Proc. Indian natn. Sci. Acad., B **45**, No. 2, pp 129-141 (1979)
Fisheries Biology

ON THE BURYING BEHAVIOUR OF THE TROPICAL LOACH *LEPIDOCEPHALUS THERMALIS* (CUV. & VAL.)

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(*Received* 1 *October* 1978)

Burying behaviour of the fish *Lepidocephalus thermalis* (Cuv. & Val.) was examined under experimental conditions and data quantified in relation to the nature of the substratum, light, density of population and sex. The fish shows a substrate preference for sand over gravel. The proximate functional significance and causes of the burying behaviour are discussed. Burying is apparently not meant for procurement of food, for avoidance from intense sunlight, heat of summer, or any reproductive activity, but seems to be a routine resting phase of its daily activity, the peculiar posture facilitating a certain degree of concealment and also protection from the predators of its habitat.

INTRODUCTION

Some species of loaches are known to bury themselves in sand or mud. However, there are differences even between conspecific subspecies in this behaviour pattern. Previous workers have dealt with this aspect only in a general way. Day (1878) recorded that the members of the genus *Lepidocephalus, Jerdonia* and the European *Cobitis taenia* bury themselves in sand. Das (1935), writing on the ecology and habits of *L. guntea* provides a brief description of this behaviour and even suggests that the fish aestivates lying in a torpid condition after burying completely. Smith (1945) reports that among the cobitid fishes of Siam, *Lepidocephalus* spp., *Acanthopsis choirorhynchos* Bleeker, *Cobitophis anguilliaris* Vaillant are known to bury in the bottom sand. Besides *Lepidocephalus* spp., *Cobitis taenia*—the spined loach (Sterba, 1967) *Misgurnus fossilis*—the pond loach (Jeuken, 1957; Kubota, 1960) and *Misgurnus anguillicaudatus*—the Japanese weather fish (Sterba, 1967; Amant & Hoover, 1969; Nalbant, 1973) are well-known representatives of the loaches that burrow until only the heads are exposed.

Although the burying behaviour in loaches has been observed and reported by many authors, no work has so far been done to study the ecological significance and the adaptive value of this behaviour. According to Patric Colgan (1975) (personal communication), this burying behaviour in fishes almost always varies noticeably within a population, this variation is almost never studied and it is an extremely important aspect of the biology of the fish. The present study was, therefore, undertaken by direct experimental approach for the first time to quantify the observed data in relation to the nature of the substratum, light, density of

population and sex of *L. thermalis*—that occur in the pools and streams of the plains of south India.

Materials and Methods

The fish used for this study was the common loach *L. thermalis*. Approximately 200 individuals—both mature and immature—were used.

When not involved in an experiment, the fish were maintained in heterosexual groupings in large aquaria supplied with sand, stones and rooted plants. The fish received tubifex worms as food. Water temperature ranged from 27 to 29°C. Experimental animals were returned to the holding tanks after each experiment and kept there for at least one week prior to being utilized in another experiment.

Glass aquarium tanks of size $60 \times 25 \times 25$ cm were used in all the experiments except in experiment III. Random samples of fish, more or less of equal size, collected from the holding tanks were used in each experiment.

The frequency of burying in fish was observed 2 or 3 times daily and the experiment continued for more than a day. The percentage of burying fish was then calculated. Relevant statistical analyses were carried out to suit the purpose of each experiment.

Each experiment was done in duplicate and the results reported represent the average. The containers were kept on a large, firm table where the fish were not disturbed in any way. Feeding the fish and changing of water were done simultaneously at 4 p.m. and no reading was taken on that day thereafter.

Observations and Results

I. *General Observations on the Act of Burying*

The act of burying in *L. thermalis* is a quick process, taking place within a period of 1 or 2 seconds, whereby the fish itself conceals, though not completely, the top of the head, with eyes and mouth and caudal fin alone being exposed. Burying occurs either from a stationary position or after swimming.

In the action of burying from a stationary position, the fish moves from its resting place and suddenly darts off, penetrating the head into the sand and then rapidly propelling the rest of its body by vigorous undulatory movements and finally assuming the characteristic position, with a slight bending of the body. In this position only the head and caudal fin are visible. During the act of burying, the penetration of the head releases a cloud of sand around the fish and this slowly settles down on the dorsal side of the fish. Burying achieved at the end of swimming also presents a very similar sequence of events.

Such a simple method of getting buried is possible only in a place where the bottom is composed of mud or fine sand particles, in which the fish will have comparatively less friction during the act of penetration. Moreover, the pointed snout, the laterally compressed and elongated body, and the mucous covering of the body all assist in the process of burying.

In a locality where the substratum is composed of small pebbles, the fish lurks in between stones but does not seem to penetrate into the substratum. Here too, the fish invariably exhibits a bent posture for the body exactly similar to that in sand.

A typical buried fish has only the anterior part of the head and the caudal fin exposed. But within a population of *L. thermalis*, the depth and extent of burial varied considerably. In this performance, sometimes only a part of the dorsal surface is hidden whereas at times the whole body behind the eye is completely concealed. The degree of the depth of burial extends from a semicircular loop to simple small curve where the middle portion of the body would alone be seen as if lying in a shallow furrow with few sand particles scattered on its dorsal surface.

Whatever be the nature and place of concealment, the fish buries invariably with its body in a characteristically bent posture. Any portion of the body from predorsal to caudal peduncle is capable of being bent while resting in this peculiar posture. The flexibility of the body is such that at times the body may be seen in a curiously bent position resembling the letter 'S'.

The duration of burial varies from less than an hour to more than 8 hours and this fossorial behaviour has been noticed among all sizes of fish.

II. *Behavioural aspects during burying in* L. thermalis

With a view to understanding the behaviour patterns during the process of burying itself into the substratum, a series of simple experiments were performed with *L. thermalis* and the observations thus recorded facilitated to throw some light on this curious habit of the fish.

Quantitative recordings of the fishes burying in relation to the following aspects were made :

(i) Burying behaviour in an aquarium
(ii) Burying behaviour in an aquarium with different substrata
(iii) Burying behaviour in relation to population density
(iv) Burying behaviour in relation to light
(v) Diurnal and nocturnal burying behaviour
(vi) Burying behaviour in relation to sex
(vii) Burying behaviour in relation to size of fish
(viii) Burying behaviour in relation to starvation

(i) *Burying behaviour in an aquarium*

With a view to getting a clear understanding of the habit of burying in *L. thermalis*, an aquarium tank was set up with fine river sand to a height of 3 cm and water to a height of 18 cm. The tank was also provided with aquatic weeds planted at irregular intervals and with three large rounded stones which were irregularly arranged on the sand. One hundred specimens of *L. thermalis* (sex not considered) ranging from 40 to 55 mm were then introduced into the aquarium. As soon as the fish were introduced in this specially set up tank, one could notice that they scattered themselves throughout the entire substratum of the tank without any preference for any particular site. But after a time

lag of about 15 minutes, some fish were seen resting on the weeds, others on stones or on sand, while a few others burying themselves in the sand.

The frequencies (number) of the fish burying in such a habitat were recorded at intervals of 24 hours from next day onwards. The percentage of the frequencies in the preferential sites are given in Table I. The 't' test was applied to find out whether the proportion of fish buried and non-buried differs significantly. Since the percentages of fish on plants and stones were less, they were not included in the analyses.

TABLE I

Preferential sites chosen by L. thermalis *in an aquarium tank*

Sl. No. of observations	Percentage of fishes on			
	Plants	Stones	Sand	Buried
1	4	—	66	30
2	4	—	54	42
3	20	2	30	48
4	6	—	24	70
5	6	2	32	60
6	10	—	18	72
7	10	2	40	48
8	4	—	28	68
9	8	4	40	48
10	18	4	16	62
Mean (Correct to the nearest integer)	9	1	35	55

The results show that the proportion buried is significantly greater than non-buried fish on sand, the value of the test criterion being 3.2063 which is significant at 1% level. Therefore, it may be inferred that the fish invariably prefer to bury themselves in the sand at the bottom of the container.

(ii) *Burying behaviour in an aquarium with different substrata*

To examine the effect of different substrata on this behaviour, a glass aquarium was set up as follows. The bottom of the tank was partitioned into three compartments to a height of 3 cm with thin wooden pieces. Each compartment was provided with a different type of substratum. One compartment was provided with coarse river sand, another with gravel, and the next with fine sand obtained from the sea shore. One hundred specimens, taken from the stocking pond, were introduced into this experimental tank and left undisturbed for 24 hours.

Specimens in each compartment, both buried and non-buried were then recorded during subsequent four days (3 observations per day) and percentages of fish in each substratum were calculated (Table II). The data were further analysed statistically to find out preference of fish to burying in any particular substratum.

TABLE II

Burying behaviour of L. thermalis *in relation to different types of substratum*

Different substrata	Percentage of fishes on					
	Gravel (G)		Coarse sand (C)		Fine sand (F)	
Sl. No. of observations	B	N	B	N	B	N
1	—	30	8	6	34	22
2	8	56	4	8	16	8
3	2	44	4	14	20	16
4	6	34	8	10	28	14
5	8	42	6	2	28	16
6	12	20	4	10	34	20
7	2	8	6	8	50	26
8	2	16	4	2	38	36
9	2	16	—	4	44	34
10	—	10	6	4	52	28
11	—	16	—	2	44	38
12	—	2	—	—	68	30
Mean (Correct to the nearest integer)	3	25	4	6	38	24

B, Buried fishes
N, Non-buried fishes

't' values

	C	F
G	1.7698 ns	5.9576 s 1%
C	—	1.2771 ns

ns— Not significant
s 1%— Significant at 1%

χ^2 test was applied to see whether the proportion buried was homogeneous in the three substrata. The χ^2 value obtained was 20.0473, which is significant at 1% level. This shows that the proportion buried is different in the different substrata.

't' test was then applied to see in which substrate the proportion buried was more considering the other two.

The results reveal that between gravel and fine sand, the proportion buried is more in fine sand compared to that in gravel. There is no significant difference in the proportion buried when otherwise compared. Thus the type of substrate is positively a factor which influences the burying behaviour in this fish.

(iii) *Burying behaviour in relation to population density*

To find whether the number of fish in a habitat influences the burying behaviour, glass troughs, 29 cm diameter and 12 cm high, with fine river sand at the bottom were used. All troughs were provided with identical conditions. Different numbers of fish were introduced and allowed to remain there for 24 hours without any external disturbances.

The results of the observations are presented in Table III. χ^2 test was applied in order to find out whether the proportion buried is same in the 5 tests when the population density was increased. The χ^2 value of 23.4962 obtained suggests that the proportion buried is different in different population density.

From the results of the observations presented in Table III, it would appear that the burying tendency decreases when the number of fish in a situation reaches above a certain point (in the present instance 30) revealing that density of fish in an area apparently has a marked influence on burying behaviour. The experiment could not be continued with more than 60 fish, since the limited quantity of water in the holding trough then became a limiting factor for the normal life of fish. The results of this test suggest that there is a relationship between crowding and burying tendency. In general, it may be said that when the number of individuals increases beyond a certain point, there is a decrease in the number of individuals that tend to bury.

(iv) *Burying behaviour in relation to light*

Tests were conducted to find whether burying tendency has any direct relation to light intensity.

For this, a glass aquarium was set up with fine river sand at the bottom. The three sides of one half of the tank were covered with black paper and 100 specimens were introduced. After 24 hours, recordings were taken of fish occupying the light and dark areas of the tank (Table IV).

The proportion of fish buried in light and dark areas to the total number of fish in that particular area of the tank is tested using the test for equality of proportions. The value of the test criterion, 0.6909, which is not significant shows that there is no preference for burying in light or dark area. Thus light seems to have no direct influence on burying behaviour.

(v) *Diurnal and nocturnal burying behaviour*

With a view to observing whether differential burying occurs during day and night, a glass aquarium was set up with bottom of fine river sand as in previous experiment, and 100 specimens were introduced. After 24 hours, the number of specimens burying during day and night was recorded (Table V).

Applying the test for equality of proportions, the proportion of fishes buried in day and night was not significant, the value of the test criterion being 1.31. This indicates that there is no diurnal variation in this behaviour pattern.

Burying behaviour in relation to sex

Fifty males and 50 females were separately kept in two glass aquaria provided with identical conditions. Observations on the percentage of fishes buried in both the troughs were recorded (Table VI).

TABLE III

Burying behaviour of L. thermalis *in relation to population density*

No. of fish used	20		30		40		50		60	
Sl. No. of observations	No. of fish in each posture									
	B	N	B	N	B	N	B	N	B	N
1	9	11	18	12	33	7	20	30	25	35
2	16	4	27	3	35	5	28	22	31	29
3	14	6	28	2	28	12	31	19	18	42
4	11	9	28	2	31	9	22	28	28	32
5	12	8	26	4	27	13	21	29	20	40
6	15	5	27	3	32	8	38	12	29	31
7	12	8	25	5	33	7	25	25	31	29
8	13	7	25	5	33	7	29	21	20	40
9	13	7	27	3	37	8	22	28	24	36
10	16	4	27	3	34	6	26	24	26	34
11	14	6	3	—	35	5	28	22	28	32
12	13	7	16	14	30	10	24	26	24	36
Mean number of fish in each posture correct to the nearest integer	13	7	25	5	32	8	26	24	25	35
Percentage	65	35	83	17	80	20	52	48	42	58

B, Buried fishes; *N*, Non-buried fishes

TABLE IV

Burying behaviour of L. thermalis *in relation to phototropism*

Sl. No. of observations	Light		Dark	
	Percentage of fishes			
	Buried	Non-buried	Buried	Non-buried
1	4	20	36	40
2	2	—	10	88
3	—	36	2	62
4	—	50	2	48
5	8	40	12	40
6	16	24	24	36
7	20	8	16	56
8	22	16	22	40
9	8	12	8	72
10	8	32	10	50
Mean percentage (Correct to the nearest integer)	9	24	14	53

TABLE V

Burying behaviour of L. thermalis *in relation to diurnal and nocturnal periods*

Sl. No. of observations	Day		Night	
	Percentage of fishes			
	Buried	Non-buried	Buried	Non-buried
1	30	70	50	50
2	40	60	45	55
3	35	65	50	50
4	35	65	35	65
5	35	65	40	60
Mean	35	65	44	56

The value of the test criterion 0.7215 was obtained, on testing the proportion buried between males and females, which is not significant. This reveals that males and females behave almost similarly in the act of burying.

(vii) *Burying behaviour in relation to size of fish*

To find out whether the size of the fish has any relation to burying behaviour, 50 fish 20 to 25 mm long and 50, 50 to 55 mm long were kept in separate glass tanks with fine river sand to a height of 3 cm at the bottom. After the introduction of fish, they were kept undisturbed for 24 hours. The recordings of burying fish (given as percentages) in both tanks (Table VII) were then made.

TABLE VI
Burying behaviour of L. thermalis *in relation to sex*

Sl. No. of observations	Male		Female	
	Percentage of fishes			
	Buried	Non-buried	Buried	Non-buried
1	70	30	80	20
2	65	35	80	20
3	80	20	90	10
4	40	60	85	15
5	65	35	75	25
6	10	90	10	90
7	10	90	35	65
8	60	40	40	60
9	80	20	75	25
10	55	45	35	65
11	60	40	80	20
12	75	25	50	50
Mean percentage (Correct to the nearest integer)	56	44	61	39

Comparing the proportion of small and large fish buried, the value of the test criterion 1.13 (not significant) shows that there is no significant difference in the proportion buried. Thus it can be inferred that this behaviour is met with in fish of all sizes, more or less in the same degree.

(viii) *Burying behaviour in relation to starvation*

With a view to finding out the nature of relationship between burying and starvation, a test was conducted in which a batch of 50 fish was subjected to continued starvation. At the end of 46 days, signs of great stress were discernible with high death rates when the experiment was discontinued.

Observations on the lst, 16th, 31st and 46th days were chosen for analyses to see whether there is any influence of starvation on the burying behaviour of *L. thermalis*. 't' test was used to see whether there is any significant difference in the proportion buried between the above-mentioned four observations (Table VIII).

As indicated in Table VIII there is no significant difference in proportion buried between the 1st and 16th day's observation. In all other observations there is significant difference in the proportion buried. This shows that 15 days of starvation does not have any influence on the proportion buried but as the number of days of starvation increases, there is a notable change in the proportion buried, thereby indicating the effect of starvation in the proportion burying.

Burying behaviour in presence of predatory fishes

In order to ascertain whether burying behaviour of *L. thermalis* has any relationship to the presence of predatory fishes in the same tank, an aquarium

tank was set up with fine river sand at the bottom. Fifty numbers of *L. thermalis* were first introduced and subsequently 3 numbers each of *Wallago attu* (15-18 cm length), *Channa striatus* (12-15 cm length) and *Anabas testudineus* (8-10 cm length) were introduced.

TABLE VII

Burying behaviour of L. thermalis *in relation to different size groups*

Sl. No. of observations	Large (50-55 mm)		Small (20-25 mm)	
	Percentage of fishes			
	Buried	Non-buried	Buried	Non-buried
1	95	5	80	20
2	85	15	70	30
3	80	20	60	40
4	90	10	85	15
5	90	10	80	20
6	95	5	100	—
7	85	15	95	5
8	95	5	85	15
9	80	20	90	10
10	80	20	80	20
11	95	5	75	25
12	90	10	90	10
13	80	20	50	50
14	70	30	80	20
15	75	25	75	25
Mean percentage (Correct to the nearest integer)	86	14	80	20

TABLE VIII

Proportion buried after each 15 days of starvation in the fish L. thermalis *when starved for 46 days*

	Period	Buried	Non-buried
I	1st day	74	26
II	16th day	82	18
III	31st day	44	56
IV	46th day	6	94

't' values

	II	III	IV
I	1.3722**	4.5249*	13.6000*
II		6.0897*	17.0022*
III			6.9343*

*Significant at 1% level

**Not significant

The presence of these fishes, did not show an increase in the number of buried *L. thermalis*, but when the other fishes caused considerable disturbances in the medium, on account of their fast swimming, probably due to fright, few fish were found to bury themselves.

Discussion

Under natural conditions, *L. thermalis*, which is an inhabitant of streams and ponds, often prefers to remain partially buried in the sand. Previous literature, dealing with the general description of cobitids, includes brief accounts on this burying behaviour. But, so far no attempt has been made to elucidate the functional significance and proximate cause of this burying behaviour in loaches.

Das (1935), Smith (1945) and Sterba (1967) describe this peculiar mode of life in cobitids as burrowing or as burying. Nair (1951) after a study of the habits of some burrowing fishes of Travancore concluded that fishes like *Symbranchus bengalensis, Taenioides cirratus* and *Amphipnous fossorius* burrow into the soil for protection and safety during unfavourable times. Further, according to him, only *A. fossorius* is a typical burrower while *S. bengalensis* and *T. cirratus* do not appear to be burrowers, but only bury themselves in the mud. Moreover they have a less snake-like body and do not possess all the characteristics of a true burrower. A true burrower should have developed permanent adaptations for a subterranean mode of life, taking food from the soil itself and depositing its eggs in the same environment. According to Das (1946), *Amphiponous cuchia* also lays its eggs in burrows and goes about in search of food from the subsoil and hence this form may be described as a true burrower. Studies on the concealing habits in *L. thermalis* reveal that the fish prefer to bury itself in the subsoil in a way similar to *S. bengalensis* and *T. cirratus*. To sum up, the sudden dive of *L. thermalis* in the water and remaining partially concealed in the substratum is certainly not a true burrowing behaviour but can be regarded as an act of burying.

Though it is not practicable to make observations on the burying under all possible combinations of factors such as time, place and altered conditions, the few simple experiments conducted to elucidate the possible causes of burying to understand the nature of the situations congenial to this behaviour have furnished interesting results.

1. Healthy and well fed fish, if undisturbed, prefer to lie buried in the bottom sand.
2. The greater frequency of burying in fine sand and coarse sand over gravel reflects substrate preference for this behaviour. Such substrate preference has been observed in two species of killifish *F. kansae* and *F. diaphanus* by Minckley and Klaassen (1969), and Colgan (1974) respectively. The substrate preference for sand over gravel may serve as a factor favouring the development of habitat selection.
3. Burying occurred in more or less the same proportions among male and female individuals. Even gravid females were occasionally seen to bury themselves in the bottom sand. Since the females also show no difficulty in burying them-

selves more or less in the same proportion as the males, the observation that the spinous first pectoral ray in the male helps in this behaviour (Day, 1878) becomes untenable.

4. Size of individuals does not seem to have any correlation or significance in burying, since burying occurred among individuals of all sizes more or less in the same proportion. So it seems unlikely that burying is associated with reproduction.
5. The duration of burial shows significant variation. Even when all fish are buried in the bottom sand, some of the fish come out and after a sojourn take up a different site for concealment. So, invariably, after a fish has buried itself in a particular spot, one could recognize the same fish to have chosen a different place in the substratum as its burying place. But as Das (1935) had observed in the case of *L. guntea* laboratory observations reveal that *L. thermalis* does not aestivate lying buried in the wet mud for days together.
6. While in the burying posture, *L. thermalis* is certainly not waiting for passing prey or other food items, since it is a detritus feeder and there is no need for a hiding posture for the procurement of food.
7. Induced disturbances created in the tank do not contribute in any way to accelerate the tendency to bury. Burying occurs even in the absence of predators in the vicinity. From observations so far made, the fish is seen to change its colour (concealing colouration) to blend with the substratum, and hence there is apparently no additional need for further protection from predators.
8. The probable advantage of such behaviour in shallow streams may not be avoidance from intense sunlight or heat in summer, since all fish in artificially illuminated troughs did not show the tendency to bury.
9. Under natural conditions, the fish occur near edges of shallow water bodies, hence this curious behaviour may, to some extent, enable the fish to escape easy detection by non-aquatic predators.

By far the most salient observation that emerges out from a scrutiny of above, mentioned results is that burying in this fish seems to be a resting phase of its daily activity and the assumption of this posture facilitates them not only to get a certain amount of concealment but also an effective protection from the predators of its habitat, both terrestrial and aquatic.

ACKNOWLEDGEMENT

One of us (S.D. Rita Kumari) is indebted to the University of Kerala, and the Council of Scientific and Industrial Research for the award of fellowships during the tenure of which the present work was carried out.

REFERENCES

Amant, St. J. A. & Hoover, F. G. (1969). Addition of *Misgurnus anguillicaudatus* (Cantor) to the Californian fauna. *Calif. Fish Game*, **55** (4).

Colgan, P. (1974). Burying experiments with the banded killifish *Fundulus diaphanus*. *Copeia*, No. 1, 258-259.

Colgan, P. (1975) Personal communication.

Das, B.K. (1935). On ecology and bionomics of an air-breathing loach *Lepidocephalus gunteo* (Ham. Buch.), with a review on air-breathing fishes. *Comptes Rendus, XII Congr. Internat. Zool.*, **2**, 866-920.

Das, B.K. (1946). Further observations on the ecology, bionomics and early development of the semi-terrestial symbranchoid eel, *Amphipnous cuchia* (Ham. Buch.)—the cuclia eel of India. *Proc. Ind. Sci. Congr. Assn.*, Part III, Abs. **42**, 11-12.

Day, F. (1878). *Fishes of India*, **2** (London : Bernard Quaritch).

Jeuken, M. (1957). A study of the respiration of *Misgurnus fossilis* (L.), the pond-loach ——'s'——Gravenhage, Excelsier, 114 p.

Kubota, Z. (1960). *Morphology, Ecology and Culturing of the Japanese loach, Misgurnus anguillicaudatus* Cantor. 452 pp. (In Japanese with English summary).

Minckley, C.O. & Klaassen, H.E. (1969). Burying behaviour of the plains killifish *Fundulus kansae*. *Copeia*, No. **1**, 200-201.

Nair, K.K. (1951). Some burrowing fishes from Travancore. *Proc. Indiac Acad. Sci.*, **34** (6), 311-328.

Naibant, (1973). Family : Loaches. In : Grzimek's *Animal life encyclopaedia*, **4** (Fishes 1), 355-360.

Smith, H.M. (1945). The fresh-water fishes of Siam or Thailand, Smithsonian institution United States National Museum Bulletin, 188.

Sterbs, Gunther. (1967). *Freshwater Fishes of the World.* Studio Viste, London.