

BIOLOGY AND DIET OF THE NORTHERN MADTOM (*NOTURUS STIGMOSUS*) AND STONECAT (*NOTURUS FLAVUS*) IN FRENCH CREEK, PENNSYLVANIA¹

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ABSTRACT

Age, oocyte condition, body size at reproductive maturity, and diet of the only Pennsylvania northern madtom *Noturus stigmosus* Taylor population were compared to the closely related, syntopic stonecat *Noturus flavus* Rafinesque. All mature stonecat females were larger (101.8–140.7 mm, SL) than mature northern madtom females (60.9–85.2) but oocytes of both species were similar in appearance and diameter (stonecat \bar{x} = 1.98 mm, CV = 3.98; northern madtom \bar{x} = 1.83, CV = 4.69) to those of other ictalurids. Stonecat clutch sizes were much larger (\bar{x} = 261, CV = 5.0), than those of the northern madtom (\bar{x} = 98, CV = 5.8), but relative fecundity was greater for the northern madtom (\bar{x} = 20.2, CV = 5.5) than the stonecat (\bar{x} = 13.5, CV = 7.5). Both species were primarily generalist feeders but the most preferred prey of each species was less preferred by the other; additionally, small stonecats had a diet more similar to similarly-sized northern madtoms than they did with larger stonecats. Stonecats averaged nearly 40% greater SL than northern madtoms; consequently, they had greater absolute fecundity and shifted their diet to include larger prey items. This study provided; 1) important, previously unavailable information regarding northern madtom biology and 2) evidence of subtle differences among syntopic madtom species that may minimize resource overlap.

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INTRODUCTION

Madtom catfishes (genus *Noturus*) represent the most speciose (25 described and valid species) and least understood genus of ictalurid catfish (Burr and

Stoeckel, 1999). Half of madtom species are listed as endangered or threatened at the state or federal level (U. S. Fish and Wildlife Service, 1998); consequently, imperiled madtoms are poorly understood, in part, because endangered species regulations typically prohibit collection of specimens for study. Life history information is lacking for the northern madtom *Noturus stigmosus* Taylor, which is naturally rare throughout its disjunct range and documented at only four sites within one stream in Pennsylvania (French Creek, Gutowski and Raesly 1993). Although not federally endangered, the northern madtom is protected by imperiled designation in several states (Michigan: Miller, 1972; Kentucky, Tennessee, Mississippi, and West Virginia: Johnson, 1987; Pennsylvania, Pennsylvania Fish and Boat Commission, <http://sites.state.pa.us/PA-Exec/Fish-Boat/endangered/species-list.pdf>). The lack of northern madtom life history information is confirmed by its near absence from Burr and Stoeckel's (1999) thorough review of madtom natural history. Furthermore, the limited northern madtom fecundity data available are variable and have been derived from small samples (n = 3 nests, MacInnis, 1998; n = 6 females, Burr and Stoeckel, 1999). Understanding the diet and reproductive biology of Pennsylvania's small, isolated, and potentially unique northern madtom population is important for protecting it from extirpation.

Few studies have investigated potential interspecific competition among madtoms (Wildhaber, et al., 1999); however, recognizing life history similarities among syntopically occurring fishes are essential for the conservation of rare species such as the northern madtom. The northern madtom and stonecat *Noturus flavus* Rafinesque have overlapping distributions and share similar habitat requirements. Both species inhabit riffles of warmwater streams and rivers with substrates of sand, sandy mud, gravel, or small pebbles (Taylor, 1969; Trautman, 1981; Cooper, 1983) and have also been found to inhabit lake shallows (Gilbert, 1953; MacInnis, 1998). The stonecat (the sole member of the subgenus *Noturus*) is the most common madtom in west-

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ern Pennsylvania (Cooper, 1983) and the largest *Noturus* species (300 mm standard length (SL) in Lake Erie, Trautman, 1981; 180 mm SL in streams, Trautman, 1981; Walsh and Burr, 1985). The northern madtom is much smaller (130 mm maximum, Trautman, 1981) and belongs to the *Rabida* subgenus.

All madtoms spawn during spring and summer, although their start (Pfungsten and Edds, 1994) and duration depend on the species and locale. MacInnis (1998) observed northern madtoms in Lake St. Clair, Ontario guarding nests on 17 July and found a gravid female on 13 August 1996, suggesting a reproductive season of at least one month. The stonecat may have a longer reproductive season as suggested by maximum ovarian mass and peak spawning conditions observed by Walsh and Burr (1985) from 4 June–28 July. The stonecat and northern madtom are cavity nesters (Mayden and Burr, 1981) and usually spawn in or under natural substrata (e.g., stones, crayfish burrows, logs) or unnatural cavities (e.g., cans, bottles, boards; Taylor, 1969; Burr and Stoeckel, 1999).

The northern madtom and stonecat occur syntopically in French Creek and have similar habitats and spawning times, therefore, they may use the same resources. Objectives of this study were to: 1) document northern madtom age structure, fecundity, and diet in French Creek and 2) compare these life history attributes to those of a syntopic and more abundant madtom, the stonecat.

MATERIALS AND METHODS

We collected northern madtoms ($n = 29$) and stonecats ($n = 87$) from 1200–1400 hours on June 15, 1999 by seining and backpack electrofishing all accessible habitats in a 200 m reach (44–64 m wide) of French Creek near the village of Venango, PA (Latitude/Longitude: 40°46'17"/80°06'30").

French Creek is a fourth-order Allegheny River tributary that drains approximately 3,000 km² of southwestern New York and northwestern Pennsylvania. French Creek underwent a stream reversal event during glaciation that changed its course from the Great Lakes to the Ohio River drainage; consequently, it harbors an unusually high diversity of aquatic fauna, including several Pennsylvania-threatened or -endangered fish and mussel species. Although not quantified, most madtoms were collected from one large riffle downstream of bridge pilings. Fishes were fixed in 10 percent formalin then transferred to 50 percent isopropyl alcohol for permanent storage.

Nine D-frame kicknet samples (20 seconds, 250 μ m mesh) were taken from the 200 m reach within one hour of the fish collections to characterize the available madtom food base. Kick samples are effective in pools, riffles, and runs, and typically collect 95 percent of the

macroinvertebrate taxa present in a stream (Frost et al., 1970). Because madtoms were collected primarily from riffles, six kick samples were taken from riffles and batched with three from pool habitats. Macroinvertebrate collections were fixed in a solution of five percent formalin/20 percent isopropyl alcohol and transferred to 70 percent isopropyl alcohol for permanent storage.

There were 29 northern madtoms in the collection; therefore, 29 stonecats were randomly selected from the 87 collected to provide equal sample sizes for comparison. After removal of gonads and digestive tracts (esophagus rearward), individuals were measured to 0.01 mm SL, blotted dry, and weighed to 0.0001 g (Adjusted Body Weight, ABW = body weight without digestive tract and gonads). Northern madtoms were collected as state agency vouchers; consequently, we could not further damage specimens for otolith removal and were limited to removing pectoral spines from the right side to determine fish age. Pectoral spines were cleaned of all flesh and skin, and then mounted in casting resin. After drying, spine cross-sections were cut at the distal end of the basal groove using a rotary tool and diamond saw blade attachment (two blades, separated by a 1.0 mm-thick washer). Spine sections were polished to 0.5–0.8 mm using wetted 440-grit wet/dry sandpaper and examined under a compound microscope. Two readers determined fish age by counting annual rings on pectoral fin spine sections following methods of Ashley and Garling (1980).

Gonads were blotted dry and weighed to 0.0001 g. These weights were used to calculate the gonadosomatic index ($GSI = [\text{gonad weight (g)} / \text{ABW (g)}] \times 1000$). Ovaries were dissected individually and oocytes were counted and classified using ovum development criteria developed by Heins and Rabito (1986) and Heins and Baker (1988), and summarized by Heins and Baker (1993 a, b). The ovum development classification was intended for North American darters (Percidae) and minnows (Cyprinidae), but is broadly applicable to other fishes that exhibit group synchronous ovum development (Wallace and Selman, 1981). For this study, clutches were defined as large, relatively synchronous oocytes recruited from a pool of smaller, heterogeneous, vitellogenic oocytes (Wallace and Selman, 1981; Heins and Rabito, 1986). Females were divided into groups according to the ordered classification reported by Baker and Heins (1994). Premature (PM) females contained small, white to cream yellow, translucent to opaque, maturing oocytes whereas mature (MA) females contained clutches of enlarged, unovulated, opaque yellow to yellow-orange polygonal oocytes (mature oocytes) with vitelline membranes not separated from the yolk mass. Ripening (MR) females had unovulated, distinctly yellow orange or orange, translucent to

TABLE 1 Standard length (SL), adjusted body weight (ABW), and gonadosomatic index (GSI) values for northern madtoms and stonecats containing only premature (PM) or maturing oocytes (\geq MA). Sample sizes are given parenthetically next to ovum condition.

Species	SL (mm)		ABW (g)		GSI	
	\bar{x}	Range	\bar{x}	Range	\bar{x}	Range
Northern madtom						
PM (7)	65.6	59.2–71.5	3.81	2.51–4.92	5.8	0.8–9.4
\geq MA (19)	69.4	60.9–85.2	5.03	3.29–8.54	21.9	5.9–46.0
Stonecat						
PM (14)	94.2	71.2–117.2	12.21	4.73–23.48	0.7	0.4–1.8
\geq MA (9)	112.8	101.8–140.7	19.79	13.75–34.17	24.6	2.9–51.1

Mature female northern madtoms in French Creek were 60.9–85.2 mm. No age 1 northern madtoms were collected; therefore, we could not determine if females were mature at age 1, but most (69 percent) females in the age 2 size class (63–68 mm, $n = 13$) contained maturing oocytes. Gonadosomatic index (GSI) values of mature females were considerably higher than premature females in both species and maximum GSI of mature individuals between the species were similar (Table 1). Although not correlated with body size (SL or ABW) for either species, stonecat oocyte diameters were slightly larger and more variable ($\bar{x} = 1.98$ mm, $SD = 0.51$) than those of the northern madtom ($\bar{x} = 1.83$, $SD = 0.39$).

Stonecat clutches were much larger (185–326, $\bar{x} = 261$, $CV = 5.0$) than those of northern madtoms (76–140, $\bar{x} = 98$, $CV = 5.8$) but relative fecundity (oocytes/g body weight) was greater for the northern madtom ($\bar{x} = 20.2$, $CV = 5.5$) than the stonecat ($\bar{x} = 13.5$, $CV = 7.5$). Although both species exhibited significant relationships ($P < 0.05$) between number of oocytes and SL and ABW, Pearson correlation between SL and clutch size and ABW and clutch size were slightly greater for the stonecat ($r = 0.74$, 0.88) than northern madtom ($r = 0.66$, 0.71).

Diet comparison

Of the 15 macroinvertebrate taxa present in northern madtom stomach contents (Table 2), blackfly (Simuliidae), midge (Chironimidae), stonefly (Plecoptera, Perlinae spp.), and caddisfly (Trichoptera) larvae comprised the majority of the species' diet in numbers consumed (Figure 2). Based on Strauss' index values, northern madtoms preferred blackfly and stonefly larvae, avoided midge and riffle beetle larvae (Figure 3), and ate the remaining taxa in nearly the same proportion to their relative abundance in the kick sample ($L < |0.10|$).

Stonecats ate fewer macroinvertebrate taxa (13) than northern madtoms and fed primarily on stoneflies, midges, *Dineutus* spp. beetle larvae, and caddisflies. The largest size class of stonecats in French Creek (≥ 130 mm) fed mostly on crayfish, darters (*Etheostoma* spp.) and mayflies, whereas smaller individuals fed exclu-

sively on insect larvae. Stoneflies occurred in all stonecat stomachs smaller than 110 mm ($n = 19$), occurred less frequently (85.7 percent) in 111–130 mm individuals ($n = 7$), and were absent from stonecats larger than 130 mm ($n = 3$). Stonecats preferred stoneflies ($L = 0.45$) more than northern madtoms did, but ate the most preferred northern madtom prey item (Simuliidae) in proportion to its abundance in kick samples ($L = 0.00$). Aside from differing preference of these two taxa, stonecats and northern madtoms had similar preference for all other food items. Non-macroinvertebrate items found in stonecat stomachs included darters, stones, fish eggs, and vegetation, whereas the northern madtom ate fish eggs and vegetation.

Large stonecat (≥ 91 mm) diet overlapped northern madtom ($C_{xy} = 0.951$) diet, but small stonecats had a more similar diet to similarly-sized northern madtoms ($C_{xy} = 0.964$) than they did to larger stonecats ($C_{xy} = 0.916$). Prey item frequency of occurrence in northern madtom and small stonecat stomachs was similar, but northern madtoms ate more dipterans than small stonecats, whereas stonecats ate more stoneflies. Prey items that stonecats ate but northern madtoms did not included dragonfly larvae, oligochaetes, and darters, whereas northern madtoms ate several taxa (e.g., two mayfly genera, amphipods, and gastropods) that stonecats did not. Elmid beetle larvae were very common in the kick sample (17.4 percent), but were absent from stomach contents of both madtom species. Within the caddisfly family Hydropsychidae, *Ceratopsyche* contributed a low percentage of the food base (1.2 percent) but madtoms ate them more frequently than the closely related and abundant (13.1) *Cheumatopsyche*, resulting in preference for *Ceratopsyche*, and avoidance of *Cheumatopsyche*.

DISCUSSION

Madtom life history studies are often limited in scope because madtom species are frequently imperiled (Burr and Stoeckel, 1999) and protected from collection. Although endangered in Pennsylvania, northern madtoms in this study were collected as state agency vouchers. These collections afforded us the otherwise impossible

TABLE 2. Proportion and Strauss' index (L) values of items found in northern madtom and stonecat stomach contents and the available food base (pooled contents of nine, 20 s D-frame kicknet samples).

Order	Family or genus	Kick sample	Northern madtom		Stonecat	
		Percent	Percent	L	Percent	L
Diptera						
	Chironimidae	34.1	16.9	(-0.17)	18.3	(-0.16)
	Simuliidae	0.1	30.0	(0.30)	0.6	(0.00)
	Atherix	0.1	—	(0.00)	—	(0.00)
Trichoptera						
	Hydropsyche	0.2	0.3	(0.00)	1.2	(0.01)
	Ceratopsyche	1.2	8.9	(0.08)	7.4	(0.06)
	Cheumatopsyche	13.1	7.5	(-0.06)	5.9	(-0.07)
	Unidentified pupae	0.6	—	—	—	—
Plectoptera						
	Perlinella	1.4	11.4	(0.10)	46.4	(0.45)
Ephemeroptera						
	Anthopotamus	0.3	4.2	(0.04)	3.7	(0.03)
	Caenis	5.4	—	(-0.05)	—	(0.00)
	Baetis	0.2	—	(0.00)	—	(0.00)
	Pseudocloeon	0.1	—	(0.00)	—	(0.00)
	Unidentifiable larvae	0.1	—	(0.00)	—	(0.00)
	Ephoron	8.6	0.8	(-0.08)	—	(-0.09)
	Stenacron	0.1	—	(0.00)	—	(0.00)
	Stenonema	0.6	1.1	(0.01)	—	(-0.01)
	Siphonisca	0.1	—	(0.00)	—	(0.00)
	Ephemerellidae	0.1	—	(0.00)	—	(0.00)
Coleoptera						
	Elmid larvae	17.4	—	(-0.17)	—	(-0.17)
	Dineutus	0.7	6.4	(0.06)	9.0	(0.08)
	Stenelmis	1.1	0.6	(-0.01)	—	(0.00)
	Optioservus	0.4	—	(0.00)	—	(0.00)
	Psephenus	1.2	7.2	(0.06)	0.3	(-0.01)
Megaloptera						
	Corydalus	0.1	—	(0.0)	—	(0.0)
Odonata						
	Anisoptera	—	—	(0.00)	0.3	(0.00)
Oligochaeta						
	Oligochaeta	9.1	—	(-0.09)	1.5	(-0.08)
Hirudinea						
	Hirudinea	0.4	—	(0.00)	—	(0.00)
Gastropoda						
	Pleuroceridae	0.6	0.3	(0.00)	—	(-0.01)
	Ferrissia	0.3	—	(0.00)	—	(0.00)
Bivalva						
	Corbiculidae	0.1	—	(0.00)	—	(0.00)
	Sphaeriidae	1.8	—	(-0.02)	—	(-0.02)
Crustacea						
	Gammarus	0.1	3.6	(0.04)	—	(0.0)
	Cambaridae	0.1	0.6	(0.0)	2.8	(0.03)
Other						
	Fish eggs	0.3	0.3	(0.0)	1.2	(0.01)
	Etheostoma	—	—	(0.0)	1.0	(0.01)

opportunity to gather previously unavailable information regarding fecundity and diet of the northern madtom. Additionally, this study documented potentially important similarities and differences among syntopic madtom species. Prey and general habitat (i.e., riffles) preferences of the stonecat and northern madtom were similar; however, stonecats were on average, nearly 40 percent larger than northern madtoms which resulted in greater stonecat absolute fecundity and potentially

important diet differences between the two madtom species.

The unusually high ratio of females to males collected for the northern madtom (9:1) and stonecat (5:1) could have been a result of nesting males being difficult to capture as suggested by Clugston and Cooper (1960) and Mayden and Burr (1981). Although the relationship between stonecat weight and length (Log ABW = -4.78 + 3.00 SL; $r = 0.99$, $n = 24$) was very

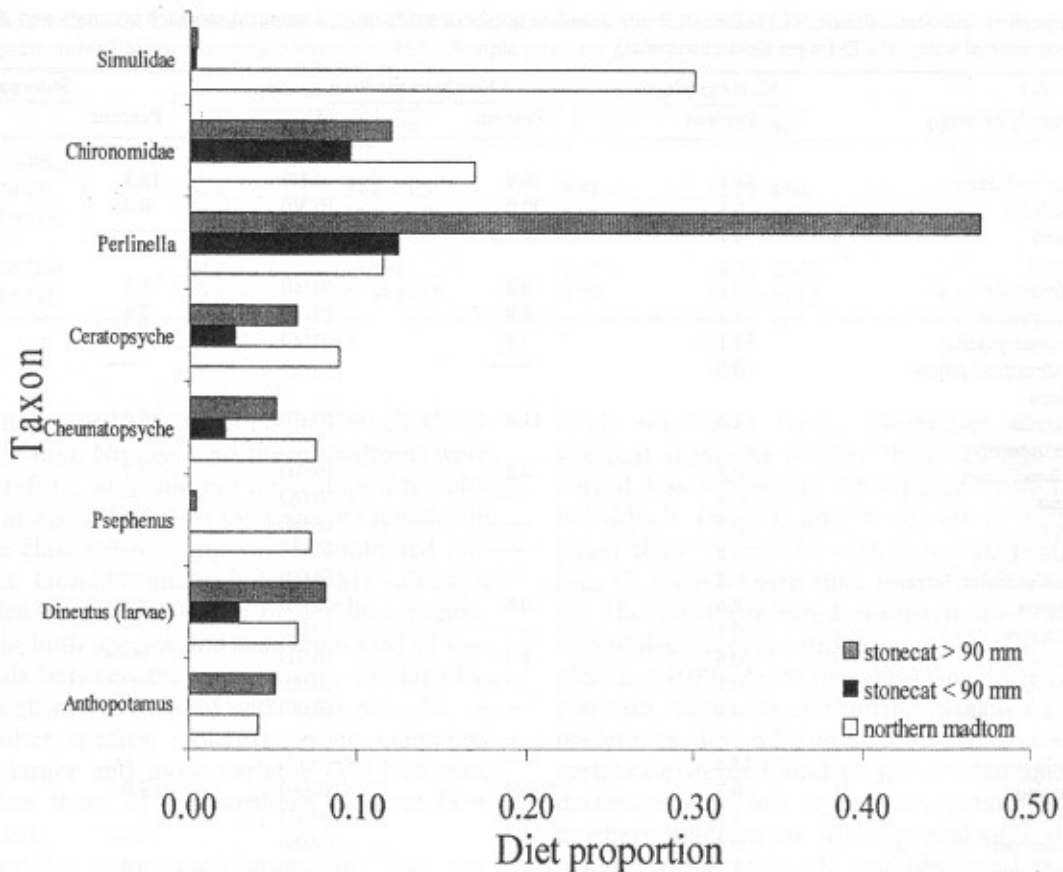


FIGURE 2. Proportion of common (> 5 percent) prey items found in northern madtom, similarly-sized stonecat (< 90 mm), and large stonecat (> 90 mm) stomach contents in terms of numbers consumed.

similar to that reported for stonecats in Illinois streams ($\text{Log}W = -4.91 + 3.04\text{SL}$, Walsh and Burr, 1985), mature female stonecats in French Creek were slightly smaller ($\bar{x} = 112.8$, $\text{SD} = 11.7$) than those in Illinois streams ($\bar{x} = 119.4$; Walsh and Burr, 1985). Age at reproductive maturity (≥ 3 y) estimates between Illinois (Walsh and Burr, 1985) and French Creek were similar; however, French Creek stonecat clutch sizes were much smaller than those of Lake Erie ($\bar{x} = 973$, 767–1205; Langlois, 1954) and Illinois streams ($\bar{x} = 377.8$, 189–570; Walsh and Burr, 1985).

The stonecat and northern madtom have similar spawning behavior and habitat (i.e., spawning in cavities or under stones during spring and summer; Taylor, 1969; Pflingsten and Edds, 1994; Burr and Stoeckel, 1999). Although largely unstudied (Burr and Stoeckel, 1999), factors suggested for partitioning of madtom spawning microhabitat include spawning time and body size (Clark, 1978). A greater proportion (73 percent) of northern madtom females contained maturing oocytes than age 3 or older (reproductively mature) stonecat females (56 percent), but because ictalurids do not consistently deposit their eggs immediately after maturation (Burr and Stoeckel, 1999), it cannot be said that

they spawn at different times in French Creek. Most mature northern madtom and stonecat specimens were collected from one large riffle, which suggested that they were preparing to spawn near one another. No age 3 stonecats, however, overlapped the size of mature northern madtoms (60.9–85.2 mm); thus, if the madtom species do spawn simultaneously as suggested by this study, the relatively small, mature northern madtom females are able to use smaller cavities than much larger stonecat females do. Northern madtom diet was undocumented prior to this study, but French Creek stonecats had similar diets to those from Illinois populations (Walsh and Burr, 1985). Both madtom species were primarily generalist in their feeding habits (consumed most prey in proportion to their relative abundance in the environment); however, based upon overall comparison of northern madtom and stonecat diet selectivity (all size classes), the most preferred prey of each species was ingested much less frequently by the other madtom species. Although blackflies were rare in the environment (0.1 percent of pooled kick samples), they accounted for 30 percent of northern madtom prey items; conversely, stonecats rarely ate blackflies, which resulted in very different preferences

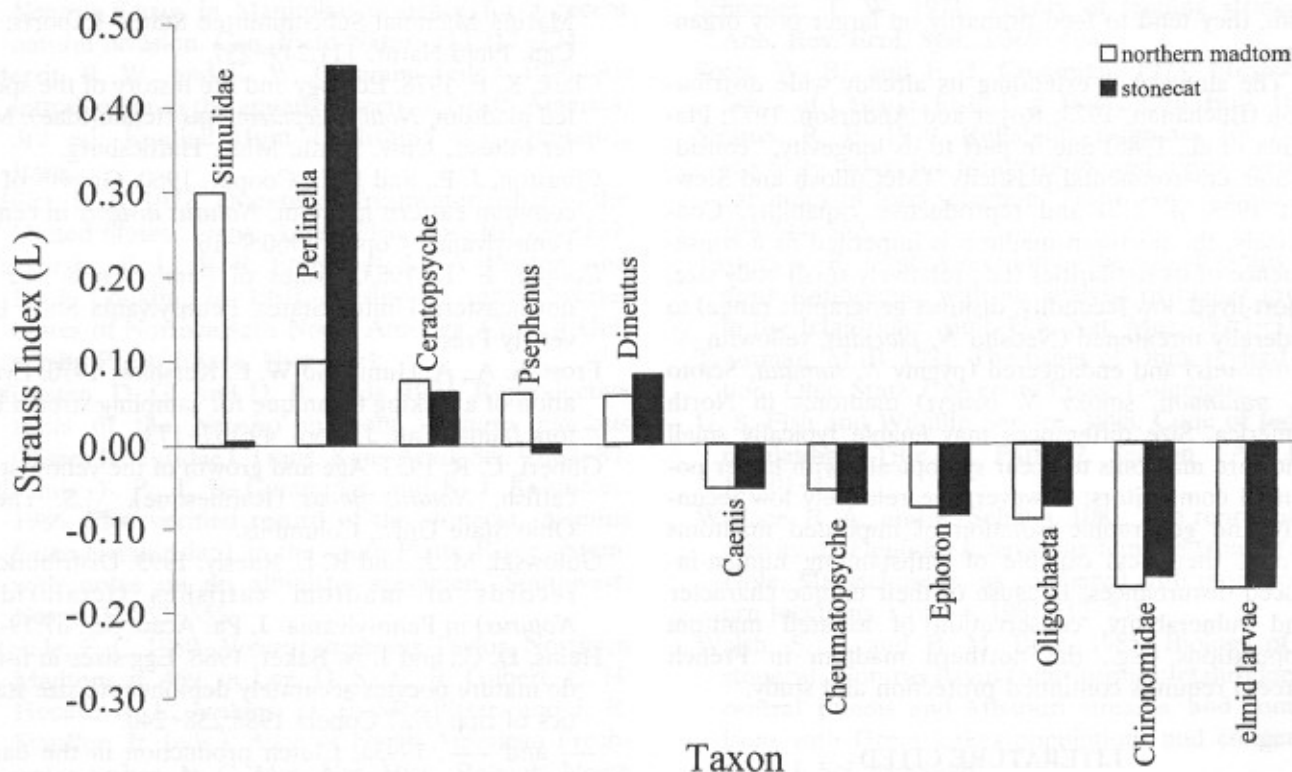


FIGURE 3. Strauss' index (L) values indicating preferred and avoided food items of northern madtoms and stonecats. Taxa that madtoms ate in equal proportion to their abundance in the environment ($L \leq 0.05$) were not included in this figure.

for blackflies by the two madtom species. Stoneflies were also rare in the kick samples (1.4 percent), but accounted for a larger portion of stonecat diet (46.4 percent) than that of northern madtoms (11.4 percent). Small stonecats had a more similar diet to northern madtoms than large stonecats did, suggesting similar resource use by young stonecats and northern madtoms. Diet overlap between madtom species declined as stonecats grew (> 90 mm) primarily because stoneflies were more prevalent in large stonecat stomach contents. Additionally, small stonecats had a more similar diet to northern madtoms ($C_{xy} = 0.964$) than they did to larger individuals of their own species ($C_{xy} = 0.916$), which further illustrated the preference for large prey items by larger stonecats.

Northern madtoms and stonecats similarly preferred several rare prey items and avoided some common prey, which suggested that primarily generalist feeders can be selective. Both madtom species apparently differentiated among three closely related (Hydropsychidae) caddisfly genera and consumed them at different levels of preference. *Hydropsyche* was rare in the environment and eaten infrequently. The more abundant *Ceratopsyche* was a preferred item for both northern madtoms and stonecats, whereas the most abundant caddisfly genus, *Cheumatopsyche* was avoided by both madtom species. Although these caddisflies are similar in

habit, color, morphology, and size (Merritt and Cummins, 1996), both madtoms preferred *Ceratopsyche* more than the other caddisfly genera. Riffle beetles are very common in riffle habitats (Merritt and Cummins, 1996) and accounted for the second largest proportion (17.4 percent) of the pooled kick samples; however, neither madtom species consumed riffle beetle larvae. Riffle beetles may have been unpalatable to madtoms or unavailable at the microhabitat scale. We collected the majority of madtom specimens from below a large riffle; consequently, several macroinvertebrate taxa (*Caenis*, *Ephoron*, *Oligochaeta*, and *Chironomidae*) that both madtom species ate in relatively low proportions may have been unavailable because these invertebrates are typically found in slow moving pools (Peckarsky et al., 1990, Merritt and Cummins, 1996).

The stonecat likely exists syntopically with rare and smaller madtoms (e.g., northern madtom) in many systems. Much is still unknown regarding interspecific interactions among madtoms; however, our results suggest stonecat competition with smaller madtoms for nesting sites is unlikely because 1) the larger size of mature stonecats than mature northern madtoms requires larger spawning cavities or, 2) small stonecats spawn later in the season than similarly-sized northern madtoms. Similarly, as stonecats outgrow the size range of smaller madtom species such as the northern mad-

tom, they tend to feed primarily on larger prey organisms.

The stonecat is extending its already wide distribution (Buchanan, 1973; Royer and Anderson, 1977; Platania et al., 1986) due in part to its longevity, "considerable environmental plasticity" (McCulloch and Stewart 1998, p. 217) and reproductive capability. Conversely, the northern madtom is imperiled as a consequence of its similarities (i.e., relatively small body size, short-lived, low fecundity, disjunct geographic range) to federally threatened (Neosho *N. placidus*, yellowfin *N. flavipinnis*) and endangered (pygmy *N. stanauli*, Scioto *N. trautmani*, smoky *N. baileyi*) madtoms in North America. Size differences may enable typically small and rare madtoms to occur syntopically with larger potential competitors; however, the relatively low fecundity and geographic isolation of imperiled madtoms render them less capable of withstanding human-induced disturbances. Because of their unique character and vulnerability, conservation of isolated madtom populations (e.g., the northern madtom in French Creek) requires continued protection and study.

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