

SUPPLEMENTARY MATERIAL:

APPENDIX S1: First-hand accounts of swimming behaviour in the Zapodinae.

APPENDIX S2: First-hand accounts of drowning in the Zapodinae.

APPENDIX S1: First-hand Accounts of Swimming Behaviour in the Zapodinae

Stone and Cram 1902: 104

“The last one [*Z. hudsonius*] I saw was on the bank of a stream in the woods where the wild grape-vines and smilax trailed along the edge of the water.

“At first it attempted to escape by crouching among the grass and dead leaves, but when I stooped down to examine it it began leaping in the characteristic aimless and erratic manner of the species. Finally when I made an attempt to capture it with a landing net it leaped well out from the bank and descended in the water where the current was pretty strong; the mouse, however, proved equal to the occasion and swam swiftly enough against the stream for several yards to a floating branch along which it ran to the other end, where it again entered the water to swim ashore and hide among the drift-wood and rubbish under the overhanging bank.”

Grinnell *et al.* 1930: 531

“An individual [*Z. p. pacificus*] that was not captured was seen at 7 p.m., July 15, in a small stream at Lake Helen, 8200 feet, where it was hopping in water twenty-five millimeters deep; thence it made off under alders.”

Hamilton 1935: 190

“Both species [*Napaeozapus i. insignis*, *Zapus hudsonius*] swim well, and can remain in the water, swimming strongly, for four or five minutes, perhaps longer. They swim not unlike other true mice, except that the head is held higher and the tail arched near its middle. The fore feet are not employed, but the hind limbs are of primary importance to the swimming mouse.”

Bailey 1936: 233

“No peculiarities of habits have been observed for this form [*Z. p. pacificus*] except the habit of swimming, which is probably common to all. On the side of Preston Peak, Calif. N. Hollister, in 1909, gave the following interesting note:

“While I was walking around the grassy border of a small pond one jumped out at my feet and struck in the water like a frog, which at first it was thought to be, until it was seen swimming across the pond on the surface of the water, when it was shot for a specimen. The animal may not have intentionally jumped into the water but he certainly handled himself as if perfectly at home and swam with little effort and great speed over the still surface of the pond.”

Sheldon 1938: 327

“On May 27, 1934, I caught a *Zapus* [*Zapus h. hudsonius*] in a hay meadow near a small hole in the grassy bank of a brook, overgrown by small willows. I released him without etherizing him. He hesitated a second, then half ran and half leaped, going past the hole near which he had been caught, upstream toward the denser undergrowth, skipping across two pools of running water an inch or more in depth. When he disappeared I investigated the place where he escaped from sight and found that there the brook ran underground for a few feet. Whether the mouse went into this place or jumped over it and made away on top I was not able to ascertain definitely, but he appeared to have gone underneath....

“Philip Allan of the U. S. Soil Service reports that in northern Minnesota he saw many *Zapus h. hudsonius* rapidly swimming 3 or 4 inches under water in crossing a deep ditch 3 or 4 feet wide. They swam upstream using only the hind legs. This occurred in July, about 2:00 P.M.”

Davis 1939: 334

“Jumping mice [*Z. princeps*] not only prefer moist places, but as I learned at Mill Creek enter the water at times, and there two were taken in traps set on artificial islands of stones in the middle of the creek where the water was about six inches deep. Apparently the only way the mice could have reached the traps was by swimming.”

Preble 1944: 200–201

“In August 1941, as Alfred E. Preble and myself were standing near the shore of Archer’s Pond, three miles southeast of Center Ossipee, New Hampshire, we were suddenly surprised to see a jumping mouse swimming rather rapidly, *under water*; toward another portion of the shore 30 or 40 feet away. As it passed by, silvery reflections caused by bubbles of air adhering to the body pelage were noted. Both fore and hind feet were vigorously employed in the swimming movements, but the long tail was trailing limply behind and contributed in no way to the animal’s movements. The incident happened so rapidly that it was not possible to estimate accurately how far beneath the surface the animal remained, although it probably was less than a foot. Neither was it possible to determine the genus involved. I had previously made mammal collections in

this same locality, securing specimens of only *Zapus hudsonius hudsonius*. The vegetation at this locality consisted chiefly of a thick growth of alders interspersed with grasses and sedges—a habitat more typical of *Zapus* than the woodland-loving *Napaeozapus*.

“The cause of this animal’s presence in the water may be attributed directly to the activities of a dog that proceeded to investigate the shore of the lake immediately on our arrival. The mouse doubtless was cut off from its usual method of retreat and forced to enter the water. The fact of submerged swimming and the necessity of holding breath lends some credence to the belief that an aquatic environment is not an unusual one after all for this rodent.”

Snyder 1947: 198–199

“The writer was standing quietly by the creek [near Pottageville, Ontario] when a small animal about fifty feet distant jumped from the grassy bank into a pool downstream. It struck the water lightly and instantly began swimming rapidly upstream toward me. Its forward propulsion was not a smooth glide. Rather it was a rapid series of short advances, the animal swimming high in the water. The sound produced was a rhythmic patter about five strokes per second, approximately the speed one can count with any articulate distinctness. Attaining a short ripples, the creature emerged on a stick lodged near mid-stream. Here it was silhouetted against the glare of the water which revealed the mouse’s general conformation, the extremely long tail and the prominent ears. There was no doubt that it was a jumping mouse [probably *Z. hudsonius*] but then and subsequently its colour could not be determined. For several seconds the mouse remained quietly washing its face with its fore-feet, but suddenly it began capering about excitedly in the rapids, finally jumping into the main stream and swimming rapidly toward me, again producing the patterning sound noticed previously.

“When within twenty feet of me it emerged on a small stone protruding from the swift current. Here the mouse seemed to become aware of me. It remained motionless for almost ten seconds as did the observer. The mouse resumed its face-washing and again this was followed by a lively sporting in the water — rolling on its side, circling, slithering — suggesting the manoeuvres of an otter. The performance left no doubt that the mouse was at home in the cold (54°F), rapid (two to three feet per second) stream. Following this display the mouse re-emerged on the stone, paused briefly, then sprang to the bank and was off.

“Obviously neither fright nor accident entered into the circumstances of this behavior. Apparently I had been witness to the bath and setting-up exercise of a jumping mouse prior to its embarking on crepuscular business.”

Priddy 1949: 74

“On the evening of May 17, 1947, at Pine Island on the Ipswich River, Topsfield, Massachusetts, a canoe party of the Essex County Ornithological Club, which I was privileged to accompany as the guest of Dr. Stuart K. Harris, was encamped in white pine woods. In undergrowth at the edge of the very quiet, sluggish river I found and attempted to corner a jumping mouse. Cut off from land retreat by members of the party, the mouse took to the water with little hesitation and swam downstream parallel to the bank for eight or ten feet, swimming a few inches below the surface with ease, skill, and fair speed, using the hind feet for propulsion. Taking to land once more, it attempted to escape through alder thickets, but was again surrounded by members of the party. The jumping mouse immediately returned to the river and escaped by swimming underwater still further downstream, repeating this maneuver until its pursuers lost sight of it in the thick shrubby growth. It should be noted that it made no attempt to swim across the river, which is about fifty feet wide at this point, in order to escape. It was impossible to determine with certainty whether the mouse was *Zapus hudsonius* or *Napaeozapus insignis*; I am inclined, however, to the latter.”

Jones 1950: 453

“While working along the Dismal River at the Thomas-Blaine County line, Nebraska, on 1 July 1948, the writer was walking along the river bank in the early afternoon. The Dismal is a wide, shallow, sandy-bottomed stream and the banks support a thick growth of grasses which are waist deep in places. As I walked through the grass, an animal which I thought to be a frog leaped into a side pool which was about six feet long, three feet wide, and two feet deep. Upon investigation I found, to my surprise, a jumping mouse [*Zapus h. pallidus*] swimming under water in the pool. The front feet of the mouse were laid back against its body and its hind feet propelled it through the water at a surprising rate of speed. The tail streamed behind and was apparently not in use. Small bubbles of air were emitted by the mouse at irregular intervals. After about 45 seconds under water, the animal headed for shore and was easily captured as it was coming up at the shore line. The mouse spent about a minute under water and at no time came up for air. It was swimming at an estimated depth of one foot most of the time. Although the mouse was undoubtedly frightened into the water by my movements the incident leads one to believe that this rodent may frequent aquatic habitats more than present knowledge indicates.”

Quimby 1951: 72

“On several occasions jumping mice [*Z. hudsonius*] were observed to take to the water when released from traps or when frightened from retreats. These observations and other evidence, discussed under habitat pref-

erence, indicate that they are somewhat aquatic.

"To more accurately observe the methods of swimming, 5 were transported by boat out into a lake and released, one at a time. By rowing the boat along side it was possible to closely observe them. In all instances the animals proved to be excellent swimmers both on and underneath the surface. The methods of progression were similar to land movements; i.e., the limbs were employed differently at various times depending upon the speed. When first placed in water they moved rapidly by lunges produced by sweeping strokes of the hind limbs employed simultaneously. This movement was accomplished similarly to the long jumps made on land.... Following the first excited lunges, they settled down to a steadier and slower gait using all 4 limbs one at a time. The anterior part of the body was held high in the water.... The long tail trailed limply behind contributing in no way to the animal's movements. When approached too closely, they attempted to escape by diving. The maximum distance noted was about 4 feet. The depth was not determined. While underneath the surface they had a silvery appearance due to air bubbles clinging to the pelage (previously reported by Preble (1944)). One was able to swim vigorously for approximately 3 minutes after which it tired greatly and was in danger of drowning."

Sutton 1956: 299

"In September 1953, while camping by a small river in northern Manitoba, my attention was attracted by continued splashing sounds at the border of the stream. Investigation with a flashlight showed a jumping mouse, *Zapus hudsonius* sp., swimming from tussock to tussock in a quiet backwater. The mouse showed no alarm at the light and continued its journeys from one small island to another for half an hour, with frequent returns to shore. In this instance, the mouse swam on the surface of the water at all times. Similar activities of presumably the same mouse were observed on the following evening, with the mouse showing no alarm and returning to shore at the writer's feet.

"On May 7, 1955, the writer flushed a jumping mouse, *Zapus h. campestris*, from the bank of a creek near Winnipeg, Manitoba. The mouse leaped into the water and immediately submerged, swimming rapidly approximately 18 inches below the surface. The animal swam submerged for about thirty seconds at a time, alternately surfacing (for an instant) and diving for about three minutes, after which it came towards shore and crouched in the shallows under some reeds where it was captured. As far as could be seen, swimming, which was extremely rapid, was accomplished by using the hind feet only, working them together in frog fashion. At this writing the mouse, a male, is thriving in captivity."

Layne 1958: 249

"One [*Z. hudsonius*], a subadult male, was found on October 8 swimming weakly within a sunken tile in a spring approximately 1 1/2 miles SE of Aldridge."

Whitaker 1963: 236

"Mice [*Z. hudsonius*] were forced to swim on two occasions during the present study. One swam on the surface, and one submerged. The mouse on the surface used both fore and hind limbs, while the one underwater appeared to use only the hind legs."

Dagg and Windsor 1972: 118

"No verbal description was provided. Data reported for a swimming *Zapus hudsonius* that was filmed were: Gait = Hs. (alt.), meaning hind feet used alternately; Speed of stroke, seconds = 0.07–0.09; Position during swimming = 2, 3, meaning animal swam horizontal to the water surface but with its back submerged and head tilted up (2) and animal swam at an angle of 25° to the water surface."

Wrigley 1972: 98–99

"In the present study a *Napaeozapus* was forced to swim in a large aquarium in order to examine the movements of the limbs and body. Its performance was compared to several other species of woodland and grassland rodents. When placed in the water the woodland jumping mouse swam with a rocking motion of the body, utilizing all four limbs. The forefeet were employed simultaneously, while the hind feet were being drawn to the body. The hind limbs were then extended together, propelling the body forward. The movements gave the impression that the animal was attempting to hop on the surface. Apparently the forelimbs are used only when swimming on the surface, as they serve to maintain the head above water. Due to the strenuous action of the limbs and body, the mouse tired quickly and was removed after three minutes.

"In sharp contrast to *Napaeozapus*, *Peromyscus leucopus* and *P. maniculatus* were able to swim for more than 30 minutes. Air trapped in the fur of *Peromyscus* appeared to assist in keeping the head and back above water, and there were short periods when the animals floated, thereby resting the limbs. The hind feet, working alternately and rapidly, provided the propulsion. There was no bending of the back, and the forefeet were only occasionally used, especially during turning movements.

"*Clethrionomys gapperi*, *Microtus pennsylvanicus*, and *M. ochrogaster* also used the hind feet in "dog paddle" fashion, utilizing the forelimbs only as a last resort to maintain the head above water. The voles were able to remain afloat for 5 to 15 minutes.

"It was not possible to measure the rate of swimming in the aquarium, but the jumping mouse seemed

to attain the greatest speed. It would be preferable to test a number of individuals of each species in a lake, where one could obtain a better estimate of speed, endurance, as well as orientation. However, the present experiments indicated that the relatively poor performance of *Napaeozapus* when compared to *Peromyscus* and *Microtus* resulted from its more strenuous movements. The body and both front and hind limbs were employed in a sequence resembling the quadrupedal hop on land. The cricetids used only the hind limbs in short alternating strokes with little effort (as long as buoyancy was maintained by the fur). The limited data suggest that *Napaeozapus* would have no difficulty in traversing small streams, but its apparent lack of endurance might preclude extended swims across lakes and rivers.”

Clippinger 2002: 31

“Meadow jumping mice [*Z. h. preblei*] in Colorado seem to require a source of open water at or near their habitat for at least part of their active season; they have been observed on many occasions to move from place to place by swimming.”

Meaney et al. 2003: 620

“Irrigation ditches mimic small creeks with slow-moving water and are easy for the mice [*Z. h. preblei*] to swim across, as has frequently been observed in the field.”

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APPENDIX S2: First-hand Accounts of Drowning in the Zapodinae

Kennicott 1857: 90 (not seen; cited in Seton 1909: 512)

“Though I collected several specimens of this species [*Myodes gapperi*], together with a great number of *Zapus hudsonius* drowned in a hole a half mile from the woods, I saw none on the prairie at any other time; whence it is inferred that they are generally confined to the woods.”

Stone and Cram 1902: 104

“Apparently they [*Zapus hudsonius*] never look before they leap, so that that which should be their safety often proves their ruin, as they are about as likely to spring directly into the clutches of a cat or other enemy as in an opposite direction; in this manner they are frequently drowned in milk-pans and tubs of water which a little ordinary caution would have avoided.”

Seton 1909: 590

“I did, however, find two old ones [*Zapus hudsonius*] drowned together in a little water-hole on my farm near Fort Pelly on the 17th of June, 1884.”

Seton 1909: 597

“If webbed feet made a swimmer, the *Zapus* should be as much at home in the water as the Muskrat, but apparently it is far from it. I never heard of or saw one swimming, and, two or three times in Manitoba I found them [*Zapus hudsonius*] drowned in spring-holes, whence they might have escaped by swimming twenty-four miserable little inches.”

Sheldon 1934: 296–297

“Two of those [*Napaeozapus insignis*] belonging to the first litter were found drowned in the drinking water can at the age of one day.”

Christian 1936: 416

“On May 5 I startled a jumping mouse [*Zapus hudsonius*] from a tuft of grass on the edge of the pond. It ran a few yards, tumbled into a post hole partially filled with water, and drowned. From May 7 until June 5, I made a daily circuit of these holes, and from them I secured a few frogs and turtles, several snakes, and about 75 mammals, including 32 *Microtus*, 26 *Zapus*, 8 *Blarina*, 3 *Peromyscus*, 2 *Sylvilagus*, and 1 *Marmota*.”

Warfel 1937: 83

“In the late summer of 1935 I was present when the superintendent of the Sunderland fish hatchery, located at the eastern edge of the Connecticut River Valley, skimmed from the rearing pools several jumping mice [*Zapus hudsonius*] that had been drowned during the night. He said that although he had never known this to happen in previous years, the occurrence had been rather common that summer. A few more were caught in this way in 1936 and the superintendent of the Mt.

Toby Forest reported finding them frequently in his cord wood lots.”

Fitch 1954: 42

“Several of these [*Zapus hudsonius*] were drowned in pitfall traps that filled with water during heavy rains, but most of them were caught in wire funnel-traps set for reptiles, along hilltop rock-ledges at the edge of woodland.”

Dexter 1954: 236

“The writer had one specimen [*Zapus hudsonius*] brought to him that had drowned in a goldfish pool.”

Kjoss and Litvaitis 2001: 156

“The only vertebrate mortalities associated with cover sheets were 6 neonatal garter snakes and 1 meadow jumping mouse (*Zapus hudsonius*) that had evidently drowned in small pools of water that accumulated on the [black plastic cover] sheets during rainstorms.”

Frey 2015: 16

“A large series of specimens [*Zapus hudsonius luteus*] collected at BANWR had been salvaged, apparently drowned, from wading pools that were being used for amphibian experiments in 1977 (D. J. Hafner, pers. comm., 2007).”

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