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A New Type of Japanese Toad Larvae Living in Mountain Torrents

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ABSTRACT Stream type tadpoles of *Bufo*, hitherto unknown from Japan, were discovered in the source area of Mt. Ohdaigahara, Nara Prefecture, and at the upper streams of the Neo-Nishitani River, Gifu Prefecture. These tadpoles live in torrents and are well adapted to a life in running water. They are morphologically different from ordinary tadpoles of still water type, and seem to resemble the tadpole of *B. b. andrewsi* reported from South China. It is highly probable that this type of toad can be recognized as a new separate form, but its taxonomic position has not yet been determined. (*Zool. Mag. 84 : 196—204, 1975*)

The Bufonidae is a large anuran family that consists of 13 existing genera and some 200 species of toads distributed all over the world, with the exception of New Guinea, the Polynesian Islands, Australia, Madagascar and Antarctica. Among these genera, the genus *Bufo* is the largest, including various forms. However, the mode of reproduction is almost uniform in this genus, and most of the members breed and spend their larval life in still waters, such as ponds and marshes (Cochran, 1961; Lutz, 1970). The three species of toads now found in the Japanese Islands, *B. bufo japonicus*, *B. melanostictus*, and *B. marinus*, are known to have a breeding habit similar to that of many other toads (Okada, 1931; Ichikawa, 1951; Nakamura and Uéno, 1963). In China, however, *B. b. andrewsi*, a close ralative of the Japanese toad, is reported to spend its larval life in running water (Liu and Hu, 1961).

In the course of ecological observations carried on as a part of systematic studies of the Japanese toad, the author recently found the existence of a n w form of the Japanese toad whose tadpoles, with unique morphology, lived in running water of mountain torrents. The results of ecological and morphological observations hitherto obtained on them will be briefly reported in this article.

Materials and method

The tadpoles living in running waters have hitherto been discovered at two localities in Honshu : a stream in Mt. Ohdaigahara, Nara Prefecture, and the Neo-Nishitani River, Gifu Prefecture. As materials, 28 tadpoles in total were collected from both localities : 11 individuals of stages 27–29 and 7 individuals of stages 32–34 from Ohdaigahara, and 10 individuals of stages 32–36 from the Neo-Nishitani River (Table 1). The developmental stages proposed by Limbaugh and Volpe (1957) are used as standard in the present work. Immediately after captured, the tadpoles were fixed with 10% formalin and stored in 70% ethanol. Measurements to the nearest 0.05 mm were made with dial calipers and under binocular dissecting microscope

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equipped with an occular micrometer. For comparisons, tadpoles of still water type from Momoyama, Kyôto (stages 27–29, N=5), and from Iwakura, Kyôto (stages 33–37, N=17), were examined in the same way.

General sketches of survey areas

a) Ohdaigahara

Mt. Ohdaigahara (1695m) is situated in the south-eastern region of the Kii Peninsula (Fig. 1). There flow down many streams on

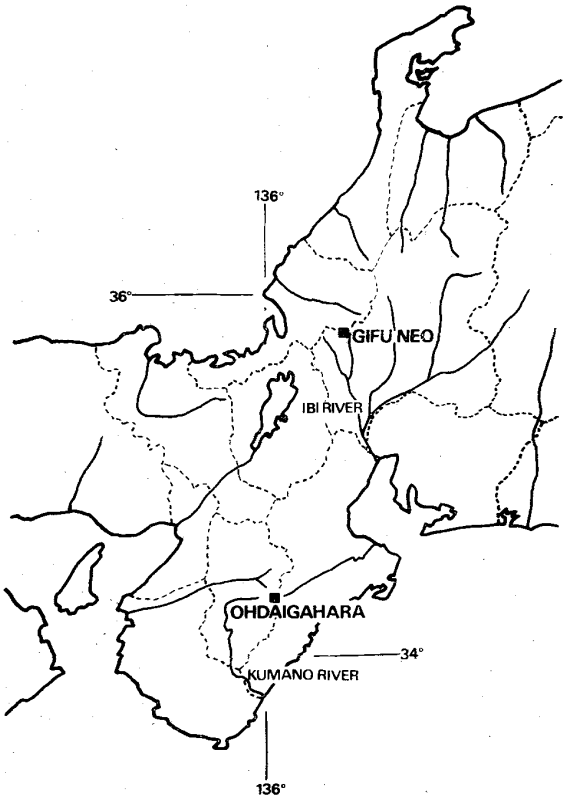

Fig. 1. Locations of Mt. Ohdaigahara and Neo-Nishitani River, where stream type tadpoles were discovered.

the mountain, forming the sources of the three main rivers, i.e., Kumano, Kino and Miya Rivers. This mountain is well known for its heavy rainfall, the rainy and snowy days averaging 205 days a year and mean annual precipitation reaching 4,770 mm. The average temperature in the summer is 17°C, while in the winter there is heavy snowfall and the temperature goes down to 4°C on an average and to a minimum of −18°C. The vegetation of the area varies with the elevation: the broad-leaved forests climb up to an elevation of about 1,600 metres, and the heights above it are covered with coniferous forests. The rocky torrent where the larvae were discovered (34°11′N, 136°6′E, altitude 1,400 m) flows through an area of secondary forests, called Higashi-Ohdai, finally to become the Kumano River (Fig. 2). At the point

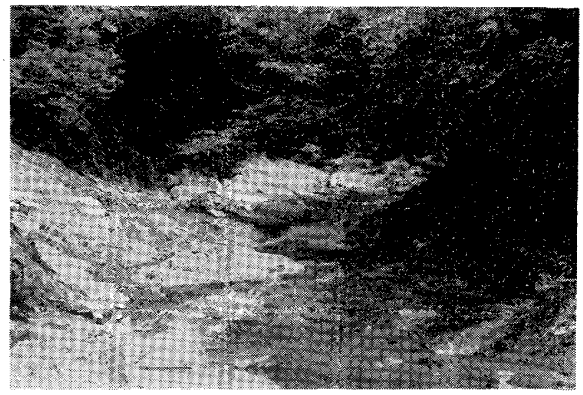

Fig. 2. Habitat of stream type tadpoles at Shiokara-dani valley, Ohdaigahara.

of survey, the stream is rather gentle with a width of about 5 metres and a maximum depth of 1 metre, and its river-type according to Kani (1944) is Aa.

b) Neo-Nishitani River

The Neo-Nishitani River arises from Mt. Nôgô-Hakusan (1,617m), which is one of the highest peaks of the Etsubi mountains and is situated on the boundary between Gifu and Fukui Prefectures (Fig. 1). It runs down southwards to become the Ibi River and finally empties into Ise Bay. Its drainage area is also well-known for high precipitation, the annual amount of which often reaches 4,000 mm or more, and 190 days of a year are rainy or snowy. In the summer it is fairly warm there (24°C on an average), while in the winter the temperature falls as low as to −4°C with a heavy snowfall of more than 2m. The vegetation in the montane zone of the mountains is composed of elements common Etsubi to the coast of the Japan Sea, and the lower areas are covered with temperate deciduous forests.

The tadpoles were found from the main stream of the Neo-Nishitani and from the Shimotsumaki Valley that runs into the former, both being situated at about 35°45′N, 136°36′E, and 550m in altitude. The former is a rapid of Bb-type with a width of about 10m (Fig. 3), whereas the latter is Aa-typs

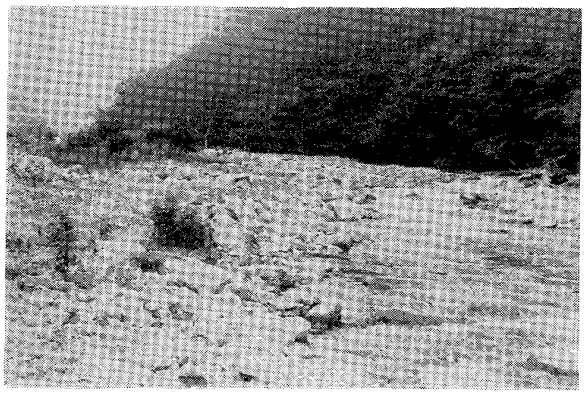

Fig. 3. Habitat of stream type tadpoles at Neo-Nishitani River.

and 3 metres wide, with rather a gentle flow because of a dam built nearby.

Microhabitat and habit of tadpoles

a) Shiokara-dani Valley, Ohdaigahara

The survey was carried out from the 14th to 16th, June, and from the 18th to 20th, July, 1974. In June, tadpoles were observed crowding at the bank of the right side, and were adhering to the surface of stones and rocks submerged in deep waters of the main stream and slack waters beside it.

The slack water, where the largest number of tadpoles crowded (Fig. 4), was 58 cm deep at its deepest point, and the water temperature at 5 cm below the surface was 15.5°C (at 13: 00, June 15). In this place, where there was little flow of water and the water was warmed by the direct sunlight, the temperature rose high in the daytime but fell below 9°C at night. In the daytime, the tadpoles were clinging to the sufraces of rocks, scraping lithophytic algae for food, and swam to the nearby rocks from time to time. They were living from the surface of the water down to about 30 cm below it and

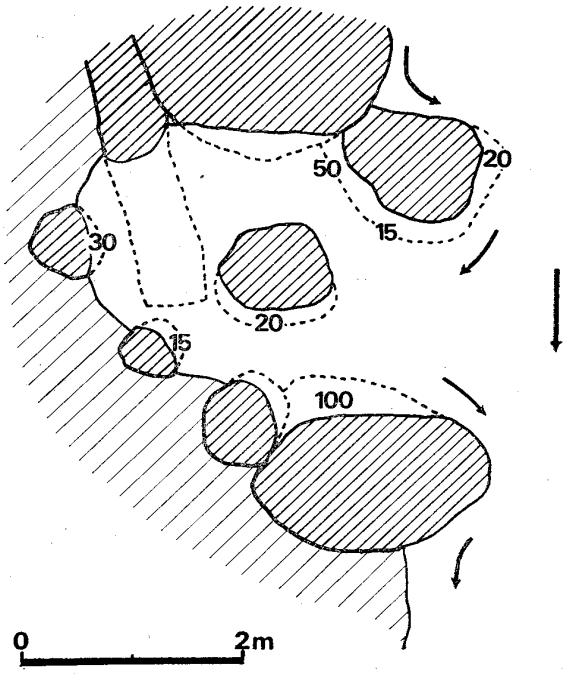

Fig. 4. An example of a slack water in Shiokara-dani Valley, where a large number of tadpoles were found. Each figure represents approximate number of tadpoles, and arrows show directions of water currents.

never seen at the bottom. At deep places of the main stream, the tadpoles were found holding on to large rocks exposed to the rather rapid current; they were clinging to either solely or in a group of several individuals, and never seen to crowd.

In the same place there were found other amphibians; larvae and adults of two species of salamanders; *Onychodactylus japonicus* and *Pachypalaminus boulengeri*. A few trouts, *Oncorhynchus rhodurus*, were also seen.

In July, on the occasion of the second survey, tadpoles were found in greater numbers at deep places of the main stream than in the slack waters. They adhered to the sides of huge rocks deeply submerged in the water, individually or in small groups (Fig. 5). Tadpoles adhering to the stones washed by swift currents were also seen. Just before being captured, they swam down quickly to the bottom to seek shelter under stonns.

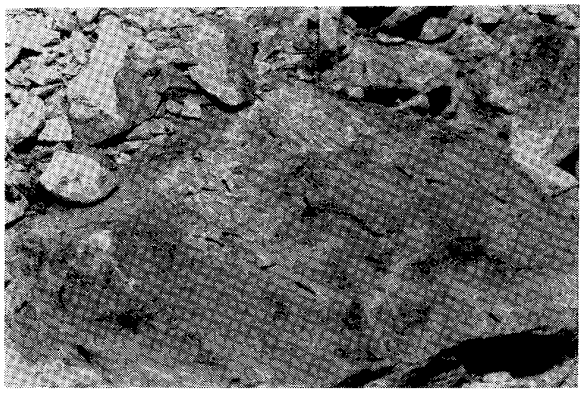

Fig. 5. Stream type tadpoles clinging to a huge rock at Shiokara-dani Valley, Ohdaigahara.

They sometimes swam against the current, and when swept away, they soon adhered to nearby stones and were never swept down stream.

b) Neo-Nishitani River and Shimotsumaki Valley

The survey was carried out during July 11–14, 1974. The place of observation, unlike that in Ohdaigahara, was in the area of transition from the upper reaches to the mid-stream with wide stony banks.

At the main stream of the Neo-Nishitani River, tadpoles were seen to cling solely or in small groups to stones measuring 30 to 50 cm near the bank of a rapid current running with white-crested waves (Fig. 6). A few individuals were also seen in slack waters about 30 cm deep with muddy bottom, connected with the main stream. Tadpoles of *Rhacophorus buergeri* were found at the same time at all the points surveyed. There is evident difference between the microhabitat of this species and that of the toad. In the main stream, the toad tadpoles adhered to sides of medium-sized stones facing the rapid currents, and they tried to escape from being captured by swimming towards the currents. By contrast, tadpoles of *Rhacophorus* usually hid themselves under smaller stones near the bank, and if driven away, they crawled through small pebbles towards the nearby bank. In the small slack waters mentioned above, the toad larvae clung to stones of large size and did not swim down to the bottom unless driven away, whereas tadpoles of *Rhacophorus* always hid themselves under small stones ashore.

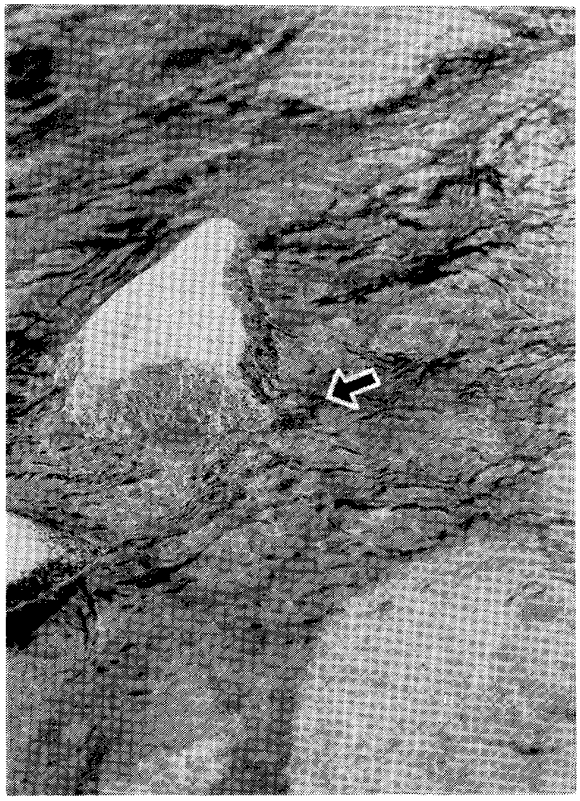

Fig. 6. Stream type tadpole sticking to a stone (black arrow) at the bank of main stream of Neo-Nishitani River.

Small fishes such as *Oncorhynchus rhodurus* and *Moroco steindachneri* were abundant in the main stream. In the small branches there were tadpoles of *Rhacophorus buergeri*. Tadpoles of *Rana ornativentris* were also seen crowding in small pools near the river.

No tadpoles were found in the source area of the Shimotsumaki Valley, which ran into the main stream of the Neo-Nishitani River, but a few tadpoles were discovered in the stream at the widened portion of the valley near the main stream. In this tributary stream, with stony banks as well, tadpoles were seen separately adhering to stones at the depth of 20–30 cm, both in the torrent and in branches 2 metres wide.

Morphology of the tadpoles

That the tadpoles in question belong to the genus *Bufo* is evident from the following characters: eyes dorsal; spiracle opening on the left side; anal tube opening median; anterior end of dorsal fin not reaching body; upper margin of upper labium lacking oral papilla; dental formula II/III.

The growth of anuran larvae from hatch to metamorphosis proceeds so quickly that descriptions and comparisons should not be made without considerations of morphological changes. In the stream type specimens, some dimensions vary with developmental stages and localities (Table 1), though the variation with the latter might be due to the scarcity of specimens examined. However, there are evident differences between the two types notwithstanding the variations within each type.

a) Stream type tadpoles

The following description is based on the features common to the specimens of all stages collected at the two localities and characteristic of the stream type tadpoles.

Total length is 17.7–19.2 mm in stages 27–29, and 22–31.4 mm in stages 33–36.

External characters : Head-body somewhat depressed, somewhat squarish rather than oval in dorsal aspect; snout not pointed; nostrils much nearer to eyes than to the tip of snout; internarial distance shorter than interorbital distance; eyes lying far behind tip of snout; spiracle opening on the left side between level of eyes and anus, directed backward.

Tail about 1.3–1.5 times as long as head-body, thick and low, not pointed at tip; ventral fin broader than dorsal.

Oral disc enormous, directed downward (Fig. 7c); dental formula II/III; upper labium thick, fringed with two rows of teeth, much broader than upper mandible (about 2.5 times mandible); second teeth row not interrupted at middle, slightly shorter than first row; three rows on lower labium also undivided.

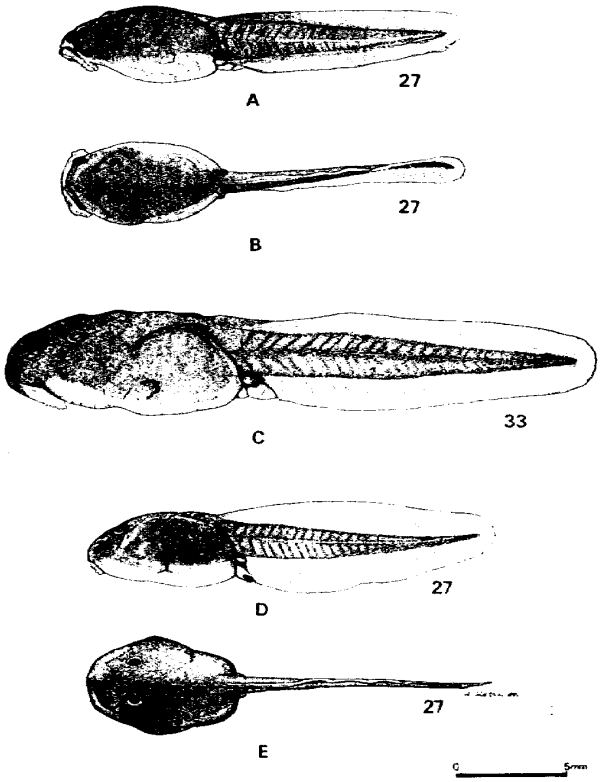

Fig. 7. Larvae of stream type (A, B, and C) and still water type (D and E), the former showing more stream-line shape. Numbers indicate stages of development.

Pharyngeal region flattened; anal tube opening median, close to the base of ventral fin.

Body color black on dorsal surface, somewhat faint on ventral surface; tail fins dark-gray in color, its tone gradually becoming paler towards margins.

b) Comparison with still water type larvae

The result of a comparison of measurements between tadpoles from Ohdaigahara (stages 27 to 29) and those from Momoyama, Kyôto (stages 27 to 29), is as follows (Table 1). Characters showing larger values in specimens from Ohdaigahara (stream type) than in those from Momoyama (still water type) are: distance from snout to eye, breadth of tail, breadth of mouth part, and depth of muscular portion. Body breadth and tail depth are conversely larger in still water type.

Another comparison was made between

Table 1. Measurements of stream type and still water type tadpoles. Head-Body lengths are actual values (in mm), and all other dimensions are represented by relative percentages divided by Head-Body length.

	Habitat and Locality				
	Stream	Still water	Stream		Still water
	Ohdaigahara	Momoyama	Ohdaigahara	Neo-Nishitani	Iwakura
Number	11	5	7	10	17
Devel. Stage	27-29	27-29	32-34	33-36	33-37
Head-Body length	7.4±0.3	7.3±0.5	11.1±1.0	12.0±1.0	9.9±0.5
Total length	250.2±8.5	244.8±21.9	236.6±9.5	231.2±7.7	248.5±7.9
Body breadth	54.1±2.8	62.6±4.0	56.5±3.0	54.9±2.6	54.7±2.6
Body depth	45.3±4.5	48.1±3.7	43.3±1.3	43.1±2.0	46.6±2.3
Snout to eye	40.2±3.6	32.9±1.2	36.7±1.7	32.3±3.1	27.7±1.6
Tail length	150.2±8.5	144.8±21.9	136.6±9.5	131.2±7.7	148.5±7.9
Tail breadth	15.8±1.0	13.4±0.6	16.1±1.0	16.7±1.3	15.7±1.2
Tail depth	42.7±2.8	58.1±1.7	40.1±0.9	37.0±1.3	48.2±3.1
Hind-limb length	6.1±1.5	6.7±1.7	12.3±1.3	16.2±5.4	16.9±3.1
Interorbital space	26.9±1.7	27.9±2.1	27.9±2.1	25.8±1.2	24.5±1.2
Snout to spiracle	67.9±3.9	68.9±2.0	68.8±3.3	66.0±2.9	59.6±2.3
Internarial space	14.7±1.1	15.3±0.7	14.2±1.5	13.3±0.9	12.7±0.9
Oral disc breadth	46.7±4.2	26.6±2.8	42.8±4.2	34.0±2.5	21.4±0.9
Depth of muscular portion	23.9±1.7	21.3±1.1	20.3±1.3	19.3±0.6	19.6±1.4

specimens from the Neo-Nishitani River and Ohdaigahara (stages 32 to 36) and those from Iwakura, Kyôto (stages 33 to 37), with the result that in stream type tadpoles, distance from snout to eye, interorbital distance, distance from snout to spiracle, and breadth of mouth part are larger, while body depth, tail length and tail depth are smaller than in still water ones. Thus, both the types are clearly distinguished from each other by at least three dimensions: distance from snout to eye, tail depth, and breadth of mouth part. In the stream type tadpoles, the eyes lie somewhat more posteriorly on the body and the oral disc is enormous, while in the still water type, the tail fins are deep.

In addition to these dimensional differences, the most remarkable structural difference between the stream type and the still water type is found in the dental formula: II/III in the former, and I: I+I/III in the latter (Fig. 8 A and B).

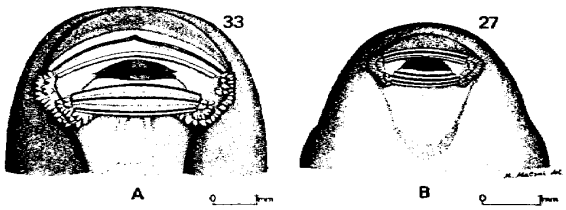

Fig. 8. Mouth parts of stream type (A) and still water type (B) tadpoles, the former showing much larger oral disc and uninterrupted second teeth row of upper labium. Numbers indicate stages of development.

Discussion

Existence of the stream type tadpoles

Orton (1953) classified anuran larvae into four types according to their mouth parts, and Starrett (1972) gave names to them. Among these four types, types 3 and 4 ('Lemanura' and 'Acosmanura' by Starrett) include stream type tadpoles whose mouth parts are somewhat modified to form suckers. Such tadpoles are known in six families: Ascaphi-

dae, Leptodactylidae, Ranidae, Hylidae, Bufonidae and Rhacophoridae, and this fact is known as an example of convergent evolution.

Among the family Bufonidae, several species belonging to *Heleophryne*, *Pedostibes*, *Ansonia* and *Bufo* are known to spend larval life in swift streams (Hora, 1930; Inger, 1960; Perret, 1966). In the genus *Bufo*, however, only a few species, such as *B. preussi* of Cameroons and *B. b. andrewsi* of Southern China, have been reported as the examples of this type (Mertens, 1938; Liu and Hu, 1961; Tandy and Keith, 1972), which may imply that the larval life in stream is peculiar and exceptional in this genus.

All the subspecies of the common toad (*Bufo bufo*) widespread in Eurasia, except for *B. b. andrewsi* of China mentioned above, have hitherto been said to breed in still waters (Smith, 1964; Mertens and Wermuth, 1960; Банников, 1969). No tadpoles of toads living in streams have been reported from Japan either.

The result of field observations hitherto made by the present author shows that in general the Japanese toabs lay eggs in still waters such as lakes, marshes, ponds and rice fields. In mountains, where no suitable still waters for breeding are found, toads lay eggs in small puddles and ditches temporarily formed by rainfall or melted snow. In all cases, however, tadpoles hatched congregate in shallow places of still waters, and if carried into rapid currents by some chance, they are unable to stay in a place and are swept down stream (Matsui, 1974b). On the contrary, the tadpoles discovered in Ohdaigahara and the Neo-Nishitani River seem to prefer more rapid parts of the currents to the places where tadpoles of *Rhacophorus buergeri* are found. The latter have been regarded as representing the stream type in Japan.

Morphological adaptation

Such peculiar mode of life as mentioned above is considered to be clearly reflected upon the external morphology of the tadpoles. The enlargement of the mouth disc seems to indicate that this organ serves as a sucker preventing tadpoles from being swept away by rapid currents. The concurrent modification of the dental formula seems also to reflect the feeding habit of the tadpoles, which adhere to and crawl on the surface of rocks and stones, and scrape lithophytic algae. The more streamlined head-body, with low tail fin and depressed profile, is parallel to that of stream dwelling salamanders. Though the significance of the larger distance from snout to eye cannot easily be interpreted, it may possibly be related to the fact that they are always exposed to direct rapid currents.

Taxonomic position

It appears reasonable to consider that these tadpoles, with the peculiar mode of life and unique morphology, represent a different form of toad clearly discriminated from the known forms whose tadpoles live in still water.

Bufo b. andrewsi, a stream type known from China, was first described in 1925 as a full species (Schmidt, 1925), and later its taxonomic status was treated in various ways. In 1958, Liu first reported that the tadpole of this toad was of stream type on the basis of an ecological survey at Likiang, and he classified it as a subspecies of the common European toad, as is now generally accepted.

There are some differences in measurements between the larvae of *B. b. andrewsi* given by Liu and Hu (1961) and those of the tadpoles from Japan shown in the present paper. Although no direct comparison can be made between them, since developmental stages were not given in Liu's data it seems obvious that, judged from the developmental condition of the hindlimbs, Liu's measurements were based on older tadpoles than

those treated by the present author. So far as Liu's description goes, no essential differences, both morphological and ecological, are found between the Chinese and Japanese tadpoles. Generally speaking, it is very difficult to discriminate tadpoles of two closely related anuran species. Moreover, it has not yet been clarified whether or not the Japanese toad really belongs to the same species as European and Chinese ones (Matsui, 1974a), and further, our knowledge of the adults of the Japanese stream type is still insufficient. It is, therefore, impossible to discuss here the taxonomic relations of the Chinese and the Japanese stream type toads.

It is interesting biogeographically that such stream type tadpoles of toads showing similar morphological and ecological features are found in the two distant and geographically discontinuous regions such as Southern China and Honshu. This fact may involve some important problems concerning relict distribution and/or parallel evolution of closely related forms.

Acknowledgments

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