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Cognitive Research in Asian Small-Clawed Otters

Bonnie M. Perdue
Georgia Institute of Technology, U.S.A.
Zoo Atlanta, U.S.A.
Georgia State University, U.S.A.

Rebecca J. Snyder
Zoo Atlanta, U.S.A.

Terry L. Maple
Georgia Institute of Technology, U.S.A.
Florida Atlantic University, U.S.A.

Little research has been conducted on cognitive abilities in Asian small-clawed otters (*Aonyx cinereus*) despite behavioral and social characteristics which suggest that this species would perform well on cognitive tasks and are likely to provide relevant data for comparison to other taxa. Asian small-clawed otters are relatively long-lived and have complex social systems that involve cooperative breeding, paternal care and reproductive suppression. These life-history characteristics have been associated with highly intelligent behavior, yet little is known about the cognitive abilities of this species. The current study explored spatial memory in Asian small-clawed otters using a modification of the radial arm maze. Performance on all measures improved significantly across sessions. These results provide evidence that Asian small-clawed otters have spatial memory for food locations and illustrate the potential for cognitive testing with this species.

Asian small-clawed otters live in a wide range of habitats throughout southeast Asia (Sivasothi & Burhanuddin, 1994) and feed primarily on crustaceans, mollusks, fish and frogs. Asian small-clawed otters are the smallest otter species and are distinct from other otters in several ways. Unlike most other otter species, males and females form a monogamous bond and mate for life. Older siblings help raise younger ones and family groups consist of approximately 10-12 individuals. Males and females jointly rear offspring and share a home range (Lariviere, 2003; Sivasothi & Burhanuddin, 1994). Individuals have very short claws and nimble fingers, making them manually dexterous and capable of searching, hunting and capturing prey with their forepaws. Asian small-clawed otters are also relatively long-lived for their size (average weight range = 1to5 kg), with an average lifespan of 10 to 15 years (up to 20 years in captivity). Many of these behavioral and sociological characteristics of Asian small-clawed otters, including cooperative breeding, complex social groups, long lifespans, and a dietary pattern that includes extractive foraging, are typically associated with enhanced cognitive abilities (Burkart & van Schaik, 2010; Kaplan, Hill, Lancaster,& Hurtado, 2000).

Surprisingly very little empirical research has focused on otters (Sivasothi & Burhanuddin, 1994). In particular, there has been almost no research on otter cognitive abilities, although anecdotal reports suggest that this is a highly intelligent taxa. For example, Asian small-

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(bonnie.m.perdue@gmail.com)

clawed otters have been reported to gather clams and lay them in the sun until the heat causes them to open even though the otters are capable of cracking them open immediately (Sivasothi & Burhanuddin, 1994). In southeast Asia, fishermen train this species of otter to swim and drive fish into nets to assist with fishing efforts. Other species of otter have been reported to use rocks as tools to break open shells (Hall & Schaller, 1964). Given these anecdotal reports about otter intelligence and the behavioral and social characteristics specific to Asian small-clawed otters, we conducted an experiment to test this species' cognitive ability in the area of spatial memory, which is critical for survival in many species. There is a robust literature on spatial memory in diverse taxa, and several techniques have been developed that allow for systematic testing of this cognitive ability with very little explicit training. Thus, we focused our investigation of Asian small-clawed otter cognition on spatial memory.

Spatial memory ability allows an individual to find and later remember the location of resources such as food, mates, and predators (Perdue, Snyder, Pratte, Marr, & Maple, 2009). At least two aspects of spatial memory can be empirically measured: spatial working memory and spatial reference memory (Olten & Papas, 1979), and both of these can be assessed with an adapted version of the radial arm maze (Olten & Samuelson, 1976). The radial arm maze, and adaptations of it, have been used with a variety of species (e.g., Bicca-Marques, 2005; Lipp et al., 2001; MacDonald, 1994; MacDonald & Agnes, 1999; MacDonald, Pang, & Gibeault, 1994; MacDonald & Wilkie, 1990), including some species from the order Carnivora (Perdue et al., 2009; Perdue, Snyder, Zhihe, Marr, & Maple, 2011; Tarou, Snyder, & Maple, 2004). A common technique is to install feeders equidistantly around an open space and for some locations to contain food and others to remain empty. Subjects are then allowed to explore the locations and the ability to locate food and avoid depleted or never baited locations indicates spatial memory ability. Specifically, avoiding re-visits to locations that have been visited within a session is considered a measure of working, or short-term, memory. Learning to avoid feeders that are never baited is considered a measure of reference, or long-term, memory (Olten & Papas, 1979).

Asian small-clawed otters are manually dexterous and exploratory and will use their paws to locate and obtain food, even when hidden under rocks. Thus we designed a task that required subjects to reach into a feeder to obtain food because of the ecological relevance and appropriateness of this behavior. We used a modified version of the radial arm maze in which eight feeders were installed in an equidistant array in the subjects' enclosure. We predicted that Asian small-clawed otters would investigate the feeders and successfully retrieve food in the first session. We also predicted that all measures of performance would improve across test sessions.

Method

Subjects

We tested 9 Asian small-clawed otters (4 male, 5 female) housed at Zoo Atlanta from May-June 2010. One female did not consistently participate in the task, and her data were dropped from the analysis. The present data were part of a larger dataset investigating sex differences in spatial memory (Perdue et al., 2011).

Apparatus

The apparatus consisted of eight feeders. A feeder consisted of a polyvinyl chloride (PVC) elbow attached to a metal corner bracket (see Figure 1). Each feeder measured 8.9 cm tall, 8.9 cm long, and 2.7 cm wide. The metal bracket was screwed into the concrete flooring to make the feeders immovable. The eight feeders were arranged in an equidistant circular pattern approximately 1 m apart from one another. Feeders were designed so that depleted feeders were not visually apparent or distinct from other feeders. All feeders were rubbed with the scent of the food item (fish) before each session so that the baited feeders could not be identified by olfactory cues. Feeders were cleaned between sessions using soap and water and were allowed to air dry.

Figure 1. Apparatus used for testing. Eight of these feeders were installed equidistantly in a circular configuration on the enclosure floor.

Procedure

Subjects were tested in the flat, upper area of one of their indoor enclosures (3.20 m long x 3.35 m wide, see Figure 2). All subjects were tested (individually) in the same test area. Prior to the first session, four feeders were randomly selected as the feeders to be baited with food. For each session, these same four feeders were baited with the fish (1 capelin or 2 smelt cut into 4 even pieces) and the other four were left empty but rubbed with fish before the trial so olfactory cues alone could not guide performance. Thus, during the baiting procedure, the experimenter visited each location, spent the same amount of time, and went through the same motions at each feeder, regardless of whether it was actually baited or not. The test area was in an enclosure that was separated by a human walkway from where the otters were housed during baiting (E1, see Figure 2), but it is possible that they could observe the experiment so these steps were taken to control for any potential cuing. Baiting was always conducted by the same experimenter.

After baiting, an animal keeper shifted one otter through a PVC pipe tunnel into another enclosure (E2, see Figure 2) that was adjacent to the test area. The experimenter started a stopwatch and the keeper opened the door separating E2 from the test area. Subjects were allowed to freely explore the feeders for a 2-min period. Any contact with a feeder was recorded as a visit, and the pattern of visitation was recorded for each session. Specifically, the location visited, the time at which it was visited, and the order of visits was recorded. One experimenter scored all trials by hand. After the 2-min period, the keeper opened the shift door between the test area and E2 and shifted the animal out of the test area. Then the otter was shifted to an outdoor exhibit. The experimenter reentered the test area and re-baited the feeders (and rubbed the fish on the unbaited feeders). Then the next otter was shifted from E1 into E2, and then allowed into the test area for the 2-min period. This process was repeated until all otters had been tested.

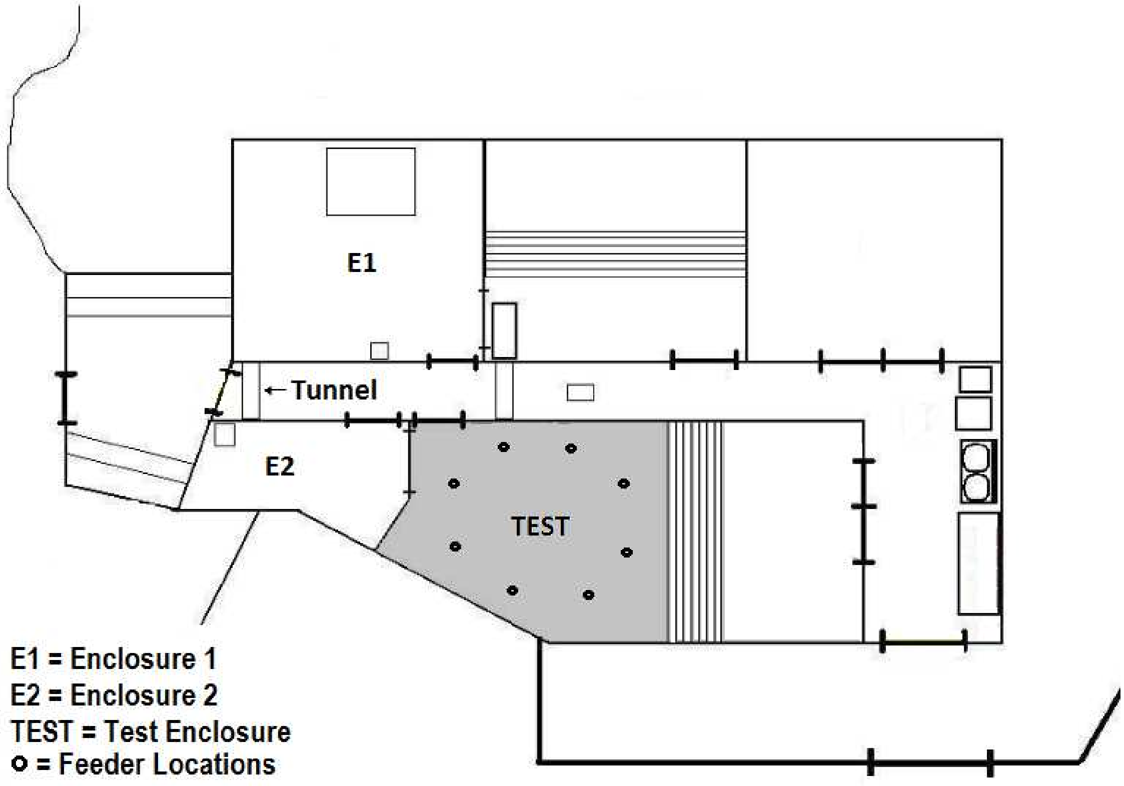


Figure 2. Schematic of the otter building. All otters were located in E1 prior to a trial, then shifted individually to through the tunnel to E2 before a trial began. Then a single otter was allowed into the Test Area to complete the task and then shifted outdoors at the end of the trial.

As discussed in Perdue et al. (2011), a “probe trial” was conducted in which all feeders were empty. In the probe trial, all feeders were rubbed with the scent of the food item, but *none* of the feeders contained food. If performance remained unchanged on the probe trial compared to the previous trials, this confirmed that subjects were remembering spatial locations, rather than responding to some other cue, such as the smell of the food, in the previous sessions. Only four visits were needed to recover all food items, so the proportion of the first four responses to correct locations was determined. If this performance fell below chance when food was absent, subjects may have been relying on cues from the food itself. However, if performance remained above chance on the “probe trial,” then it could be concluded that subjects were remembering spatial locations.

Subjects were tested individually in the same enclosure for each session. Morning sessions occurred approximately between 10:00 – 12:00 and afternoon sessions occurred between 14:00 – 16:00. Two sessions of testing per day were conducted in May 2010 for a total of 21 test sessions. On the session immediately following the last regular trial, the probe trial was completed.

Table 1
Performance across 3-session blocks

Measure	Description	Friedman's test
Total Number of Visits	*Number of visits within a session*	$X^2 = 39.29$ $p = .0000$
# Correct in First Four Visits	*Number of visits to baited locations in first four visits.*	$X^2 = 23.51$ $p = 0.001$
Reference Memory Error	*Visit to a location that is never baited with food.*	$X^2 = 18.95$ $p = 0.004$
Working Memory Error	*Re-visit to a location that has already been visited in that session.*	$X^2 = 38.02$ $p = 0.000$

Data Analysis

A number of measures were recorded based on the pattern of visitation data (see Table 1 for a summary). The "total number of visits" refers to *all* visits made within a session. For example, if a subject retrieved a piece of food from a feeder, but then returned to the feeder three more times within the session, all of these visits would be counted in the total number of visits score. A total of four visits would be sufficient to retrieve all available food items. Given that only four visits were necessary, we also recorded the "number correct in the first four visits." For this measure, we only looked at visits one through four, and recorded the number of these visits that were made to one of the correct locations. We also recorded two types of errors: working and reference memory errors. "Working memory errors" were scored if a subject re-visited a location that had already been visited in that session. "Reference memory errors" were scored for the first visit to a non-baited location (subsequent visits to these locations were recorded as working memory errors).

For each of these measures, test trials were summarized into 3-session blocks, resulting in seven 3-session blocks. We tested whether performance on all measures improved across sessions using Friedman's test ($\alpha = 0.05$), a nonparametric repeated measures test.

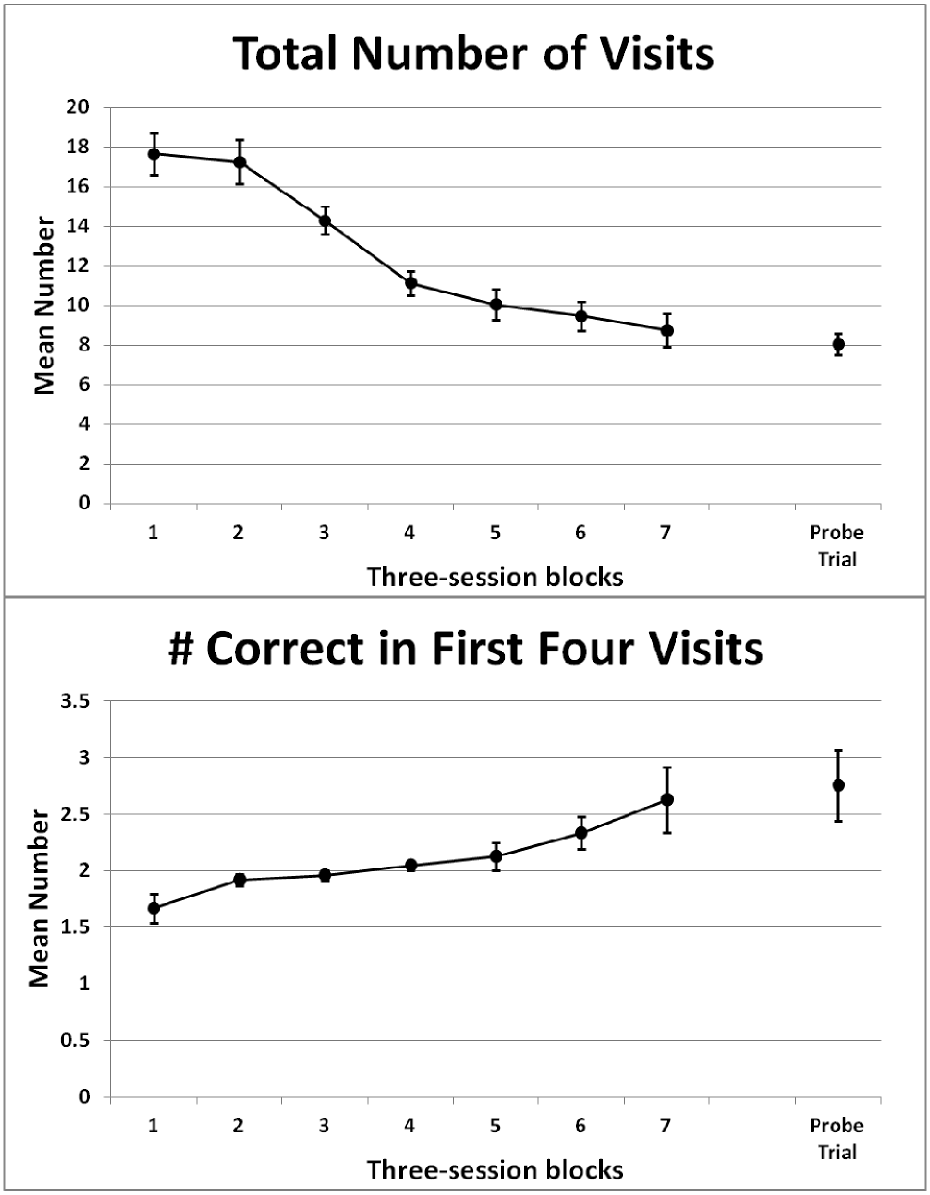
The day after the test sessions, a "probe trial" was conducted in which all feeders were rubbed with the scent of the food item, but none were baited with food. The probe trial further tested the possibility that subjects were using extraneous cues (e.g., scent) rather than spatial cues to find food in the previous task. Only four visits were needed to recover all food items, so the proportion of the first four responses to correct locations was determined. If this performance fell below chance when food was absent, subjects may have been relying on cues from the food itself. However, if performance remained above chance on the "probe trial," then it was concluded that spatial location was the relevant information used to solve the task.

Results

Subjects adapted to the apparatus very quickly, and successfully interacted with it to obtain food on the first session. On average, the otters made a total of 12.65 total visits per session, decreasing from 17.7 visits in the first 3-session block to 8.75 in the last block. The decrease in the total number of visits was significant across all blocks, $X^2= 39.29$, $p < 0.001$.The mean number correct in the first four visits increased significantly across 3-session blocks, $X^2= 23.51$, $p = 0.001$, with the mean increasing from 1.7 in the first 3-session block to 2.6 in the last. Both types of errors, working, $X^2= 38.02$, $p < 0.001$ and reference memory errors, $X^2= 18.95$, $p = 0.004$, decreased across sessions. In the first session-block, subjects made an average of 3.83

reference memory errors, or visits to unbaited locations, and this mean decreased to 2.9 by the last block. Similarly, subjects made an average of 10 working memory errors, or re-visits to already visited locations, in the first block, but only 1.9 errors in the last session-block.

Otters were significantly more likely than chance to visit correct locations (i.e., baited on previous trials) in the first four visits of the probe trial, even though no food was present, $t = 2.39$, $df = 7$, $p < 0.05$ (as reported in Perdue et al., 2011).


Total Number of Visits

Correct in First Four Visits

Figure 3. Performance across 3-session blocks for the total number of visits and the number correct in the first four visits. The probe trial data point indicates mean number of errors on the probe trial in which no food was present.

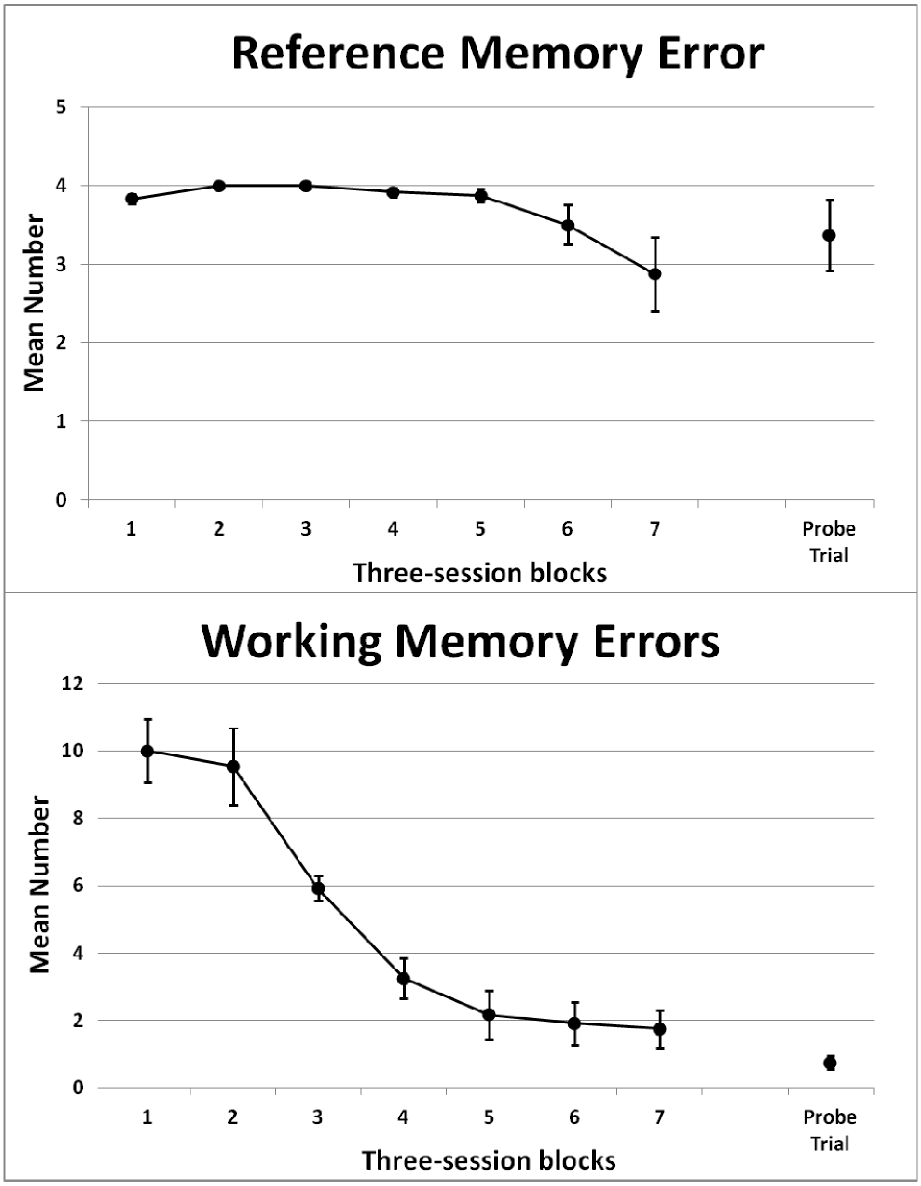


Figure 4. Performance across 3-session blocks for working and reference memory errors. The probe trial data point indicates mean number of errors on the probe trial in which no food was present.

Discussion

Asian small-clawed otters showed significant spatial working and reference memory for food locations in a spatial memory task. Across 3-session blocks, there was a significant increase in the number correct in the first four responses. There was also a significant decrease in the total number of responses, reference memory errors, and working memory errors. Finally, performance was above-chance on the probe trial (Perdue et al., 2011), suggesting that subjects were indeed responding based on spatial location. Thus, otters successfully learned the correct spatial locations in a simulated foraging task. These results provide useful information about otter spatial abilities and illustrate the potentially impactful role cognitive research in this species could have.

All subjects readily and successfully investigated the feeders, suggesting that this methodology and type of apparatus would be appropriate with a broader range of individuals and more diverse taxa. The implementation of similar methodologies across species will benefit comparative cognition research by identifying similarities and differences across species more appropriately than when disparate techniques are used. Given otters' manual dexterity and adeptness at the present task, it is likely that other types of manipulations and devices used with other species, including but not limited to the broad range of tasks that have been developed for nonhuman primates, could be easily adapted for otters and this presents a fruitful line of potential research.

Otters show substantial variation in behavior and ecology within species, populations and even at the individual level (Kruuk, 1995). Future research should capitalize on this variation to make comparisons among the various otter species. For example, these data were from a larger study of sex differences in spatial memory, and these otters showed no sex differences in performance (Perdue et al., 2011). This finding, in combination with the fact that giant pandas, a related promiscuous species, show sex differences in spatial ability provided strong support for the range size hypothesis in a recent study (Perdue et al., 2011). Even more compelling support for this hypothesis could be found if another species of otter with a mating system that involved differential range size showed sex differences. Several otter species, such as the Cape clawless otter (*Aonyx capensis*), exhibit intra-sexual territory patterns where males inhabit larger ranges that encompass female ranges (Somers & Nel, 2004). The range size hypothesis would predict sex differences on a spatial task for this closely related otter species. Additional insightful comparisons could be made between Asian small-clawed otters and North American river otters. The diet and expected lifespan of Asian small-clawed otters and North American river otters is similar, but there is great variation in breeding system. Asian small-clawed otters exhibit cooperative breeding and remain in family groups. In contrast, the North American river otter is solitary and the mother raises her pups alone. Thus, one would expect superior performance on socio-cognitive tasks in Asian small-clawed otters. There are many potential questions that can be addressed regarding the contribution of ecological and sociological factors to cognitive abilities by studying otters. Furthermore, we can better address conservation needs by learning more about otters in zoological settings.

Otters are often considered to be an “indicator” species that reflects the health of an environment. They are sensitive to water quality and their presence and behavior reflect the effect of pollution on aquatic habitats. As a result of human activity, five of the thirteen otter species are endangered and only three species have stable populations (IUCN, 2011). In the wild, otters are often hard to study because some are secretive and live in hard to reach habitats (Kruuk, 1995). Testing in a zoo environment provides a useful opportunity to learn more about cognitive abilities in these taxa. Furthermore, it has been suggested that conducting cognitive research, and conveying findings about animal intelligence to the general public, may increase human empathy for nonhuman species and improve conservation efforts (Sickler et al., 2006). By learning more about otter behavior and cognition in captive environments, we can improve conservation efforts and educate people about these species, which will hopefully motivate changes in human behavior that will ensure the survival of otters.

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