Ontogenetic Dietary Shift of Water Snakes (Nerodia rhombifera) in a Fish Hatchery
Author(s): Michael V. Plummer and Jo M. Goy
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Gary C. Packard, Mary J. Packard, *Department of Zoology and Entomology, Colorado State University, Fort Collins, Colorado 80523 and* Thomas J. Boardman, *Department of Statistics, Colorado State University.* Accepted 18 July 1983.

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ONTOGENETIC DIETARY SHIFT OF WATER SNAKES (*NERODIA RHOMBIFERA*) IN A FISH HATCHERY.—The primary diet of the water snake *Nerodia rhombifera* consists of fish (Sisk and McCoy, 1963; Hess and Klimstra, 1975; Mushinsky et al., 1982). Mushinsky et al. (1983), working in a Louisiana swamp, found a gradual ontogenetic dietary shift from small fish species to larger fish species for snakes with a snout–vent length of 40–80 cm. Here we verify the findings of Mushinsky et al., for a population of *N. rhombifera* inhabiting a fish hatchery.

Snakes were collected at the Joe Hogan State Fish Hatchery in Lonoke County, Lonoke, Arkansas 2 Jun–5 Sep 1980. Snakes were collected by hand from dusk to midnight since this species is strongly nocturnal (Mushinsky and Hebrard, 1977). Captured snakes were immediately placed on ice to retard digestion of prey. In the laboratory sex, weight (to nearest g), and snout–vent length (SVL, to nearest mm) were recorded for each snake. Mandible length, measured from the anteriormost to the posteriormost points of the mandible as determined by external palpation, was recorded to the nearest mm. Prey in stomachs were obtained by dissection and identified. For prey items total length (to nearest mm) and when possible, greatest diameter (to nearest mm), weight (to nearest g) and volume (to nearest ml or ml × 10^{-1} by water displacement in narrow-necked graduated cylinders) were measured. Because of rapid digestion of soft body parts it was not always possible to take any measurements other than total length. Standard length of fish (SL) was computed as 80% of total length (C. Hubbs, pers. comm.).

Ponds were all ca 1.5 m deep except within ca 3 m of the shoreline where there was a gradual slope up to a low (ca 0.3 m) mud bank. Tunnels dug by muskrats (*Ondatra zibethicus*) in the mud banks provided retreats for snakes. Shoreline vegetation, mostly grasses, was kept short by mowing. Overall, the shoreline microhabitat was similar to the species' preferred "sparsely vegetated shorelines with gentle slopes" (Hebrard and Mushinsky, 1978). Ponds ranged in size from ca 100 × 100 m to ca 175 × 375 m and were separated from each other by distances of ca 5–10 m. "Catfish ponds" contained primarily channel catfish (*Ictalurus punctatus*) and a smaller number of small sunfish (*Lepomis* spp.). "Minnow ponds" contained primarily fathead minnows (*Pimephales promelas*) and a few small largemouth bass (*Micropterus salmoides*) and channel catfish. Snakes apparently could move among ponds unhindered. Abundance of fish in the ponds was conservatively estimated by Berry Beavers, hatchery manager, to be from 8 (catfish) to 30 (minnows) times greater in the ponds than would normally be found in natural lowland lakes and streams in the area (pers. comm.).

Following Mushinsky et al., (1982) we evaluated ontogenetic patterns in diet by pooling prey data within snakes size classes of 10 cm increments in SVL and calculated an index of relative importance for each prey category. The index is: IRI = (%N + %Vol) (%F) where %N = numerical percent of a prey category in the pooled stomachs, %Vol = percent volume of that prey category, and %F = percent stomachs that contained that prey category. Prey categories were catfish, minnows and centrarchids.

Of 274 *N. rhombifera* examined food was found in 134 (48.9%) stomachs. Of these, 66 (49.3%) were males and 68 (50.7%) were females. The difference between males and females with food was not significant ($\chi^2 = .03$, $P > .50$). Despite a great abundance of frogs at the ponds, only 1 (0.5%) out of 195 prey items was a frog (*Rana sphenocephala*). The remaining items were fish. Each of 102 snakes had one fish in its stomach, 16 had 2 fish, 11 had 3 fish, 3 had 4 fish, 1 had 6 fish and 1 had 9 fish. Of 32 snakes with more than one fish in their stomachs only one (3.1%) had more than one prey category (1 catfish, 1 sunfish). Thus, individual snakes tended to feed within one prey category.

Analysis of snake size classes by the IRI revealed a distinct shift in prey importance from minnows and centrarchids to catfish at a SVL

Table 1. Product-moment Correlation Coefficients between Various Predator Size and Prey Size Measures. All coefficients are significant at $P < .001$. Data are presented as r(n).

		Fish			
		Standard length	Maximum diameter	Weight	Volume
Snake	SVL	.74 (145)	.60 (112)	.66 (104)	.64 (100)
	Weight	.61 (144)	.46 (111)	.55 (103)	.54 (99)
	Mandible length	.68 (143)	.49 (111)	.58 (103)	.56 (99)

of 50–70 cm (Fig. 1). Significant correlations were found between all combinations of prey size and snake size measures (Table 1) with the greatest (r = .74) being between SL of prey (fish) and SVL of snake (Fig. 2). Analysis of covariance (Nie et al., 1975) revealed no sexual differences ($P > .05$) between the slopes or intercepts of the regressions of SL on SVL (Fig. 2) or $\log_{10}$ prey mass on $\log_{10}$ snake mass.

Our findings generally verify those of Mushinsky et al. (1982) of a gradual ontogenetic shift in diet from small fish species to larger species. However, there seem to be some differences. Despite the dietary shift, the large snakes (>80 cm) of Mushinsky et al. (1982) continued to feed on small prey as was found in field studies of other snakes (Beavers, 1976; Voris and Moffett, 1981). These results are predicted by foraging theory, i.e., large predators should eat larger prey as well as a greater range of prey sizes (Schoener, 1971). Our data indicate a more abrupt and complete shift in diet within a 20 cm change in SVL. Small prey were conspicuously absent in the diet of the large (>80 cm) Lonoke snakes (Figs. 1, 2). Our results possibly could be attributed to the extremely dense fish populations, which may have permitted more selective feeding (Schoener, 1971). The fact that ponds were essentially fish monocultures may have also contributed to the decreased variance in prey size.

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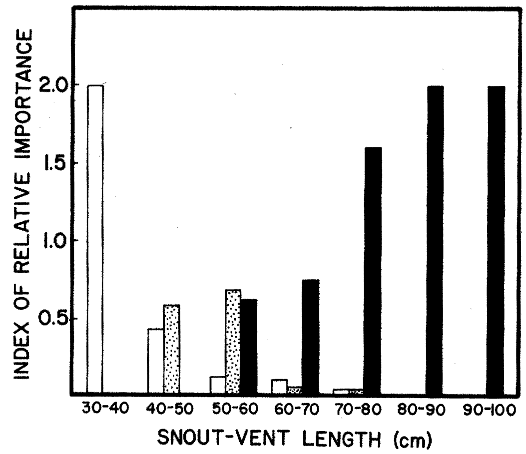

Fig. 1. Relative dietary importance of minnows (open bars), centrarchids (stippled bars) and catfish (solid bars) according to body size in 84 *N. rhombifera*. The index of relative importance is explained in text.

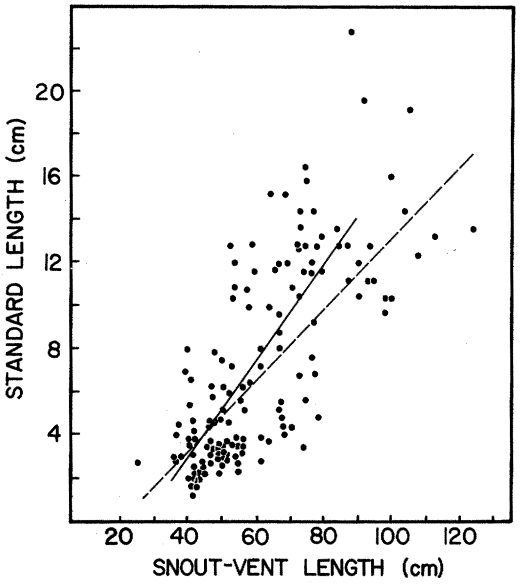

Fig. 2. The relationship of standard length of fish to snout–vent length of snake (r = .74; $P < .001$). There is no significant difference ($P > .05$) between the regression lines for males (solid) and females (dashed) (males, $Y = -5.9 + .23X$, r = .69; females, $Y = -3.6 + .17X$, r = .81).

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MICHAEL V. PLUMMER AND JO M. GOY, *Department of Biology, Harding University, Searcy, Arkansas 72143 (Present address (JMG): Department of Biology, University of Southwestern Louisiana, Lafayette, Louisiana 70504).* Accepted 11 July 1983.

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A BENTHIC FEEDING RECORD FROM NERITIC WATERS FOR THE LEATHERY TURTLE (*DERMOCHELYS CORIACEA*).—A record of deep water feeding by *Dermochelys coriacea* was among a number of reports of sightings of this turtle recently received from Western Australia. In mid Aug. 1982 a professional fisherman using a handline baited with octopus was fishing for reef fish in approx. 50 m depth in the Zeewyk Channel (28°50′S, 113°50′E) between the Pelsart Group and Easter Group of Houtman Abrolhos approximately 80 km offshore from Geraldton in Western Australia. The octopus bait was just above bottom when he hooked a *D. coriacea.* When the turtle was eventually brought to the surface alongside the fishing boat the fishhook could be seen inside the mouth of the turtle. The line was cut near the hook and the turtle dived out of sight with no apparent debilitation after having been hauled to the surface from such a depth. Because it was estimated to have a 1.2 m midline carapace length, it was probably immature.

The distribution of *D. coriacea* in Western Australian waters is poorly documented (Limpus and McLachlan, 1978; Anon, 1982). However the increasing number of reports of sightings at sea being received from fishermen and the absence of nesting records from the adjacent coast suggest that a regularly used *D. coriacea* feeding ground exists within the Western Australian continental shelf waters and extends south from Shark Bay (25°S).

D. coriacea has been regarded "as a true pelagic animal, highly adapted for life in the open ocean" (Hendrickson, 1980). Pritchard (1979) postulated that *D. coriacea* lives at great depths in the ocean but he gives no supporting evidence for the idea. However, observations from eastern United States suggest that the species may aggregate principally over the continental shelf rather than in the more oceanic waters (Hoffman and Fritts, 1982). Records of the depth range inhabited by *D. coriacea* are limited. Limpus and McLachlan (1978) reported a sighting of an adult at about 43 m depth swimming up from a 55 m depth bottom off southern New South Wales. Hughes (1978) when reporting an inspection by a female *D. coriacea* of divers working on the bottom in 46 m depth off the South African coast noted that there were no records of how deep the species may dive to feed. den Hartog (1980) found the remains of deep water siphonophores in a stomach content sample from the Mediterranean. The above Western Australian record indicates that *D. coriacea* will feed to at least 50 m depth. This report supports the view of den Hartog that *D. coriacea* need not necessarily restrict its feeding to the surface but may feed at considerable depth.

The unique temperature regulating features which enable this giant turtle to forage in cool temperate waters (Mrosovsky, 1980) could well