Title

Dominance Hierarchies in Captive Painted Turtles (Chrysemys picta)

Journal

International Journal of Comparative Psychology, 37(1)

ISSN

0889-3675

Authors

Koprowski, Justin
Hu, Cassidy
Narula, Aayush
et al.

Publication Date

2024-08-30

DOI

10.46867/ijcp.21167

INTERNATIONAL JOURNAL OF COMPARATIVE PSYCHOLOGY

2024, 37
Charles I. Abramson
Editor
Peer-reviewed

Dominance Hierarchies in Captive Painted Turtles (*Chrysemys picta*)

Justin Koprowski, Cassidy Hu, Aayush Narula, Bernard Sanchez, Sanjana Sankaran, and Alice S. Powers

Department of Psychology, Stony Brook University, Stony Brook, NY

We investigated dominance in two groups of captive painted turtles, each over a period of 8 weeks. In each case, we began with five turtles, then added a sixth after 6 weeks. One group was run in the fall, the other in the spring, and the makeup of males and females differed in the two seasons. We measured two behaviors while they were feeding: mounting, defined as placing a claw or head above the carapace of the other turtle for at least one second, where the mounter was stationary, and biting, defined as snapping at another turtle. We hypothesized that the turtles would demonstrate a dominance hierarchy. Our results showed that painted turtles show individual differences in behavior. These differences are consistent over time and allow dominance hierarchies to be established. Both mounting and biting demonstrated consistency, but mounting was more consistent than biting. The amount of mounting and biting differed by sex and season, but turtle size did not seem to influence their activities. Finally, the introduction of a new turtle disrupted the dominance behaviors of the turtles, suggesting that turtles recognize a new turtle as unfamiliar. Understanding the complex dynamics of captive turtle populations has implications for the management and welfare of turtles in captivity and in the wild.

Keywords: biting, mounting, reptile, season, sex, size

飼育下のニシキガメ（*Chrysemys picta*）における順位制

私たちは飼育下のニシキガメの 2 つの群れについて，それぞれ 8 週間にわたって順位を調査した．1 つのグループは秋に，もう一方のグループは春に調査を実施し，オスとメスの構成は 2 つの季節で異なっていた．私たちはカメが摂餌している間の 2 つの行動を測定した：マウンティング（相手のカメの甲羅の上に爪や頭を少なくとも 1 秒以上置き，その状態で静止すること），噛みつき（相手のカメに噛みつくこと）．私たちは，ニシキガメが順位制を示すという仮説を立てた．結果は，ニシキガメの行動には個体差があることを示した．このような違いは長期にわたって一貫しており，順位制を確立することを可能にしている．マウンティングも噛みつきも一貫性を示したが，マウンティングの方が噛みつきよりも一貫性があった．マウンティングや噛みつきの回数は性別や季節によって異なったが，カメの大きさはその行動に影響しないようであった．最後に，新規個体の導入がカメの順位行動を乱したことから，カメは新規個体を見慣れないものと認識していることが示唆された．飼育下のカメ個体群の複雑な動態を理解することは，飼育下および野生のカメの管理と福祉に影響を与えると考えられる．

キーワード：噛みつき，マウンティング，爬虫類，季節，性別，大きさ

Jerarquías de dominancia en tortugas pintadas en cautiverio (*Chrysemys picta*)

Se investigó sobre las relaciones de dominancia en dos grupos de tortugas pintadas en cautiverio, cada uno durante un período de 8 semanas. En cada caso, se comenzó con cinco tortugas y luego se agregó una sexta después de 6 semanas. Un grupo se estudió durante el otoño y el otro durante la primavera, y la proporción de machos y hembras fue distinta en las dos estaciones. Se midieron dos comportamientos durante la alimentación: montar, definido como colocar una garra o la cabeza sobre el caparazón de la otra tortuga durante al menos un segundo, donde el montador estaba estacionario; y morder, definido como morder a otra tortuga. Se propuso la hipótesis que las tortugas demostrarían una jerarquía de dominancia. Los resultados mostraron que las tortugas pintadas muestran diferencias individuales en el comportamiento, diferencias que son consistentes en el tiempo y permiten establecer jerarquías de dominancia. Tanto montar como morder fueron consistentes, pero montar fue más consistente que morder. La cantidad de monturas y mordidas difirió según el sexo y la estación, pero el tamaño de las tortugas no pareció influir en sus actividades. Finalmente, la introducción de una nueva tortuga alteró los comportamientos dominantes de las tortugas, lo que sugiere que las tortugas reconocen a una nueva tortuga como desconocida. Comprender la compleja dinámica de las poblaciones de tortugas en cautiverio tiene implicaciones para el manejo y el bienestar de las tortugas tanto en cautiverio como en la naturaleza.

Keywords: morder, montar, reptil, estación, sexo, tamaño

Please send correspondence to Alice S. Powers, Ph.D., Department of Psychology, Stony Brook University, Stony Brook, NY 11794-2500, 516-521-6210. Email: alice.powers@stonybrook.edu

In many animals, the emergence of stable social structures is determined by the social and agonistic interactions among individuals. Animals in groups typically form dominance hierarchies, in which some animals are privileged relative to others, especially when feeding and in reproductive competition (Tibbetts et al., 2022). Linear dominance hierarchies are frequently observed, in which the top animal is dominant over all others, the second-ranked is dominant over all but the first, and so on. The specific benefits and drawbacks of a dominance hierarchy differ among the members in the group. Dyadic interactions among individuals usually favor the dominant individual, who benefits by gaining more access to resources like food and mates. However, since dominant individuals tend to perform more aggressive behaviors, they may have higher stress or physiological demands because of the need to maintain their dominance status (Borgmans et al., 2020; Hogstad, 1987). In contrast, by recognizing and conforming to an established hierarchy, submissive individuals may also benefit by reducing the risk of injury, saving time and energy. Once dominance hierarchies are established, submissive individuals may comply with their lower ranking due to the risks of repeated conflict. Certain interactions will be selected to determine whether the individual gains benefits that outweigh their costs, providing support that dominance hierarchies may provide an evolutionary advantage (Chase et al., 2002). Knowledge of the social relations of turtles can provide insight into both the conservation and care of turtles in captive and natural environments.

We studied social behavior and dominance hierarchies in painted turtles (*Chrysemys picta*) housed in our laboratory in groups of five, in order to address four issues: First, do painted turtles show individual differences in behavior? Second, are these differences consistent over time? Third, can we identify a dominance hierarchy, and what variables influence it? And fourth, how does introduction of a new animal affect the group structure, and do painted turtles recognize other conspecifics as familiar or unfamiliar?

Painted turtles are a common pond species in North America, but their social interactions have not been studied intensively. Roth et al. (2020) studied painted turtles in the field and noted marked individual differences in aggression, sociability, and boldness. They were not able to follow the animals over time, however, and thus did not measure consistency or social structure. To measure consistency of behavior, either confinement or repeated capture is necessary. Pich et al. (2019) studied box turtles (*Terrapene Carolina triunguis*) that they recaptured 3-21 days later, testing them first for boldness in an artificial confinement situation, where they measured how rapidly the turtles would put out their heads after being confined in a black bag for 3 min, then in a more naturalistic predator attack (using a raccoon puppet). They found that the boldest turtles in one situation were also the boldest in the other, thus providing evidence that the boldness trait was consistent over time and across different measures in the field. Additional information about the natural history and behavior of painted turtles can be found in Ernst et al. (1994), Roth & Krochmal (2015), and Valenzuela (2009).

Although consistency of behavior and dominance hierarchies have not been studied in painted turtles, other turtle species have been studied. Captive box turtles showed consistent behaviors measured during feeding between pairs of turtles housed together (Boice, 1970; Boice et al., 1974). The authors were able to observe linear hierarchies that became stable over time (they observed the animals for 14 months), always with a female as the most dominant by the end. Aggressive behaviors declined over time, but the ranking remained the same. Consistency of behavior and stable hierarchies were observed in juvenile snapping turtles (*Chelydra serpentina*) that were housed together and tested in competition for food (Froese & Burghardt, 1974). The ranking was consistent over at least 4 months. European pond turtle hatchlings (*Emys orbicularis galloitalica*) developed hierarchies over the first few months after birth, and these become linear over time (Masin et al., 2020).

The present study is the first to examine dominance hierarchies in captive painted turtles. We hypothesized that the turtles would exhibit consistent behaviors over time, with some consistently more dominant over others. We first examined the consistency of behavioral traits and the development of a dominance hierarchy over a 6-week period in a group of five turtles; we then added a sixth turtle for another two weeks. The addition of the sixth turtle allowed us to determine whether they recognized that new turtle as unfamiliar. The first study was run in the fall of 2021. In the spring of 2022, we formed another group of five turtles, in which three turtles from the original group were included, along with two new ones. Again, we added a sixth turtle after 6 weeks. The two groups differed in that there were more females in the second group than in the first. We found that painted turtles in captivity demonstrate consistent behavior over time; furthermore, individual animals show similar behaviors in groups made up of different individuals. They form long-lasting dominance hierarchies, and these dominance hierarchies are not markedly disrupted by the introduction of an unfamiliar animal. They do, however, appear to recognize that an unfamiliar turtle has been added to the group.

Method

Subjects

Nine western painted turtles obtained from The Turtle Source, Fort Myers, FL, were used in this experiment. The number of subjects was determined primarily by convenience: these were animals that were not needed in other investigations. They arrived in the laboratory between June 2019 and October 2021 and were run in this study in fall 2021 and spring 2022. Before the study began, they were housed in groups of 8-10 in an environment that was kept at a constant temperature of 27-29.5ºC, in a room with a long day/short night cycle (14 hr on, 10 hr off) to prevent the animals from trying to estivate. The study was conducted in that environment. Age was unknown. Sex was judged by external sex characteristics: males have longer claws on the forelimbs and a longer tail, while females have shorter tails and nails, with the cloaca closer to the shell. There were six males and three females. Weights, lengths, and sex are given in Table 1.

Table 1

Weights, Lengths, and Sex of Turtles in Each Group

Animal Number	Weight (g)	Length (cm)	Sex
Fall			
305	257.5	12.3	M
358	164	10.8	M
369	230.5	12.2	F
372	249.5	13.1	M
373	291	13.2	M
377	161	10.5	M
Spring			
369	260.8	12.2	F
372	297.5	13.1	M
373	332.3	13.2	M
382	415.5	14.0	F
385	256.5	12.0	F
381	286.4	13.2	M

Turtles were fed three times a week; pellets of a specialized turtle diet (Mazuri Aquatic Turtle Diet, mazuri.com) were fed twice a week on Mondays and Fridays, and pieces of fish (tilapia) were fed once a week on Wednesdays. They were given more food than they would eat each day, and then, after 30 min, the tank was drained and cleaned, and the water was replaced with clean tap water.

Ethical Statement

The study was approved by the Institutional Animal Care and Use Committee of Stony Brook University (protocol#IACUC2021-00127) and complied with all Federal, State, and University regulations regarding the use of animals in research.

Apparatus

A group tank, 55 × 68 cm, with a depth of 110 cm, was used for housing. The water in the tank was 12 cm deep. This is the standard housing used in this laboratory for groups of turtles (e.g., Hanusch et al., 2021). It is considered the appropriate size for housing as many as 12 turtles at a time. A Fluker UVB Lamp was provided for ultraviolet B ray supplementation. The tank contained a two-tier orange slatted platform for basking (lower tier 49 × 38 cm, upper tier 33 × 20.5 cm, height 12 cm), which was removed for the duration of the feedings, to allow all turtles to be observed during the videos. The recordings were provided by a Logitech HD Webcam 310.

Procedure

The turtles had been housed in groups in the laboratory since their arrival, but the particular constellations used in this study were formed less than a week before we began recording their behavior. For both replications, we marked the turtles on the carapace with white tape, using different shapes to provide a code for identification in the videos (see Figure 1). The video camera began recording shortly prior to feeding and continued for 28 min. No humans were in the room during the recording of each video. The fall replication included six turtles, five males and one female, ranging in weight from 161.0 g to 291.0 g (Table 2). Four males and the female were housed together for the first six weeks, and the sixth (male) turtle was added for the final two weeks. The spring replication included three males and three females ranging in weight from 256.5 g to 415.5 g. For the first six weeks, two males from the first replication, one female from the first replication, and two new females were housed together. A third male, not used in the first replication, was added for the last two weeks.

Table 2

Number of Male and Female Subjects in Each Replication

Fall Replication (Data collected 3 days per week)	Number of turtles of each sex
Initial six weeks	4 males, 1 female
Final two weeks	1 male added
Spring Replication (Data collected 3 days per week)	
Initial six weeks	2 males (both from Replication 1), 3 females (1 from Replication 1)
Final two weeks	1 male added

Figure 1

The Five Turtles in the Fall Replication. The Turtles Were Marked with Tape to Allow Identification in the Videos

Data Analysis

We identified three behaviors that were used to quantify dominance during the 28-min observation periods: biting, mounting, and food stealing. Biting was defined as snapping at a nearby turtle combined with a flinch from the receiving turtle. No injuries were inflicted by biting. Mounting was defined as placing a claw or head above the carapace of the other turtle for at least 1 s, where the mounter was stationary (not walking by). Food stealing was identified when one turtle possessed a piece of fish, and a second turtle succeeded in taking the fish from the first. Food stealing interactions were monitored only on fish days (Wednesdays), and that behavior occurred so rarely that it was not used in the analyses.

For biting and mounting, we calculated daily ranks. These were based on the number of times each turtle mounted or bit another turtle compared to the number of times it was mounted or bitten. We subtracted the latter from the former (e.g., number of times it mounted another turtle minus number of times it was mounted). Thus a turtle that bit more than it was bitten received a positive difference score, and one that was bitten more received a negative score. We then ranked the turtles with the highest positive difference score ranked #1 and the lowest difference score ranked #5 (or #6 in the last two weeks). This resulted in the most dominant turtle (the one that mounted the most) ranked #1 and the least dominant #5 (or #6). Then we averaged the mounting and biting scores per day by weeks.

To determine consistency over time, we employed Kendall's W, or Kendall's coefficient of concordance, to assess the agreement level among individual turtle rankings across multiple days. Our aim was to investigate whether the rankings for biting and mounting behaviors over weeks exhibited consistent patterns. The last two weeks of data, when the sixth turtle was added to the group, were not included in these calculations.

The calculations above did not take into account how many different turtles were bitten or mounted, only how many times a given turtle was bitten or mounted. We also calculated who mounted or bit whom each day of the experiment and then calculated the number of different other turtles each turtle mounted or bit. For example, in the fall, turtle 373 bit four other turtles and was not bitten by any of them. We calculated the dominance rankings, using the formula: $DDP = \left(\frac{Nd-Ns}{S}\right) * 100\%$ (Schnell et al., 2021). *DDP* is the degree of dominance percentage, s is the total number of subjects, *Nd* is the total number of turtles a given turtle was dominant over, and *Ns* is the total number of turtles that same turtle was subordinate to. To calculate *Nd*, a turtle had to meet a minimum threshold of 4 or more dominant behaviors. Similarly, in the case of *Ns*, the subordinate turtle had to have shown a minimum of 4 or more subordinate behaviors to be considered in the equation (Schnell et al., 2021). After finding the percentage dominance for each turtle, we ranked the turtles by these *DDP* values.

Results

Frequency of Mounting and Biting

Mounting was more common than biting, and both behaviors were more common in the fall than in the spring (Figure 2). Stealing food turned out to be so rare (one or two instances per turtle over 8 weeks) that it was not possible to rank turtles on that behavior.

Figure 2

The Total Number of Mounts and Bites in Fall and Spring

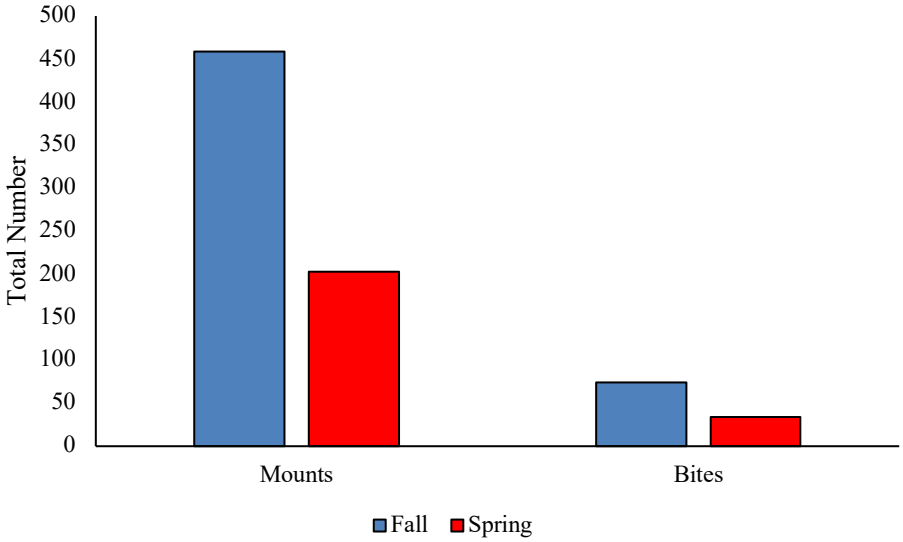
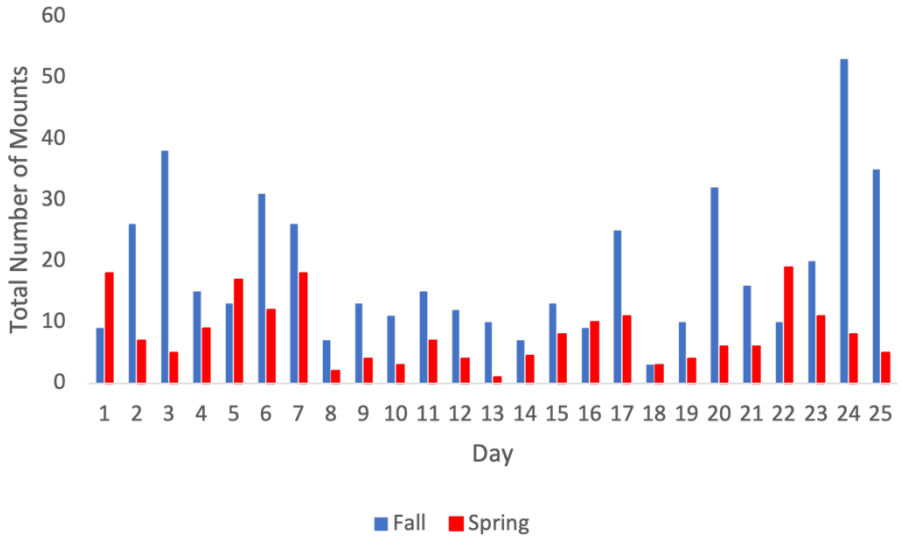
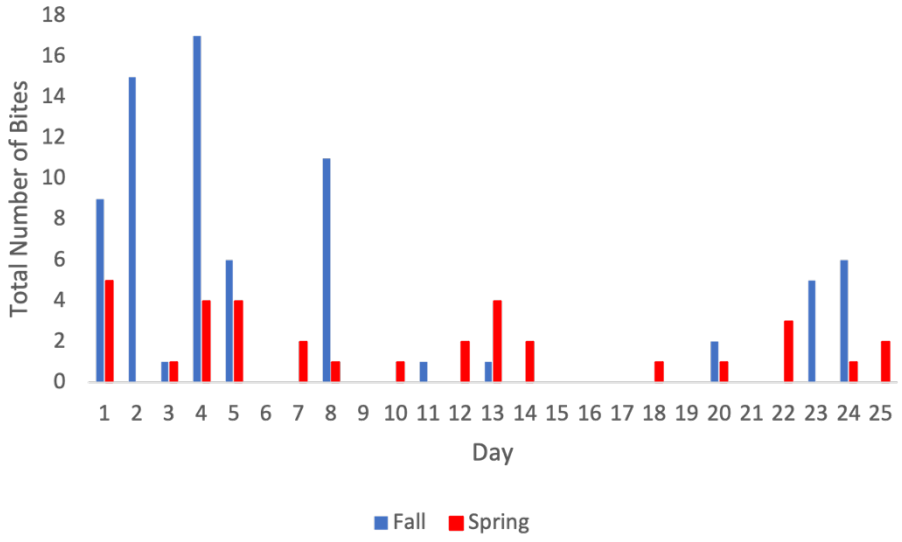


Figure 3 shows the number of mounts and bites per day in each season. Although both measures declined over the six weeks of the experiment, bites declined more than mounts. When the new turtle was introduced, in both fall and spring, bites and mounts increased.

Figure 3

The Total Number of Mounts and Bites in Fall and Spring by Day



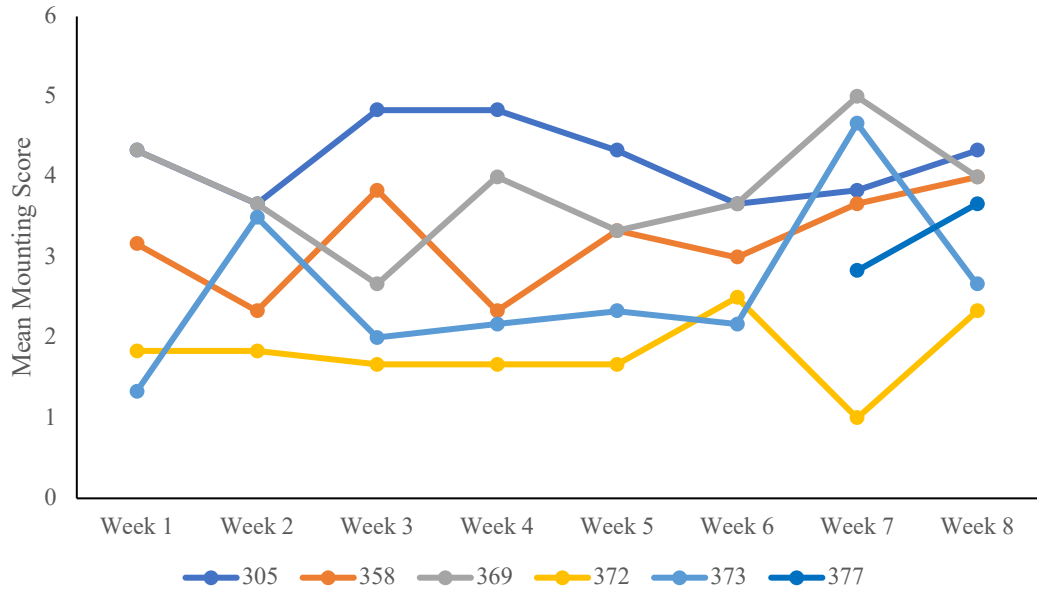


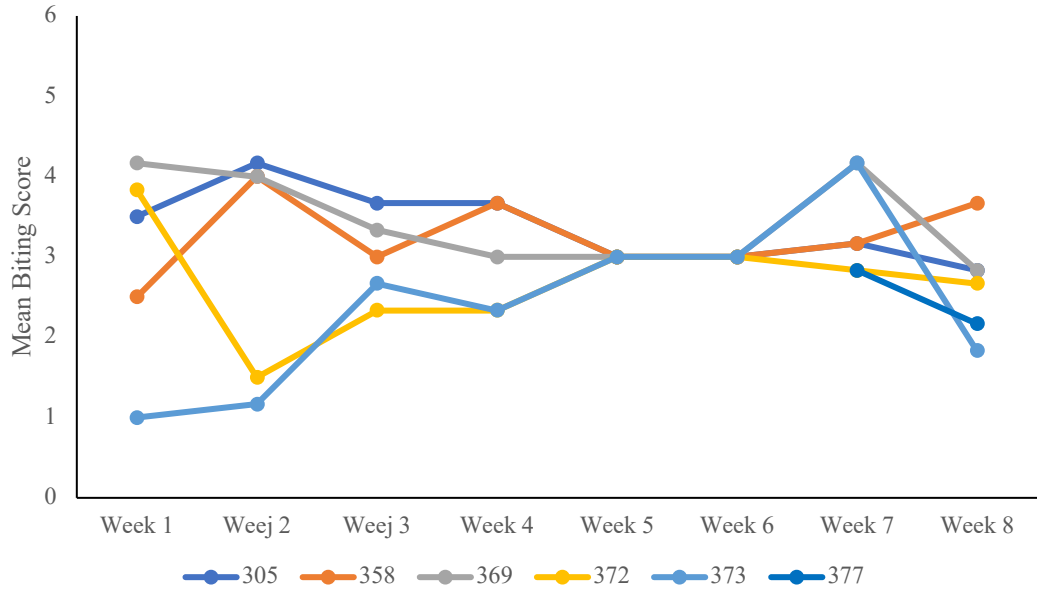
Consistency

We saw evidence of consistent behavior across the days of the study in both fall and spring. This consistency is illustrated by Figures 4 and 5, showing mounting and biting, over weeks, in fall and spring respectively. We calculated the ranks in these figures based on a difference score that was the number of times a turtle mounted (or bit) on a given day less the number of times it was mounted (or bitten), then calculated the mean for the three feeding days in a week. In these figures, the lowest numbers are the highest ranks.

Figure 4

Mounting and Biting Rank in Fall, Averaged Across Weeks

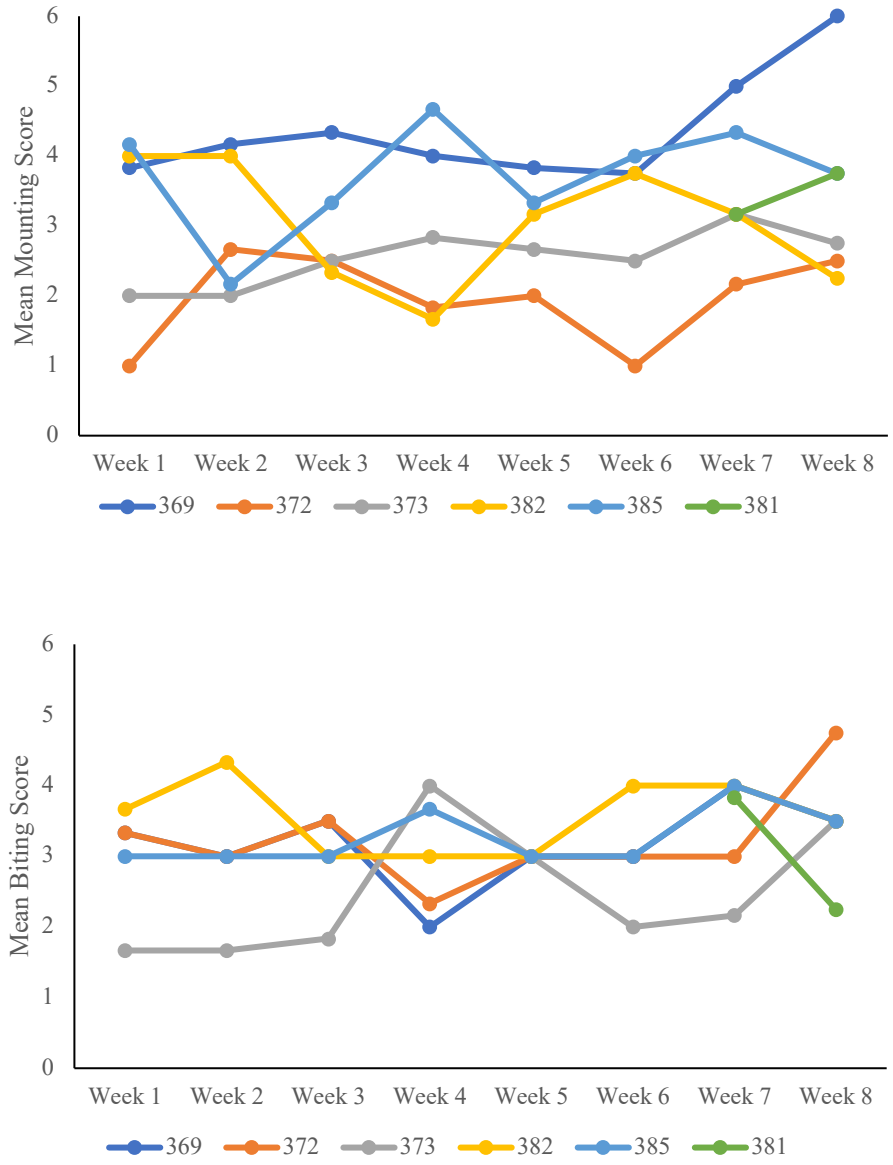




Note. Ranks were calculated based on the difference score between the number of times a turtle mounted or bit another turtle compared to the number of times it was mounted or bitten. The turtles with the highest positive difference score (the most dominant) ranked #1.

Figure 5

Mounting and Biting Rank in Spring, Averaged Across Weeks



Note. Ranks were calculated based on the difference score between the number of times a turtle mounted or bit another turtle compared to the number of times it was mounted or bitten. The turtles with the highest positive difference score (the most dominant) ranked #1.

This consistency was demonstrated in a statistically significant Kendall's *W* for mounting in both fall and spring. We examined mounting in each week, for the first six weeks of each replication, before we introduced an additional animal. Mounting was significant in both fall and spring, $W(4) = .85$, $p = .0004$ for fall, $W(4) = .55$ $p = .010$ for spring. As can be seen, biting was not as consistent: in both fall and spring, biting ranks came together or even reversed toward the middle of the observation period. Biting was not significant for either fall or spring, $W(4) = .12$, $p = .57$ for fall, $W(4) = .27$, $p = .16$ for spring, demonstrating that biting behavior was not as consistent as mounting.

We also calculated the degree of dominance percentage (*DDP*) (Schnell et al., 2021), based on the observations of who mounted whom and who bit whom. The DDP made it possible to rank the turtles and observe a linear hierarchy. In the fall, #373 ranked first for both mounting and biting and #372 ranked second but was tied with #369 and #358. In the spring, #372 and #373 again ranked first and second: for mounting, #373 ranked first, and #372 was second, and for biting #373 was #1, and #372 tied for second with #369 and #385.

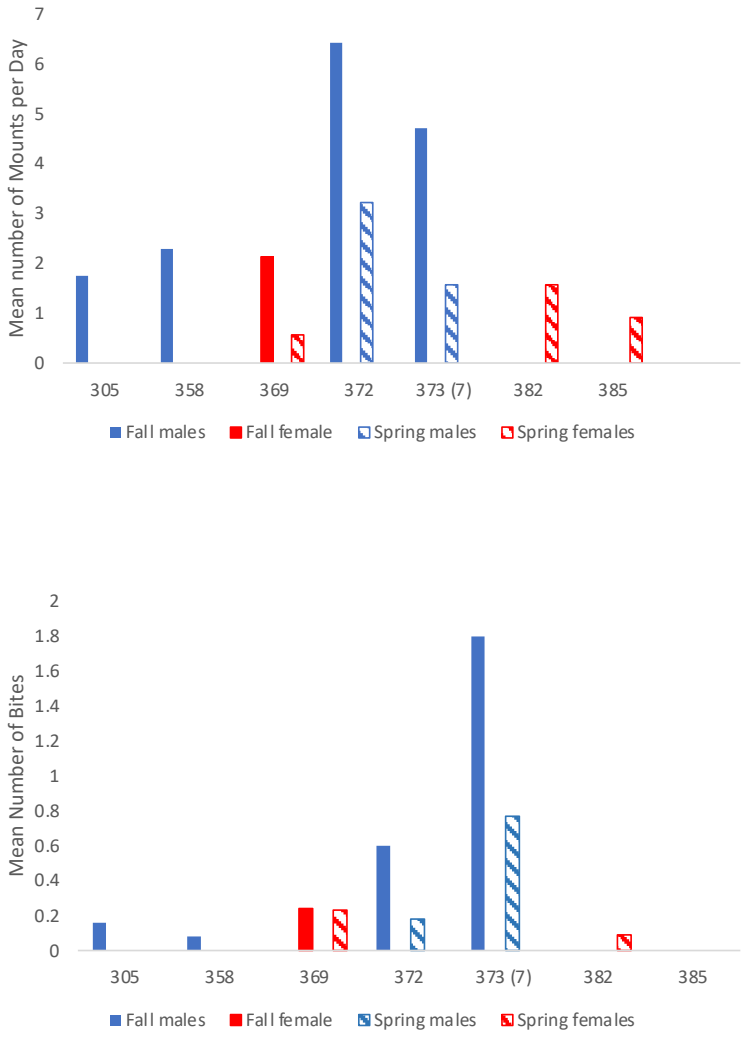
The ranks calculated from Kendall's *W* and *DDP* were similar but not identical. Correlations between Kendall's *W* and *DDP* were 0.67 for mounting and 0.87 for biting in the fall ($p > .05$ for each), and 0.97 and 0.89 respectively for the spring ($p < .05$ for each).

Comparison of Fall and Spring

We examined the average number of mounts and bites per day in fall and spring. This allowed us to compare three turtles directly, those that were included in both the spring and fall groups. These results are shown in Figure 6, which also indicates the sex of each turtle. As can be seen from the figure, males mounted and bit more than females in general, but most of the difference was because of two males, #372 and #373. When the number of mounts for the three turtles included in both the fall and spring groups were compared, there was a significant reduction in the spring, $t(2) = 4.90$, $p = .04$. The same comparison for biting yielded a nonsignificant result, $t(2) = 1.65$, $p = .24$.

Figure 6

The Mean Number of Mounts and Bites per Day, by Season



Introduction of Sixth Turtle

After the introduction of a sixth turtle, there was a change in behavior, shown by the increase in mounting and biting in both seasons (Table 3). Chi square calculations for these measures revealed that the difference between mounts was significant in the fall, $\chi^2(1) = 16.2$, $p < .0001$, but not in the spring $\chi^2(1) = 1.5$, $p = .23$. For bites, the change was significant in the fall, $\chi^2(1) = 7.0$, $p = .008$, and trended toward significance in the spring, $\chi^2(1) = 3.6$, $p = .06$. The increases in mounting and biting were not directed at the new turtle. Rather, they were directed at a range of different target turtles.

Table 3

The Total Number of Mounts and Bites in the Five Days Before and After the Addition of a New Turtle

	Fall Before	Fall After	Spring Before	Spring After
Mounts	60	113	36	47
Bites	0	7	1	6

There was no significant change in ranking after the addition of a new turtle. The most dominant turtles remained the most dominant, and the most submissive remained the most submissive. Kendall's *W* calculated for the last two weeks of the study was not significant for mounting or biting.

Size

We looked at the size of the turtles to determine whether the largest turtles were the most dominant. Number 373 was the largest turtle in the fall, and he was the most dominant for biting and second most dominant for mounting. The most dominant for mounting in the fall, was #372, and he was the second most dominant for biting, but he was not the second largest by weight. Number 305 was the second largest, and he ranked fifth for mounting and fourth for biting. The two most dominant, #372 and #373, were the largest two turtles by length of carapace, however.

In spring, we deliberately added two females, including one, #382, which was the largest turtle in the group, both by weight and by length, but #372 and #373 continued to be the most dominant (#372 for mounting and #373 for biting). Number 382 ranked third for mounting and fourth for biting. Thus, size did not determine rank in this experiment.

Discussion

The establishment of stable social structures in numerous animal species hinges upon their interactions, both social and aggressive, among individuals. The establishment of dominance hierarchies is one of the processes that facilitate these interactions, particularly during feeding situations, wherein a select few individuals attain privileged positions while others assume subordinate roles. This intricate social dynamic is not unique to a single species but can be observed across various taxa, including turtles. Studies focused specifically on painted turtles are scarce.

Our study aimed to measure mounting and biting behaviors, specifically through observing the snapping and mounting behaviors directed at other turtles, during feeding sessions. We were unable to analyze the significance of food stealing due to its infrequent occurrence. The turtles were always fed abundant food; therefore, they had no need to steal from other animals. This approach allowed us to examine the consistency of these behavioral traits over 6 weeks. Additionally, we investigated the impact of introducing another turtle into the group, as well as potential variations observed across different seasons and sexes. By encompassing these factors, we sought to increase our understanding of the consistency of behavioral traits in captive painted turtles.

The results of this study led to four conclusions, to be discussed below. First, painted turtles do indeed show individual differences in behavior. Second, such differences are consistent over time, and third, dominance hierarchies are present in painted turtles and can be demonstrated through the observation of their biting and mounting behaviors. Fourth, because introduction of a new turtle disrupted the behaviors of the turtles, it appears that turtles recognize a new turtle as unfamiliar.

Painted Turtles Show Individual Differences in Behavior

As shown by Roth et al. (2020), who examined traits such as boldness, sociality, and aggression in painted turtles, our turtles also showed individual differences in behavior. We measured mounting and biting and observed marked differences in how many of these behaviors each turtle demonstrated.

Individual Differences are Consistent Over Time

The behavioral differences we observed were consistent over the 6 weeks of our experiment. By using Kendall's coefficient of concordance (*W*), we were able to demonstrate the consistency of individual turtle rankings across multiple weeks. Despite the small sample size, we were able to obtain consistent rankings. Kendall's *W* for mounting was significant in both fall and spring, showing that the mounting ranks were consistent over weeks. Kendall's *W* was not significant for biting. Yet there too, we saw that some turtles were much more likely to snap at another turtle than were others.

We saw reduced numbers of dominance behaviors, however, as the hierarchy became established with time. This was especially true for biting, which on some days did not occur at all. Such declines have been reported in the dominance literature (Tibbetts et al., 2022). When a new turtle was introduced, however, both mounting and biting increased. These increases might have been efforts to maintain the dominance hierarchy.

Dominance Hierarchies are Present in Painted Turtles

The results are in line with our hypothesis, which predicted that some form of hierarchy would develop in our turtles. To address the question of which turtles a given turtle was mounting or biting, we employed the *DDP*. This measure allowed us to determine a linear dominance hierarchy for each measure.

The calculated Kendall's *W* values for the spring replication correlated significantly with the *DDP* measures (both above 0.88), but the two measures did not significantly correlate in the fall, either for mounting or for biting. Nonetheless, both correlation values for the fall (mounting and biting) were positive and above 0.66, suggesting that these measures were indexing similar behaviors.

Our findings are consistent with other research on the behaviors and hierarchical structure of other members of the suborder Cryptodira. This includes the consistency in behavior of captive box turtles during feeding (Boice, 1970; Boice et al., 1974), the consistency of behavior and the presence of stable hierarchies in juvenile snapping turtles who were similarly housed together during feeding (Froese & Burghardt, 1974), and the presence of linear hierarchies in European pond turtles (Masin et al., 2020). A striking similarity includes the decline of aggressive behaviors in captive box turtles (Boice, 1970; Boice et al., 1974), which our own study mirrored with the decline in frequency of biting behavior.

The presence of dominance hierarchies demonstrates that painted turtles are capable of sophisticated social behavior. Hierarchies facilitate social behavior by reducing conflict and aggression between individuals. They also improve the fitness of individual dominant animals by giving them more access to resources such as mates and food.

Turtles Change Their Behavior When a New Turtle is Introduced

When a new turtle was added, both in the fall and in the spring, we observed an increase in the mounting and biting behaviors. In the fall, both mounting and biting increased significantly. In contrast, in the spring both increased, but neither difference was significant. We attribute these changes to the turtles' being able to recognize that a new turtle was in their midst. The increased mounting and biting were not, however, directed at the new turtle. It is possible that the animals recognized only that there was a change in their number but not that there was a new animal in the tank. Distinguishing between these two possibilities is not possible with the data we have, but it would be interesting to pursue this question.

Size, Sex, and Season

Size, sex, and season were confounded in our experiment. The fall replication had more males, and the largest animals were males. The spring replication had more females, and the largest animal was a female. Thus, we cannot draw conclusions about any of these three variables. The experiment would have needed to manipulate each variable systematically to be able to conclude anything about these issues.

One interesting aspect of the findings is that the environment in which the turtles were housed had constant temperature and day: night cycles throughout the year. Yet our data show that the dominance behaviors of biting and mounting were more frequent in the fall and less frequent in the spring (Figure 2). These seasonal effects mirror the findings of Thomas et al. (2002) in sliders (*Trachemy scripta*), a closely related species, in the wild. In that study, males showed a higher prevalence of biting and chasing behaviors in September and October than in other months. It is intriguing that the observed behaviors exhibited substantial variation despite the consistent environmental conditions. Most of the turtles in the study arrived in the laboratory before July 2021 and had not seen natural light or temperature variations since that time. Thus the detection of the season is somewhat unlikely, and it seems more likely that the high proportion of males in the fall led to the increased mounting and biting. Male sliders have been shown, in general, to engage in more biting and chasing behaviors than females in the wild (Thomas et al., 2002). Therefore, having fewer males is consistent with a reduction in occurrence of these behaviors. A second possible explanation is that the unbalanced sex ratio in the fall could have led to increased competition. With only one female in the fall trial, male: male competition might have been more prevalent. This result could also support the idea that increased male presence in a hierarchy leads to more aggressive interactions, and perhaps more rapid development of a dominance hierarchy. Further systematic work will be necessary to distinguish between these possibilities.

Strengths and Weaknesses

A strength of this study is the niche it fills in the field of reptile behaviors. While there are a plethora of studies investigating the behaviors and social structures of a variety of reptiles, there are a sparse amount of similar data on painted turtles. Another strength of this study was the differences between both groups observed. Some variables extraneous to the stability of behaviors were accounted for by conducting the study in both the fall and spring, using different sized turtles, and having different gender compilations between groups. Video recording behavior during feeding represents another strength of the study. Captive painted turtles display a fear of humans, and such videos eliminated the presence of humans while the animals were feeding. They also provided a record that could be scored and confirmed offline.

One weakness of this study is the overall sample size. Our sample size was 6 turtles overall in both the fall and spring, yet painted turtles in the wild have population densities "rang[ing] from 10 to 840 turtles per hectare (2.5 acres) of water surface" (Ernst et al., 1994). The overall size of the apparatus is another weakness in that turtles were living in a restricted space, not in the type of pond they would live in in the wild.

Future research should investigate removing a turtle from the group to determine the effect of this manipulation. It would also be interesting to study a larger group of turtles and larger housing. Although methodologically challenging, a comparison of these results to dominance behaviors of painted turtles in the wild would also be enlightening.

Conclusions

This study has shown that captive painted turtles form a dominance hierarchy when housed together. Their behavior is consistent over time, and for some animals even across seasons. Introduction of an additional turtle disrupts their behaviors but does not change the rankings overall. The finding that painted turtles in captivity show such consistent behavior over time, and even in different social groups, is evidence that this species is capable of sophisticated social behaviors.

Acknowledgments

This research was supported by Stony Brook University.

References

Boice, R. (1970). Competitive feeding behaviours in captive *Terrapene C. carolina*. *Animal Behaviour, 18,* 703–710. https://doi.org/10.1016/0003-3472(70)90015-1

Boice, R., Quanty, C. B., & Williams, R. C. (1974). Competition and possible dominance in turtles, toads, and frogs. *Journal of Comparative and Physiological Psychology, 86*(6)*,* 1116–1131. https://doi.org/10.1037/h0037641

Borgmans, G., Van den Panhyusen, S., & Van Damme, R. (2020). The (dis)advantages of dominance in a multiple male group of *Anolis carolinensis* lizards. *Zoology, 139,* 125747. https://doi.org/10.1016/j.zool.2020.125747

Chase, I. D., Tovey, C., Spangler-Martin, D., & Manfredonia, M. (2002). Individual differences versus social dynamics in the formation of animal dominance hierarchies. *Proceedings of the National Academy of Sciences, 99*(8), 5744–5749. https://doi.org/10.1073/pnas.082104199

Ernst, C. H., Barbour, R. W., & Lovich, J. E. (1994). *Turtles of the United States and Canada*. Smithsonian Institution Press.

Froese, A. D., & Burghardt, G. M. (1974). Food competition in captive juvenile snapping turtles, *Chelydra serpentina. Animal Behaviour, 22(3),* 735–740. https://doi.org/10.1016/S0003-3472(74)80025-4

Hanusch, B., Ayanru, A., & Powers, A. S. (2021). Housing experience affects adult neurogenesis in turtles (*Chrysemys picta*). *Behavioral Neuroscience, 135*(1), 24–31. https://doi.org/10.1037/bne0000473

Hogstad, O. (1987). It is expensive to be dominant. *The Auk, 104*(2), 333–336. https://doi.org/10.1983/auk/194.2.333

Masin, S., Bani, L., Vardanega, D., Chiodini, N., & Orioli, V. (2020). Hierarchies and dominance behaviors in European pond turtle (*Emys orbicularis galloitalica*) hatchlings in a controlled environment. *Animals, 10*(9)*,* 1510. https://doi.org/10.3390/ani10091510

Pich, J. M., Belden, A. J., & Carlson, B. E. (2019). Individual variation in boldness in turtles is consistent across assay conditions and behavioural measures. *Behaviour, 156*(10), 1039–1056. https://doi.org/10.1163/1568539X-00003555

Roth, T.C., & Krochmal, A. R. (2015) The role of age-specific learning and experience for turtles navigating a changing landscape. *Current Biology, 25*(3), 333–337. https://doi.org/10.1016/j.cub.2014.11.048

Roth, T. C., II, Rosier, M., Krochmal, A. R., & Clark, L. (2020). A multi-trait, field-based examination of personality in a semi-aquatic turtle. *Ethology*, *126*(8), 851–857. https://doi.org/10.1111/eth.13030

Thomas, R. B. (2002). Conditional mating strategy in a long-lived vertebrate: Ontogenetic shifts in the mating tactics of male slider turtles (*Trachemys scripta*). *Copeia*, *2002*(2)*,* 456-461. https://doi.org/10.1643/0045-8511(2002)002[0456:CMSIAL]2.0.CO;2

Tibbetts, E. A., Pardo-Sanchez, J., & Weise, C. (2022).The establishment and maintenance of dominance hierarchies. *Philosophical Transactions of the Royal Society B, 377*(1845)*,* 20200450. https://doi.org/10.1098/rstb.2020.0450

Valenzuela, N. (2009). The painted turtle, *Chrysemys picta*: A model system for vertebrate evolution, ecology, and human health. *Cold Spring Harbor Protocols, 4*(7), 1-10. https://doi.org/10.1101/pdb.emo124

Financial conflict of interest: No stated conflicts.
Conflict of interest: No stated conflicts.

Submitted: *May 8th, 2024*
Resubmitted: *June 25th, 2024*
Accepted: *July 17th, 2024*