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DESCRIPTION OF DEVELOPMENTAL STAGES OF THE STONECAT, *NOTURUS FLAVUS* AND THE SLENDER MADTOM, *NOTURUS EXILIS* (SILURIFORMES: ICTALURIDAE)

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ABSTRACT. The stonecat, *Noturus flavus*, and the slender madtom, *N. exilis*, deposit clumps of adhesive eggs on firm substrates beneath slab rocks. In both species, eggs are spherical, demersal, possess a narrow perivitelline space, and are held together by an adhesive gelatinous substance. Diameters of stonecat eggs range from 3.4–3.8 mm, while the slender madtom eggs range from 3.2–3.6 mm. Eggs differ in yolk color. Stonecat egg yolk is yellow, and yolk from the slender madtom varies from amber to orange. Slender madtom eggs incubated at 25 °C hatched in 8–9 days (187–210 hr). Stonecats hatch as 7.2–7.5 mm larvae, while slender madtom hatch at 5.5–6.3 mm total length (TL). Larval stonecats possess 18–24 preanal myomeres and 24–29 postanal myomeres. Slender madtoms have 17–26 preanal myomeres and 21–29 postanal myomeres. Newly-hatched larvae of both species do not possess cutaneous melanophores; however, slender madtom had a uniform subcutaneous pigmentation pattern that gave the body an overall light brown color. Pigmentation of yolk sac larvae consists of scattered melanophores over the dorsum in slender madtom, while stonecat are unpigmented except for the retinae. Yolk sacs were absorbed in some stonecats by 12.3 mm, and most were completely absorbed by 13.0 mm TL. Slender madtom yolk sacs were absorbed between 12.6 and 13 mm TL. In stonecats the adult diagnostic character of an overhanging jaw is apparent by 11.3 mm TL.

Keywords: Development, *Noturus*, *Schilbeodes*, early life history

The stonecat, *Noturus flavus*, is one of the widest-ranging madtoms, occurring throughout the upper and mid-Mississippi River basin, south to Tennessee and Arkansas, much of the St. Lawrence–Great Lakes basin, the Hudson Bay (Red River) drainage, and the Hudson River drainage, New York (Taylor 1969; Burr & Warren 1986; Page & Burr 1991). The slender madtom, *Noturus exilis*, has a smaller and overlapping range with two centers of distribution. It occurs in the Tennessee, Cumberland, and Green river drainages from northern Alabama to central Kentucky, and in the upper Mississippi River basin from southern Wisconsin and southern Minnesota to the Ozark and Ouchita highlands of Arkansas, Kansas, and Missouri (Taylor 1969; Page & Burr 1991). Neither Taylor (1969) nor Grady & LeGrande (1992) considered the two species to be close relatives; however, their superficial similarity often makes identification difficult in areas of sympatry.

Walsh & Burr (1985) and Mayden & Burr (1981) report on many aspects of the biology of *N. flavus* and *N. exilis*, including reproduction and early life history. Additional life history information is provided by Greeley (1929), Gilbert (1953), Carlson (1966), and Becker (1983) for *N. flavus*. Taylor (1969), Burr & Mayden (1984), Vives (1986), and Etnier & Starnes (1994) provide additional life history information for *N. exilis*. Except for information on egg incubation, general larval development, and illustrations of various larval or juvenile stages (e.g., Mayden & Burr 1981; Burr & Mayden 1984; Walsh & Burr 1985), no meristic or morphometric data is available for either species. Herein we provide details of meristic, morphometric, and pigmentation characters with the goal of determining diagnostic characters necessary for separating sympatric species of *Noturus*.

METHODS

Laboratory-raised series of egg, larval, and early juvenile stonecat and slender madtom were examined. Stonecat eggs were field-collected from nests and from laboratory-spawned fish from the Meramec River, Missouri. Stonecat ovaries were dissected from adults collected from the Kankakee River, LaPorte County, Indiana. Slender madtom eggs were collected from nests in Green Creek and Hutchins Creek, Union County, Illinois. Specimens were reared in small culture containers, and representative series were preserved in 10% formalin. Culture water was Carbondale, Illinois, tap water that was carbon filtered and conditioned to remove chloramines. Water quality included neutral pH and temperatures ranging from 22–24 °C. Partial water changes were made daily to reduce increases in ammonia from food and waste.

Ontogenetic series, comprised of six eggs and 34 larvae and early juvenile slender madtoms and 23 eggs and 32 larvae and early juvenile stonecats, were studied for changes in 31 morphometric and 13 meristic characters. Preanal myomeres included all body segments from the head to an imaginary vertical line at the posterior anus (including those bisected by the line), while postanal myomeres included those posterior to the vertical line plus an urostyle segment (Snyder 1979). All lengths are reported as total length (TL) unless otherwise noted. Vertebral counts were made from specimens cleared and stained using the techniques described by Fritzsche & Johnson (1980). Minor modifications were made to the method used at the Mississippi River Fisheries Center (L.E. Holland-Bartels pers. commun.). Figures were drawn following Sumida et al. (1984).

The following length, depth, and width measurements were made: horizontal length from anterior margin of snout to anterior margin of eye (snout length), to dorsal finfold/spinous dorsal fin (D origin), to origin of adipose fin (adipose origin), to posterior margin of vent (preanal length), and to posterior margin of hypural plate or notochord (standard length), maximum horizontal length of yolk sac (yolk sac length). Fin lengths (P1 and P2) were measured along the plane of the fin from the origin to the most distal margin. Body depths were measured vertically from the dorsal to ventral margins and included the yolk sac but not the fins or finfolds. The vertical depths were measured immediately behind the posterior margin of the eye (head depth), at origin of pectoral fin (shoulder depth), behind the posterior vent (preanal depth), and mid-postanal myomere (mean countable whole myomere myosepta between anus and penultimate myomere: mid-postanal depth), at penultimate myosepta (caudal peduncle depth), and maximum yolk sac depth (includes only yolk: yolk sac depth). Body width was measured immediately posterior to the eye (head width).

RESULTS

Stonecat
Noturus flavus Rafinesque

Eggs.—Preserved vitellogenic oocytes removed from specimens from the Kankakee River, LaPorte County, Indiana, were amber and ranged in diameter from 1.9–3.4 mm (n = 23, $\bar{x}$ = 3.0 mm). Mature eggs are yellow, demersal, spherical, and adhesive. Eggs contain a translucent yolk, a compound oil globule ($\bar{x}$ = 1.18 mm), a smooth, unpigmented chorion, and a narrow perivitelline space (0.1 mm). Stonecat eggs used for the larval series were field collected from beneath slab rocks; thus, the age of the eggs was unknown.

Larvae.—*Morphology:* Morphometrics of stonecat larvae and early juveniles are reported in Table 1. The following lengths describe the initial onset of select structure development. At 7.2–7.6 mm (newly hatched): mandibular and mental barbels present as buds, weakly developed jaw and pectoral fins, yolk sac spherical and pale yellow, with a distinct vitelline vein network and a single cluster of composite oil globules, head deflected slightly over the yolk sac, and eyes oval. Notochord flexion occurs by 8.2 mm, nasal barbels present as buds by 8.5 mm, caudal fin rays form by 8.6 mm, anal fin rays by 9.8 mm, and the soft dorsal rays and anterior spine by 9.8 mm. Pelvic fin buds form by 9.8 mm and first pelvic fin rays form by 10.9 mm. Ten incipient pectoral fin rays form by 9.6 mm, and first rays form in pectoral fins by 12.3 mm. Dorsal origin situated over preanal myomere 5, adipose fin origin over preanal myomere 13 (9.4–11.9 mm). Gut straight, caudal fin truncate (9.4 mm). Principal rays of median fins seg-

mented by 10.8–11.4 mm. Infraorbital and lateral head canals form by 9.7 mm, completely formed by 11.3 mm. Lateral line begins to form at 9.9 mm. Upper jaw overhangs lower jaw by 11.3 mm. Yolk absorbed between 12.3–13.0 mm. Supraorbital, supratemporal, and preoperculomandibular head canals form and infraorbital completely form by 12.9 mm. Incipient dorsal and anal finfolds partially differentiated by 9.6 mm, completely differentiated by 19.2 mm. No pectoral spine serrae develop on anterior or posterior margins.

Meristics: Preanal myomeres 18 (3), 19 (5), 20 (9), 21 (9), 22 (5), or 24 (1) (n = 32, $\bar{x}$ = 20.4), postanal myomeres 24 (1), 25 (4), 26 (9), 27 (7), 28 (9), 29 (2) (n = 32, $\bar{x}$ = 26.8), with 44 to 50 total myomeres. Total vertebrae 37–40 (n = 3, $\bar{x}$ = 38.5), including one urostylar element. Fin ray counts and length at appearance are presented in Table 2.

Pigmentation: Newly-hatched larvae (7.2–7.5 mm), body without dermal pigment, yolk yellow, and eyes pigmented. At 8.0–8.6 mm, cutaneous melanophores concentrated on cephalic region and nape (Figs. 1, 2). At 9.4–10.6 mm, scattered cutaneous melanophores cover dorsal and dorso-lateral surface with concentrations of melanophores on the cephalic region and posterior to the eye. The body has scattered cutaneous melanophores that outline epaxial myosepta of each myomere. No pigmentation on the ventral half of the body, barbels, or finfolds (Fig. 3). Between 10.7–11.3 mm, scattered cutaneous melanophores outline the eye and the epaxial myosepta, and postanal hypaxial myosepta are pigmented from the anus to the caudal peduncle (Fig. 4). At lengths from 12.3–22.5 mm (late larvae and early juveniles), pigmentation pattern continues as described but increases in density and concentration between the myosepta; barbels, fins, and the ventral surface anterior of the vent remain without any pigmentation (Fig. 5).

Slender Madtom
Noturus exilis Nelson

Eggs.—Vitellogenic oocytes removed from specimens from Mill Creek, Missouri, are orange and range in diameter from 1.5–3.4 mm (n = 12, $\bar{x}$ = 2.9 mm). Mature eggs are amber, demersal, spherical, and adhesive. Eggs contain a translucent yolk, a composite oil globule ($\bar{x}$ = 1.18 mm), a smooth and unpigmented chorion, and a narrow perivitelline space (0.1 mm). Slender madtom eggs were spawned and incubated under laboratory conditions. Eggs hatch in 187–210 h at 25 °C.

Larvae.—*Morphology:* Morphometrics of slender madtom larvae and early juveniles are reported in Table 3. The length at initial formation of select structures is summarized. At 5.5–6.5 mm (newly hatched): mandibular and mental barbels present as buds, weakly-developed jaw and pectoral fins, yolk sac spherical, yolk sac amber to orange, with a single cluster of composite oil globules, a distinct vitelline vein network, head deflected slightly over yolk sac, and eyes spherical. Incipient fin rays form in dorsal fin by 6.7 mm, notochord flexion and caudal fin rays, anal fin rays, soft dorsal rays and anterior dorsal spine form simultaneously by 8.2 mm, and pectoral fin rays form by 8.8 mm. Nasal barbel buds developed by 7.5 mm. Upper and lower jaws of equal length (11.3 mm). Pelvic fin buds and first pelvic fin rays form by 11.7 mm. Yolk absorbed between 12.6–13.0 mm, dorsal and anal finfolds partially differentiate by 12.2 mm, completely differentiated by 18.8 mm. Dorsal origin situated over preanal myomeres 4–5, adipose fin origin over preanal myomere 12–16 (6.7–14.2 mm). Gut straight, caudal fin truncate (12.0 mm). Principal rays of median fins segmented between 10.9–11.5 mm. Infraorbital and lateral head canals form between 9.1–10.9 mm, completely formed by 11.5 mm. Lateral line began to form at 11.9 mm. Supraorbital, supratemporal, and preoperculomandibular head canals begin to form and infraorbital completely forms between 11.5-13.5 mm. Differentiation of pectoral spine posterior serrae apparent by 19.0 mm.

Meristics: Preanal myomeres 17 (1), 18 (3), 19 (20), 20 (8), 24 (1), or 26 (1) (n = 34, $\bar{x}$ = 19.4), postanal myomeres 21 (1), 24 (11), 25 (3), 26 (10), 27 (3), 28 (5), or 29 (1) (n = 34, $\bar{x}$ = 25.6), with 42–49 total myomeres. Total vertebrae 36–39 (n = 3, $\bar{x}$ = 38.1), including one urostylar element. Fin ray counts and length at appearance presented in Table 2.

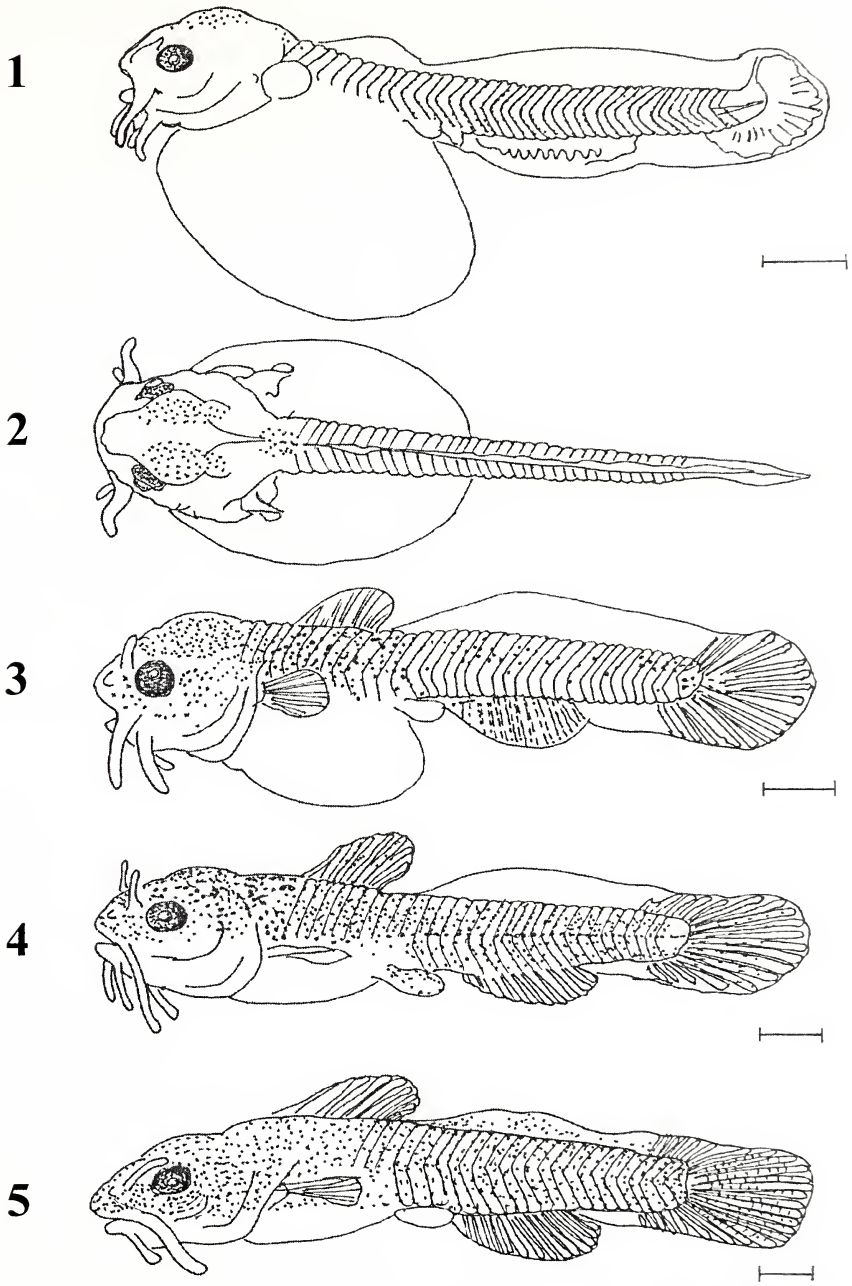
Pigmentation: Newly-hatched larvae (5.5–8.0 mm), eyes pigmented, yolk amber to orange, dermal pigment absent; however, a subdermal pigmentation gives body a brown appearance. No pigmentation is present in either the barbel or finfolds (Figs. 6, 7). Between 8.8–11.7 mm, cutaneous melanophores

Table 1.—Morphometry of *Noturus flavus* and early juveniles grouped by select intervals of total length (n = sample size). Characters expressed as mean of percent head* and total length with a single standard deviation.

	Total length (TL) intervals (mm)					
Measure	7.6–8.6 (n = 3)	9.4–11.9 (n = 19)	12.3–14.0 (n = 4)	14.2–14.6 (n = 3)	19.2 (n = 1)	21.9–22.5 (n = 2)
Length, % TL						
Standard	91.3 ± 0.7	85.6 ± 1.9	82.0 ± 1.3	82.8 ± 0.8	82.0	84.6 ± 3.3
Snout*	23.9 ± 11.6	30.2 ± 4.3	30.9 ± 2.7	30.0 ± 0.1	29.9	31.1 ± 3.1
Eye*	23.4 ± 1.2	19.2 ± 3.9	19.2 ± 1.5	18.0 ± 0.2	17.6	18.3 ± 1.4
Head	23.6 ± 0.4	23.4 ± 1.6	25.2 ± 3.5	28.4 ± 0.3	25.1	24.0 ± 0.9
Dorsal origin	28.0 ± 0.2	27.8 ± 1.5	28.6 ± 2.3	28.7 ± 0.3	30.8	32.0 ± 1.4
Preanal	49.0 ± 0.5	46.6 ± 1.6	46.7 ± 1.5	46.3 ± 0.4	49.7	48.2 ± 3.9
Adipose origin	41.2 ± 0.6	42.0 ± 1.9	42.7 ± 0.9	42.9 ± 0.4	49.5	47.0 ± 0.3
Yolk sac	36.8 ± 7.8	27.4 ± 5.7	17.3 ± 2.7			
Fin length, % TL						
Pectoral	7.3 ± 1.3	12.0 ± 1.5	14.4 ± 1.3	12.7 ± 0.1	17.1	13.7 ± 2.1
Pelvic	2.56 ± 0.0	4.4 ± 1.9	7.5 ± 1.2	6.6 ± 0.0	9.7	10.5 ± 1.0
Depth, % TL						
Head	22.0 ± 2.4	15.4 ± 2.4	16.6 ± 4.2	13.0 ± 0.4	16.2	13.7 ± 0.6
Shoulder	31.3 ± 3.0	23.6 ± 4.3	18.0 ± 2.7	15.0 ± 0.1	17.0	15.6 ± 1.1
Anus	9.1 ± 0.6	9.3 ± 1.0	9.6 ± 1.4	9.7 ± 0.0	9.9	10.6 ± 0.1
Mid-postanal	7.9 ± 0.4	7.7 ± 0.8	7.6 ± 0.6	7.9 ± 0.1	7.3	7.6 ± 0.9
Caudal peduncle	5.8 ± 0.2	6.7 ± 0.6	6.0 ± 1.2	6.5 ± 0.0	6.5	6.4 ± 0.6
Yolk sac	24.6 ± 3.0	17.4 ± 5.1	8.2 ± 0.3			
Width, % TL						
Head	81.9 ± 7.1	77.8 ± 10.0	79.1 ± 10.6	61.5 ± 0.4	77.2	71.3 ± 5.4

Table 2.—Comparative meristic counts of *Noturus flavus* and *N. exilis* larvae and early juveniles based on length at initial formation and completion of adult complement.

Character	*Noturus flavus*	*Noturus exilis*
Dorsal spine/rays	I/6	I/6–7
First formed	9.8/9.8	9.8/6.7
Adult complement	9.8/9.8	9.6/8.8
Pectoral spine/rays	I/9–11	I/8–10
First formed	9.6/9.6	9.6/8.8
Adult complement	12.3/12.3	9.6/8.8
Anal rays	15–19	17–20
First formed	9.7	8.2
Adult complement	9.8	10.9
Pelvic rays	8–9	8–10
First formed	10.9	11.7
Adult complement	10.9	11.7
Caudal rays (upper + lower half)	29–32 + 27–31	20–26 + 21–36
First formed	8.2	8.2
Adult complement	11.4	11.6
Myomere counts		
Predorsal	5	4–5
Preanal	18–24	17–26
Postanal	24–29	21–29
Total	42–49	44–50



Figures 1–5.—*Noturus flavus*, stonecat, laboratory raised from Meramec River, Missouri. Scale bar equals 1 mm. 1. Yolk sac larva, lateral view, 8.5 mm TL; 2. Dorsal view; 3. Late yolk sac larva, lateral view, 9.9 mm TL; 4. Early juvenile, lateral view, 11.3 TL; 5. Juvenile, lateral view, 13.5 mm TL.

are concentrated dorsally over the optic and olfactory lobes and extending anteriorly onto upper lip. A few melanophores outline epaxial myosepta 6–8 and concentrate along these preanal myomeres. The barbels, finfold, and hypaxial portions of the body were unpigmented. Subdermal melanophores continue to cover the entire body with the exception of the finfolds and barbels (Figs. 8, 9). From 11.9– 12.9 mm, cutaneous melanophores

Table 3.—Morphometry of *Noturus exilis* and early juveniles grouped by select intervals of total length (n = sample size). Characters expressed as mean of percent head* and total length with a single standard deviation.

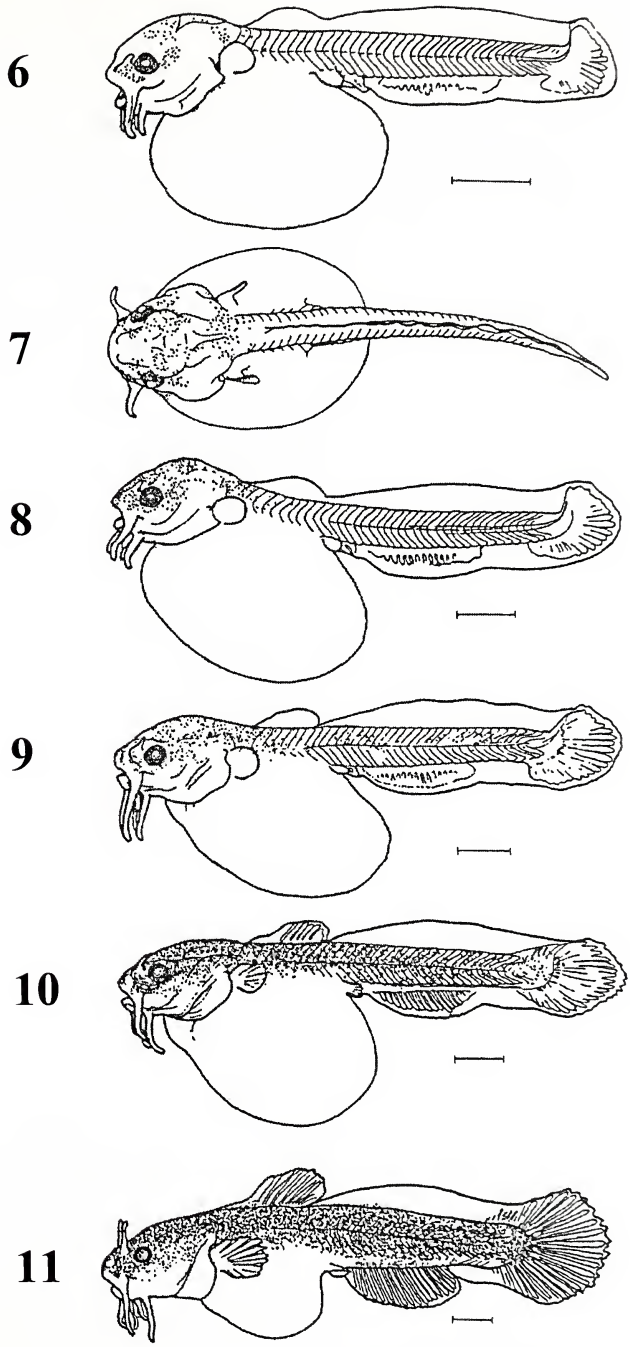
	Total length (TL) intervals (mm)					
Measure	6.7–9.6 (n = 9)	10.2–11.7 (n = 6)	12.0–13.7 (n = 10)	14.1–14.2 (n = 2)	19.0–23.6 (n = 3)	24.7–26.5 (n = 4)
Length, % TL						
Standard	89.1 ± 5.5	85.8 ± 3.2	83.7 ± 1.3	84.4 ± 0.4	74.7 ± 2.3	85.6 ± 1.0
Snout*	27.0 ± 5.5	28.9 ± 5.9	31.9 ± 2.5	26.3 ± 1.8	25.5 ± 0.8	30.2 ± 0.9
Eye*	19.1 ± 3.3	17.9 ± 1.8	16.8 ± 2.6	17.2 ± 1.6	13.3 ± 4.2	14.9 ± 2.2
Head	20.8 ± 3.3	23.6 ± 1.4	24.3 ± 2.4	22.8 ± 1.3	30.2 ± 3.2	21.8 ± 0.5
Dorsal origin	27.1 ± 2.7	28.8 ± 2.6	29.1 ± 2.2	28.9 ± 0.3	37.7 ± 2.2	29.4 ± 0.4
Preanal	48.5 ± 3.3	48.1 ± 1.2	47.7 ± 1.6	48.9 ± 3.3	51.6 ± 0.8	51.7 ± 0.6
Adipose origin	40.8 ± 2.5	45.0 ± 3.6	43.5 ± 2.5	41.9 ± 0.3	55.6 ± 0.7	44.5 ± 0.8
Yolk sac	42.7 ± 4.6	29.2 ± 4.4	25.6 ± 3.3			
Fin Length, % TL						
Pectoral	7.9 ± 2.2	11.8 ± 2.9	11.7 ± 1.7	13.1 ± 2.3	14.7 ± 1.2	11.9 ± 2.3
Pelvic	4.1 ± 1.5	4.9 ± 1.6	7.8 ± 1.9	7.1 ± 0.1	16.9 ± 4.4	11.9 ± 3.1
Depth, % TL						
Head	18.2 ± 6.4	15.5 ± 1.6	16.5 ± 1.9	16.6 ± 0.4	13.2 ± 0.2	11.7 ± 1.0
Shoulder	32.4 ± 5.2	26.7 ± 1.7	20.5 ± 3.2	20.0 ± 2.0	19.5 ± 1.2	15.4 ± 0.8
Anus	8.7 ± 1.3	10.6 ± 1.2	11.2 ± 1.2	11.7 ± 0.7	17.9 ± 0.2	12.7 ± 0.4
Mid-postanal	7.2 ± 1.1	8.1 ± 1.2	8.3 ± 1.0	8.3 ± 0.0	12.1 ± 0.6	10.1 ± 0.4
Caudal peduncle	5.5 ± 1.1	6.6 ± 0.9	6.1 ± 0.9	6.5 ± 0.4	11.1 ± 1.3	9.1 ± 0.9
Yolk sac	29.9 ± 8.1	23.1 ± 2.5	13.9 ± 7.4			
Width, % TL						
Head	86.6 ± 13.8	77.0 ± 7.4	74.7 ± 7.4	85.5 ± 0.6	76.8 ± 1.8	86.7 ± 5.4

cover the entire dorsum of the head and body exclusive of the fins. Punctate melanophores are distributed in the epaxial myosepta and over the myotomes. A secondary band of melanophores start at the snout and continues through the eye posteriorly to the origin of the dorsal fin. No melanophores occur on the fins or barbels. Subdermal pigmentation occurs over the entire body as in previous length intervals (Fig. 10). At 13.4–26.5 mm, juvenile pigmentation consists of discrete, punctate, cutaneous melanophores dorsally from the mandible to the caudal peduncle. The ventral portion of the body from the mandible to the vent is unpigmented, as well as the barbels, and median and paired fins. Subdermal pigmentation covers the remainder of the body (Fig. 11).

DISCUSSION

Development of the stonecat and slender madtom is similar to that of previously described *Noturus* (Burr & Mayden 1982; Dinkins 1984; Shute 1984; Starnes & Starnes 1985). At hatching, larvae are small (6.5–7.5 mm TL) and possess weakly-developed pectoral fins without incipient fin ray development until late in the yolk stage. Adult complements of fin rays develop prior to complete yolk absorption. The absorption of the large yolk sac causes the reduction of several depth measurements, including body depth/TL. Yolk sac larvae have a large, spherical yolk sac (yolk sac length/TL approximately 40%).

The description of *Noturus flavus* and *N. exilis* larvae increases the total number of *Noturus* with early life history morphometrics to six species. Additional species with some descriptive information include *N. miurus* (Burr & Mayden 1982), *N. flavipinnis* (Shute 1984), *N. baileyi* (Dinkins 1984), and *N. eleutherus* (Starnes & Starnes 1985). Described species of *Noturus* share similar body shape and overlapping numbers of preanal and postanal myomeres. The use of developmental characters will enable hypotheses of sister taxa relationships once additional compatible character sets are developed. The six species



Figures 6–11.—*Noturus exilis*, slender madtom, laboratory raised from Green Creek, Illinois. Scale bar equals 1 mm. 6. Newly-hatched yolk sac larva, lateral view, 6.5 mm TL; 7. Newly-hatched yolk sac larva, dorsal view; 8. Yolk sac larva, lateral view, 8.8 mm TL; 9. Yolk sac larva, lateral view, 10.6 mm TL; 10. Late yolk sac larva, lateral view, 11.9 mm TL; 11. Early juvenile, lateral view, 12.8 TL.

treated thus far exhibit subtle differences in the positioning and density of melanophores, myomere modes, and depth at select landmarks.

Adult characters, such as barbel length, position of the upper jaw, and pectoral spine development, are not adequate characters for separation of larval madtom development. Development of serrae on the anterior and posterior margins of pectoral fins are not reliable characters for separation of species until lengths are ≥ 19 mm TL. Length of the mandibular, mental, and nasal barbels change throughout larval development. The overhanging upper jaw is not a diagnostic trait until specimens reach minimum sizes of 11.3 mm TL; however, the slight differences at this size are difficult to distinguish. These characters are useless for identification of larval and juvenile specimens less than 24 mm TL.

Walsh and Burr (1985) found that stonecat egg diameters ranged from 3.5–4.0 mm, while eggs from the Kankakee River, LaPorte County, Indiana, ranged from 3.9–4.5 mm. Egg diameters of *N. exilis* ranged from 1.5–3.4 mm. Despite our reported egg diameters being slightly larger than those previously reported for *N. flavus* and slightly smaller than reported for *N. exilis*, we assumed that this was because ova were from different drainages and that different demes would have some intraspecific variation. The yolk coloration of *N. flavus* is yellow, while *N. exilis* is either amber or orange. The difference in yolk coloration between the two species is sufficient to distinguish them, since yolk color was similar between field-caught and laboratory-reared specimens. Yolk coloration is not considered to be affected by maternal diet nor yolk sac larval diet since it remains consistent during yolk sac stages and was similar between field and laboratory specimens.

No single character will distinguish larval stonecat and slender madtom; however, they can be diagnosed using a combination of pigmentation, myomere counts, and development of select structures relative to size. Adult *N. flavus* can be distinguished from all other *Noturus* species by the posterior extension of the premaxillary tooth patch. Larval slender madtom can be easily differentiated from stonecat since subdermal pigmentation gives the entire body an overall brown appearance. The stonecat does not possess subdermal pigmentation; however, extensive cutaneous melanophores occur dorsally over the body. At lengths greater than 9.4 mm TL, the stonecat has extensive dorsal melanophore pigmentation. Slender madtoms do not develop cutaneous melanophore pigmentation over the body until they reach at least 11.9 mm TL.

The stonecat and slender madtom differ in the modal number of preanal and postanal myomeres; however, the total number of preanal, postanal, and total myomeres overlaps. Modal number of myomeres for the stonecat is 20–21 preanal and 26–28 postanal. The slender madtom had a modal number of 19 preanal and 24–26 postanal myomeres.

Number of vertebrae is similar to values reported by Taylor (1969); however, we found 4–5 more postanal myomeres than vertebrae for the several specimens examined. Specimens examined for vertebral counts were juveniles, while Taylor examined adults. The discrepancies between vertebral number and number of myomeres are similar to that reported from Cyprinidae and Catostomidae (Snyder 1979). Snyder (1979) found that differences between number of vertebrae and myomeres vary by as much as six myomere elements for some taxa. In Synder's study, differences in myomere counts were attributed to technique differences in determining the most anterior and posterior myomeres. In our study, changes in vent position occur between larval and juvenile stages, as they do in Cyprinidae and Catostomidae. While vertebral numbers are within the expected range of values for preanal myomeres, values for postanal myomeres are higher than vertebral counts. In yolk sac and larval stages, there are greater numbers of postanal myomeres than postanal vertebrae. The difference in counts is attributed to the greater number of myomeres near the caudal peduncle and additional myomeres near the most anterior preanal myomere. Some variation between postanal myomere and vertebral counts can be due to a reduction in postanal myomere number during the formation of the hypural plate. The specimens we cleared and stained for our vertebral estimates were juveniles, while ranges in postanal myomere counts for each species were determined for yolk sac to early juvenile stages.

Madtoms exhibit developmental differences in select structures with increased growth. The slender madtom hatches at smaller sizes (5.5–

6.3 mm TL) than stonecats (7.2–7.5 mm TL). The slender madtoms develop dorsal, pectoral, and anal fin rays at smaller sizes than do stonecats, while pelvic fin rays form earlier in the stonecat. Complete yolk absorption occurs at approximately the same size in both species (12.3–13.0 mm TL for stonecat and 12.6–13.0 mm TL for slender madtom). Finfold absorption, lateral line, and cephalic canal formation occur at smaller sizes in the slender madtom than in the stonecat. Although none of these characters are diagnostic for either species, it is apparent that a combination of characters is adequate for separation. Although this is the first detailed description of these species and our material is based on limited geographic sampling, we suggest that identification of additional nesting populations will enable more detailed comparisons between these species.

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MATERIAL EXAMINED

Noturus flavus.—Southern Illinois University Collection (SIUC) uncatalogued. **MISSOURI:** *Franklin County:* Meramec River at State Park, 16 July 1981 (11); 16 July 1982 (10); 18 July 1982 (2); 20 July 1982 (2); 23 July 1982 (6). Large Rivers Research Collection (LRRC): **INDIANA:** *LaPorte County:* Kankakee River, at Kingsbury State Park, INBS 950 (1).

Noturus exilis.—Southern Illinois University Collection (SIUC) uncatalogued. **ILLINOIS:** *Union County:* Green Creek, 7.2 km W Anna and Illinois, Union County, Hutchins Creek; 4.8 km ENE Wolf Lake, 24 June 1982 (4); 29 June 1982 (2); 26 June 1982 (4); 20 June 1982 (1); 21 June 1982 (1); 21 June 1982 (1); 23 June 1982 (1); 24 June 1982 (1); 25 June 1982 (1); 26 June 1982 (1); 28 June 1982 (1); 2 July 1982 (5); 5 July 1982 (2); 7 June 1982 (4); 7 July 1982 (3); 18 August 1979 (1). U.S. National Museum: **TENNESSEE:** *Williamson County:* tributary of Harpeth River, E edge of Arrington, USNM 244958 (2).

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