; under exceptionally favourable thermic conditions it begins as early as April (FUHN, 1960; ŠTĚPÁNEK, 1949; FREYTAG and FROMMHOLD, 1959).

In the steppe region of the Ukraine these frogs mate from the end of April throughout June (CHARLEMAGNE, 1917; TARASHCHUK, 1959) and in the central region of the U.S.S.R. the mating season begins at mid-May, and thus a month later than in the steppes of the Ukraine, and lasts till the end of June (TERENTYEV and CHERNOV, 1949).

The foregoing would indicate that in the continental climate in the east the edible frogs start laying eggs earlier than they do in the maritime climate in the west. Also in southern Poland the mating season occurs earlier than in the countries situated south and west of it. Apparently, both the high humidity of the air and the high air and water temperatures are necessary for these frogs to breed.

The views, met with in literature, on the embryonic and larval life of the edible frog differ very much. Berger and Michałowski (1963) and Młynarski (1966) state that the metamorphosis of tadpoles occurs after 72—214 days and that the tadpoles sometimes hibernate. According to Sekutowicz (1938), the larvae metamorphose after about 90 days.

Different soviet authors believe that the development of tadpoles of the edible frog lasts from 70 to 133 days. Thus, e.g. Terentyev and Chernov (1949) are of opinion that the development of the larva takes as many as 133 days, whereas, according to Bannikov and Denisova (1956), it lasts about 70—75 days (according to the former authors, nearly twice as many as that). Tarashchuk (1959), in turn, writes that the development of the embryo lasts for about a week and that of the larva for 3—4 months (Table IV).

In Germany, Czechoslovakia and Romania the metamorphosis of the larva is completed after about 3 months (Sternfeld, 1913; Štěpánek, 1949; Fuhn, 1960; Freytag, 1966).

In the region of Częstochowa the metamorphosis of the larva into a terrestrial form occurs after 67—111 days according to environmental factors, and the full development of the embryo and larva after 71—114 days. The larvae hatched from the eggs laid in the 1st decade of August do not metamorphose until the April of the next year.

A comparison of my results with the data obtained by other authors shows that in the south of this country the larval stage of the edible frog lasts approximately as long as in the south-western regions of the U.S.S.R. In the German areas of maritime climate its larval stage lasts considerably longer.

10. *Rana temporaria* Linnaeus, 1758

Basing himself on the material collected in his 25-year study of the annual rhythm of amphibians in the Kraków region, Juszczyk (1967a) writes that the common frog begins laying eggs in the 3rd decade of March, immediately or soon after leaving its winter shelter.

In the study area (about 100 km north-west of Kraków) the breeding season of this species generally occurs in the 2nd or 3rd decade of March, more rarely in the 1st half of April, when the water temperature in the shallow reservoirs reaches 7—8° C. In the mountains, where spring is retarded by nearly a month and a half, the breeding season falls in May and June. There the first common toads often turn up when many spots are still covered with snow. Eggs are laid in very various water reservoirs, even in wet moss and in rock depressions (Młynarski, 1962).

Juszczyk and Zamachowski (1965) state that in the territories inhabited by the common toad in Europe, it may lay eggs from January (Brittany) to the end of May (Finland).

The occurrence of the common frog's mating season in the western provinces of the U.S.S.R. in 1939—1960 presents itself as follows:

1. Leningrad Province	from 10 April	to 30 April
2. Latvian S.S.R.	from 25 March	to 15 April
3. Kursk Province	from 6 April	to 26 April
4. Poltava Province	from 1 April	to 21 April
5. Kiev Province	from 25 March	to 20 April

These data show that the higher the annual amount of heat and, partly, the higher the rainfall is, the earlier this species begins to breed. In the northern Caucasus the mating season occurs in March, in the Baltic Republics, Leningrad Province, Byelorussia and Ukraine in April and in the regions situated north-east of Moscow in May. The dependence of the mating season on climate is particularly well illustrated by the data given by Terentyev and Chernov (1949): "This species breeds near Moscow in March-April, in the region of Leningrad in April, in the drainage area of the River Amur and in Sakhalin in May, and in the region of Okhotsk at the end of June".

In Poland, situated in Central Europe, in the temperate climate with high annual rainfall, the mating season occurs in the 2nd half of March or the 1st half of April according to the thermic conditions. In the mountains spring is retarded by a month and a half in relation to the lowlands and, consequently, the mating season falls in May or June (Kowalski and Młynarski, 1965).

Juszczyk (1967 a) and Tarashchuk (1959) dealt with the minimum temperatures at which common frogs wake from torpidity and start mating. According to Juszczyk, a rise in ambient temperature above the threshold temperature (3°C above zero) during hibernation causes its interruption. In Tarashchuk's opinion, at a temperature of 7°C common frogs begin to form pairs and spawn.

My observations quite agree with the results of studies carried out by the authors quoted.

Although the common frog is one of the most frequent amphibians of Poland and its tadpoles are met with in nearly all small water reservoirs, the data concerning the dependence of the development of the embryo and larva upon ecological-climatic factors are very scanty. This is also indicated by the fact that the times and lengths of the larval stage given in literature do not coincide.

Thus, e.g. Berger and Michałowski (1963) state that the metamorphosis of tadpoles occurs after 50—180 days and Sekutowicz (1938) reduces the time of the larval stage of the common frog to 90—100 days.

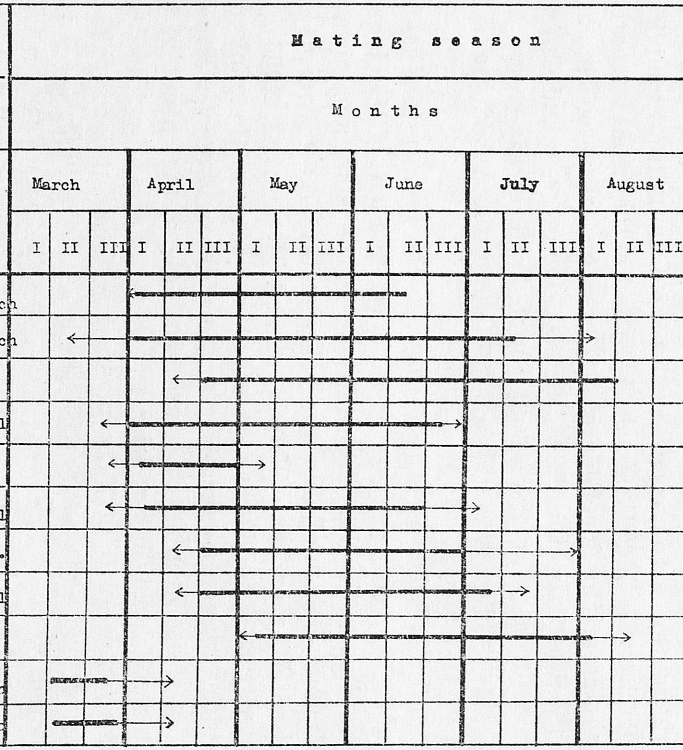
A similar discordance can also be seen in the foreign literature. For example, Bannikov and Denisova (1956) hold the opinion that in the European territories of the U.S.S.R. the larvae metamorphose after 50—60 days, according to Terentyev and Chernov (1949) and Tarashchuk (1959), after 50—90 days, whereas the German herpetologists write that in their country the larvae of the

METEOROLOGICAL CONDITIONS AND DURATION OF MATING SEASONS OF AMPHIBIANS IN THE REGION OF CZĘSTOCHOWA

Table VII

Species	Earliest and latest dates of appearance of **first specimens on land** /1960–1968/		Daily max. min. opt. temperatures						
			Air		Soil		Water		
	Earliest dates	Latest dates	Maximum	Minimum	Maximum	Minimum	Maximum	Minimum	Optimum
Triturus cristatus /Laur./	7.Febr.	25.March	28	9	27	9	27	9	15 – 20
Triturus vulgaris /L./	5.Febr.	21.March	30	9	29	9	27	9	15 – 20
Bombina bombina /L./	21.March	Febr. April	30	14	–	–	30	15	17 – 26
Pelobates fuscus /Laur./	8.March	6.April	28	13	28	9	26	12	13 – 16
Bufo bufo /L./	9.March	Febr. April	26	5	21	4	22	6	13 – 17
Bufo viridis /Laur./	28 March	6.April	30	14	29	12	28	14	15 – 24
Bufo calamita Laur.	10 April	26.Apr.	25	7	25	8	25	14	18 – 22
Hyla arborea /L./	6.April	30.April	30	16	29	12	27	14	20 – 26
Rana esculenta L.	Febr. March	24.Apr.	32	15	29	14	31	14	17 – 27
Rana temporaria L.	5.Febr.	21 March	22	7	19	4	17	7	11 – 15
Rana arvalis Nils.	4.Febr.	21 March	22	7	20	4	19	7	10 – 15

Mating season — Months: March, April, May, June, July, August (decades I, II, III of each month)



Explanation

duration of mating season — decades of month

maximum duration of mating season

common frog go through metamorphosis after 60—90 days (FROMMHOLD, 1959; FREYTAG, 1966, and other authors).

The foregoing data allow the conclusions that, firstly, the big differences between the data concerning the length of the larval stage of the common frog are related to the geographical situation of the regions in question, characterized by different climatic conditions and, secondly, the larvae of this species are very sensitive to the action of environmental factors, to which they respond by accelerating or slowing down the processes of particular embryonic and larval stages. A striking example, indicating the dependence of particular moments of the development of the larval common frog upon the temperature of the environment, is the fact that in the lowlands the tadpoles metamorphose in June and in the Tatra Mts., especially in cooler summers, their metamorphosis is often protracted into the end of August or September (SEMBRAT, 1955), and even their collective hibernation has been observed (MŁYNARSKI, 1966).

Many Soviet and German authors also state that after a cool summer and short autumn the larvae of the common frog are compelled to hibernate and do not metamorphose until the spring of the next year (STERNFELD, 1913; TARASHCHUK, 1959; FREYTAG, 1966, and other authors), and exceptionally under very unfavourable mountainous conditions their metamorphosis may occur in the second or even third season (BANNIKOV and DENISOVA, 1956).

In the Częstochowa District the embryos of the common frog begin to develop towards the end of March or at the beginning of April at a relatively low temperature, owing to which their development lasts for about 8—10 days. A further development of the tadpole proceeds at a considerably higher temperature, ranging between 6 and 30°C (mean water temperature — about 17°C). Under such conditions the young frogs leave the reservoir after 64—65 days. The larvae that develop in the cooler water of claypits (mean — 14—15°C) complete their metamorphosis after the lapse of 75 days.

There are several hypotheses as to the cause of the autumnal migrations of the common frog. According to some authors, the migrations from the summer grounds are started in close dependence upon the meteorological changes in the environment inhabited by the frogs.

In JUSZCZYK'S (1961) opinion, common frogs start their autumnal migrations at the beginning of September and the earliest gregarious migration in his 10-year investigation was observed on 12 September 1957. These migrations are started immediately after, or perhaps during, the period of the greatest amplitudes between the maximum and minimum daily air temperatures (on the average 20·8 and 13·1°C, respectively; amplitude — 7·7°C — 1st decade of September), occurring in the last period of summer. This suggests that the activeness of frogs is released by the fluctuations in air temperature during the 24-hour cycle. According to JUSZCZYK, the autumnal migrations of the common frog are continued more or less till mid-October and, thus, in the 3rd decade of this month nearly all these frogs are in their winter quarters, at the bottom of running waters.

BANNIKOV (1940) thinks that the autumnal migrations of frogs are induced by a fall in the temperature of soil and air below the water temperature and by the seasonal peculiarities of the food base. At that time the terrestrial insects begin to disappear and, consequently, frogs have to feed on aquatic animals and forms inhabiting very damp places.

In the study area the common frogs begin migrations when, on the one hand, the air and soil temperatures lower systematically (maximum temperatures from about 24 to 13°C and the minimum ones from 13 to 2—4°C), on the other hand, the amplitudes between the daily and the early-morning temperatures grow rapidly and reach the highest values (up to 15—17°C, and in places exposed to the sun's rays even to 20°C).

11. *Rana arvalis* NILSSON, 1842

As regards the time and the length of the mating season of the field frog the opinions met with in literature are very various. Some authors hold the opinion that these frogs appear for mating two days after the common frog (NIKOLSKIY, 1918; ROSZKOWSKI, 1924; BANNIKOV and DENISOVA, 1956; TARASHCHUK, 1959). According to UDZIELA (1910) the mating season of the common frog begins in the 2nd half of March and that of its smaller relative as late as May, i.e. a month and a half later. On the other hand, JUSZCZYK and SZARSKI (1950) consider that the mating season of the field frog usually begins several days after the outset of the mating of the common frog, and BERGER and MICHAŁOWSKI (1963) are of opinion that the mating seasons of these species fall at the end of March or at the beginning of April, i.e. they coincide in time.

In the study area the specimens of these species wake from torpidity and mate at the same time and in the same environments. However, it happens that field frogs start mating several days later than the common frog does. In the case of the rapid warming up of the air and, what follows, the soil and water in the winter, the adult specimens interrupt hibernation and wander to a water reservoir to mate.

The correlation of the time of mating with the thermic conditions of environment is also indicated by the following facts: in Germany the sexually mature specimens begin mating in the 1st half of March (STERNFELD, 1913; WERMUTH, 1957), in Czechoslovakia in the 2nd half of March (ŠTĚPÁNEK, 1949), in Romania at the end of March or at the beginning of April (FUHN, 1960), in the region of of Smolensk in April, in the regions of Moscow and Kazan' towards the end April and in the 1st half of May (TERENTYEV and CHERNOV, 1949; BANNIKOV and DENISOVA, 1956; GARANIN, 1961).

The data concerning the embryonic and larval development of the field frog are scanty and, in addition, they disagree with each other. This is well shown by juxtaposition of the lengths of the larval stage given by some Polish and foreign authors:

Udziela (1910)	about 100 days
Berger and Michałowski (1963)	50—120 days
Terentyev and Chernov (1949)	51—120 "
Bannikov and Denisova (1956)	60—65 "
Tarashchuk (1959)	75—90 "
Fuhn (1960)	51—120 "
Freytag (1966)	60—90 "

This comparison shows that even under the same climatic conditions but in different biotopes the larval stage may vary in length. For this reason, as stated by Juszczyk (1967a), the giving of the length of the embryonic stage only, without mentioning the water temperature at which it occurred, is a great scientific inaccuracy. This statement may also be applied for the larval stage of all our amphibians, both *Anura* and *Urodela*. This is why I have presented the development of the embryos and larvae of the species under study against the background of the most important climatic factors, above all, the air and water temperatures, the exposure of water reservoirs to the sun's rays and the humidity of air (Table III).

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REFERENCES

Bannikov A. G. 1940. Ekologičeskije uslovia zimovok travianoj laguški v Moskovskoj oblasti. Sbor. nau. rab. Moskov. Gos. Univ., Moskva, **16**: 41—64.

Bannikov A. G. & Denisova M. N. 1956. Očerki po biologii zemnovodnych, Moskva.

Bayger J. A. 1937. Klucz do oznaczania płazów i gadów. Klucze do oznaczania zwierząt kręgowych Polski pod red. H. Hoyera, Kraków.

Berger L. & Michałowski J. 1963. Płazy-*Amphibia*. Klucze do oznaczania kręgowców Polski, Warszawa—Kraków, (2).

Braunier A. 1923. Sielskokhoziajstviennaja zoologia, Odessa.

Cena K. & Wołoszyn B. W. 1966. Investigation on the diurnal changes of the skin temperature in bats. Folia Biol., Kraków, **14**: 159—203.

Charlemagne E. B. 1923. Vodoziani zaby Ukrainy. Kijev.

Charlemagne E. B. 1917. Zametka o faunie presmikajuščichsja i ziemnovodnych okrestnostiej Kijeva. Kijev.

Emme A. 1962. Časy živoj prirody, Moskva.

Frommhold E. 1959. Wir bestimmen Lurche und Kriechtiere Mitteleuropas, Leipzig.

Freytag G. E. 1966. Lurche-*Amphibia* in E. Stresemanns Exkursionsfauna von Deutschland, Berlin.

Fudakowski J. 1953. Wędrówki zwierząt lądowych i wodnych, Warszawa.

[Fuhn I. E.] 1960. *Amphibia* in: Fauna Republicii Pôpulare Rŏmine, Bucureşti.

Garanin W. J. 1961. K ekologii ostromordoj laguški, Kazan.

Juszczyk W. 1938. O porze godowej naszych płazów bezogonowych. Spraw. Kom. Fizjograf., Kraków, **71**: 131—145.

Juszczyk W. & Szarski H. 1950. Płazy i gady krajowe. Klucz do oznaczania, Warszawa.

Juszczyk W. 1954. Życie i właściwości ropuchy, Warszawa.

Juszczyk W. 1961. Rozwój narządu rozrodczego samicy żaby trawnej (*Rana temporaria* L.) w cyklu rocznym. Ann. Univ. MCS., Lublin, Sec. C, **14**: 169—231.

Juszczyk W. & Zamachowski W. 1965. Terms of ovulation and oviposition of the grass frog (*Rana temporaria* L.) in conditions of an artificial and prolonged hibernation. Acta biol. cracov., Kraków, s. zool., **8**: 211—223.

Juszczyk W. 1967a. Zjawisko rytmu rocznego u płazów. Roczn. Nauk.-Dydakt. WSP, Kraków, Zool., **29**: 67—86.

Juszczyk W. 1967b. Traszki. Warszawa.

Kowalski W. & Młynarski M. 1965. Uwagi o płazach i gadach Pienińskiego Parku Narodowego. Ochrona Przyrody, Kraków, **31**: 87—115.

Kowalewski L. 1967a. Nowe stanowisko ropuchy paskówki (*Bufo calamita* Laur.) Przegląd Zool., Wrocław, **11**: 310—312.

Kowalewski L. 1967b. Płazy i gady okolic Częstochowy. Ibidem, **11**: 414—423.

Kowalewski L. 1969. Roczny cykl życia ropuchy paskówki (*Bufo calamita* Laur.). Ibidem, **13**: 198—205.

Madej Z. 1966. Kumaki (*Bombina* Oken, 1816) Beskidu Niskiego i terenów przyległych. Acta zool. cracov., Kraków, **11**: 335—355.

Madej Z. 1973. Ekologia europejskich kumaków (*Bombina* Oken, 1816). Przegląd Zool., Wrocław, **17**: 200—204.

Młynarski M. 1962. Płazy i gady. Tatrzański Park Narodowy, Kraków, 428—440.

Młynarski M. 1966. Płazy i gady Polski. Warszawa.

Nikolskij A. M. 1918. Fauna Rosiei i sopridelnych stran. Ziemnovodnyje. Moskva.

Oliger J. 1955. Kratkij opredelitel pozvonočnych životnych. Moskva.

Rammer W. 1956. Fische, Laurche, Kriechtire "Brehms Tierleben", Leipzig, **2**.

Riabinin S. 1955. Uwagi o fenologii. Kosmos A., Warszawa, **1**: 103—107.

Riabinin S. 1961. Fenologia — nauka o sezonowych rytmach w przyrodzie. Przegląd Zool., Wrocław, **5**: 28—29.

Riabinin S. 1968a. Zagadnienia synchronizacji zjawisk fenologicznych na dużych obszarach. Ekologia Polska B., Warszawa, **14**: 19—28.

Riabinin S. 1968b. Zadania fenologii w zoologii. Ibidem, **4**.

Roszkowski W. 1924. Amphibia-płazy. Podręcznik do zbierania i konserwowania zwierząt pod red. W. Polińskiego, Warszawa, **7**: 23—36.

Rzepecki J. 1965. Nowe niezwykle bogate stanowisko ropuchy paskówki (*Bufo calamita* Laur.) w Michałowie. Przegląd Zool., Wrocław, **9**: 46—51.

Schreiber E. 1912. Herpetologia Europaea. 2 Aufl., Jena.

Sekutowicz S. 1938. Gady i płazy. Lwów—Warszawa.

Sembrat K. 1953. O ropuchach krajowych. Chrońmy przyr. ojczystą, Kraków, ("Warszawa") **5**: 30—39.

Sembrat K. & Nowakówna J. 1959. Zimowanie larw traszki górskiej *Triturus alpestris* Laur., i karpackiej *Triturus montandoni* Blngr., w Stawie Toporowym Niżnim w Tatrach. Przegląd Zool., Wrocław, **3**: 58—60.

Sternfeld R. 1913. Die Reptilien und Amphibien Mitteleuropas. Leipzig.

Štěpánek O. 1949. Obojživelnicí a plazí zem českých. Archiv přir. Čech., Praha, **1**.

Szarski H. 1939. Płazy. Lwów—Warszawa.

Tarashchuk V. J. 1959. Zemnovodny ta plazuni. Fauna Ukrainy, Kijev, **7**.

Terentiev P. V. & Chernov S. A. 1949. Opredelitel presmykajuščichsja i ziemnovodnych. Moskva.

Terentiev P. V. 1961. Gerpetologia. Moskva.

UDZIELA S. 1910. *Amphibia* i *Reptilia*. Klucze do oznaczania kręgowców ziem polskich pod red. H. Hoyera, Kraków.
WERNER F. 1932. *Reptilia* und *Amphibia*. Leipzig.
WERMUTH H. 1957. Taschenbuch der heimischen Amphibien und Reptilien. Leipzig—Jena

STRESZCZENIE

Praca przedstawia wyniki 9-letnich badań dotyczących fenologii i ekologii 11 gatunków płazów występujących w okolicach Częstochowy (szer. geogr. 51°, dług. geogr. 19°, wysokość 200—400 m n. p. m.).

Są to:

1. Traszka grzebieniasta — *Triturus cristatus* (LAURENTI, 1768),
2. Traszka zwyczajna — *Triturus vulgaris* (LINNAEUS, 1758),
3. Kumak nizinny — *Bombina bombina* (LINNAEUS, 1761),
4. Grzebiuszka ziemna — *Pelobates fuscus* (LAURENTI, 1768),
5. Ropucha szara — *Bufo bufo* (LINNAEUS 1758),
6. Ropucha zielona — *Bufo viridis*, LAURENTI, 1768,
7. Ropucha paskówka — *Bufo calamita* LAURENTI, 1768,
8. Rzekotka drzewna — *Hyla arborea* (LINNAEUS, 1758),
9. Żaba wodna — *Rana esculenta* LINNAEUS, 1758,
10. Żaba trawna — *Rana temporaria* LINNAEUS, 1758,
11. Żaba moczarowa — *Rana arvalis* NILSSON, 1842.

Na obszarze o łącznej powierzchni 50 km^2 wybrano pięć kontrastujących ze sobą stanowisk (Brzeziny, Blachownia, Kucelinka, Ostatni Grosz, Złoty Potok) i przeprowadzono na nich analogiczne obserwacje. Objęły one: początek życia aktywnego i porę godową, rozwój zarodków i larw, życie aktywne po zakończeniu pory godowej, wędrówki jesienne i sen zimowy. Prześledzono również u poszczególnych gatunków zależność terminów występowania kolejnych faz rocznego cyklu życiowego od zmiennych w poszczególnych latach warunków meteorologicznych. Na tej podstawie ustalono optymalne, minimalne i maksymalne temperatury, w których mogą przebiegać czynności życiowe poszczególnych gatunków.

Dużo miejsca w pracy poświęcono szczegółowemu omówieniu pór godowych, z uwzględnieniem wpływu temperatury i innych czynników fizycznych na ich przebieg. Osobny rozdział poświęcono przebiegowi przemian wzrostowych i stadialnych u zarodków i larw. Wreszcie przedstawiono wyniki obserwacji nad przyczynami i warunkami migracji wiosennych i jesiennych poszczególnych gatunków oraz przedstawiono w formie tabeli (VI) czasokres hibernacji. W dyskusji dokonano konfrontacji uzyskanych wyników z danymi zaczerpniętymi z literatury przedmiotu.

РЕЗЮМЕ

Материал к настоящей работе собран в течение 9-летних фенологических и экологических наблюдений. Под наблюдением находилось 11 видов амфибий выступающих в окрестностях Ченстоховы (геогр. шир. 51°, геогр. длина 19°, высота 200—400 метров над уровнем моря). Аналогические наблюдения проведено в пяти контрастных местностях (Бжезины, Бляховня, Куцелинка, Остатни Грош и Злоты Поток) в общей площчади около 50 км².

Под наблюдением находились следующие виды земноводных:
1. Тритон гребенчатый — *Triturus cristatus* (LAURENTI, 1768),
2. Тритон обыкновенный — *Triturus vulgaris* (LINNAEUS, 1758),
3. Жерлянка краснобрюхая — *Bombina bombina* (LINNAEUS, 1761),
4. Чесночница обыкновенная — *Pelobates fuscus* (LAURENTI, 1768),
5. Жаба обыкновенная — *Bufo bufo* (LINNAEUS, 1758),
6. Жаба зелёная — *Bufo viridis* LAURENTI, 1768,
7. Жаба камышовая — *Bufo calamita* LAURENTI, 1768,
8. Квакша обыкновенная — *Hyla arborea* (LINNAEUS, 1758),
9. Лягушка прудовая — *Rana esculenta* LINNAEUS, 1758,
10. Лягушка травяная — *Rana temporaria* LINNAEUS, 1758,
11. Лягушка остромордая — *Rana arvalis* NILSSON, 1842.

Во время наблюдений особое внимание обращено на такие проявления жизни, как пробуждение из зимнего сна, размножение, развитие личинок, обитание на суше, осенние миграции и переход в состояние анабиоза. Одновременно велось наблюдение над сроками фенологических периодов в определённых годах в зависимости от метеорологических и климатических условий. Сконстатировано, что определённые виды имеют свои собственные оптимальные температуры, в которых жизненные процессы пробегают наилучше, а также минимальные и максимальные, которые заметно ограничивают их физиологические процессы или вызывают в организмах животных пагубные изменения. Много места в работе посвящено подробному описанию размножения земноводных, учитывая здесь оптимальные и скрайние температуры половой активности, а также влияние физических факторов на их распространение и пределы. Отдельный раздел посвящён процессу возрастных и стадиальных перемен у зародышей и личинок в зависимости от условий среды. Проведено тоже наблюдения над причинами и условиями весенних и осенних миграций земноводных, а также определено границы переходных периодов для каждого вида.

К работе прилагаются таблицы, которые представляют минимальные и максимальные пределы гибернации земноводных.

В разделе посвящённом дискуссии полученных результатов, проведено сопоставление фактов, касающихся определённых фенологических периодов разработанных автором в сопоставлении с данными других авторов Польши и соседних стран.

К тексту прилагаются многочисленные фенограммы, таблицы, диаграммы, которые очень наглядно илюстрируют часть собранного материала.

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