HABITAT USE AND RESPONSE OF FRESHWATER TURTLES TO HUMAN PRESENCE IN AN URBAN CANAL OF CENTRAL NEW JERSEY

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ABSTRACT OF THE THESIS

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Pressures of urbanization and rapid development continue to increase and recreational activities are becoming a prominent force in many urban wildlife communities. Many urban environments are home to freshwater turtles and little attention has been given to the impact of human recreation upon these communities. We examined the response of basking turtles to observer presence along the towpath of a canal in central New Jersey. All four species, except *K. subrubrum,* were more frequently observed basking on log substrate and on substrate with less than 50% canopy cover. Along the towpath, 100% of *K. subrubrum* responded to observer presence by retreating (swimming away), while over 75% of observations on C. *picta, T.s. elegans*, and *P. rubriventris* responded to by retreating. There was a highly significant correlation between the distance from the towpath the turtle was first seen basking by the observer and the distance at which the turtle first responded to the observer. Nearly 80% of the variability in distance to first respond to the observer for *K. subrubrum* was accounted for by including the percent canopy cover, percent cloud cover, and height basking above the water, while less than 30% of the variability was accounted for *C. picta*, *T.s. elegans*, and *P. rubriventris.*

Keywords- human recreation; basking; freshwater turtles; urban wildlife; urban park

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Introduction

The effects of urbanization and human activities on wildlife have been investigated for several years with considerable attention directed towards the adverse effects on threatened taxa and whether effects result in reduced population sizes (Knight and Gutzwiller 1995; Frid and Dill 2002). Most research has concentrated on the impacts on birds, marine mammals, and large terrestrial game species, with much less attention devoted to amphibians and reptiles (Garber and Burger 1995; Burger 2001; Hammer and McDonnell 2008). Much of the literature has focused on species living in wilderness and semi-wilderness areas, nature preserves, and parks (Knight and Cole 1995a; Leung and Marion 2000; Marzano and Dandy 2012), with less attention on recreational activities in urban and suburban areas. Yet approximately 54% of the world's human population resides in urban areas, 82% of United States residents' live in urban and suburban areas (UN 2014), and nearly half the world's population lives within 100 km of coastlines (Crosset et al. 2013).

As development and expansion continues, recreational activities are becoming a leading force in many urban wildlife communities. There are at least six factors (non-consumptive) that can impact wildlife including the type of activity, recreationalist' behavior, impact predictability, impact frequency, timing, and location of human activities (Knight and Cole 1995b). Often recreational activities occur in close proximity to critical habitat areas (Knight and Temple 1995; George and Crooks 2006; Markovchick-Nicholls et al. 2008; Burger and Niles 2013), and the unintended consequences of human activity require further research to better manage local urban habitats and protect sensitive wildlife populations. In this paper we examine the effect of human presence on aquatic turtles in Central New Jersey to partly address this issue.

There is a worldwide decline of reptile and amphibian populations (Blaustein et al. 1994; Gibbons et al. 2000; Stuart et al. 2004), and despite the abundance of information for mammals and birds, little is known about how urbanization and human activities affect herptile populations. Pressures of urbanization and human recreation that negatively affect both reptiles and amphibians include habitat degradation, fragmentation and loss, changes in land cover, environmental pollution, invasive species, and road mortality among others (Garber and Burger 1995; Gibbons et al. 2000; Haxton 2000; Baldwin et al. 2004; Ner and Burke 2008; Andrews et al. 2008; Fahrig and Rytwinski 2009; Bohm et al. 2013). Subsequent consequences are profound, significantly altering life history characteristics for various herptile species and resulting in substantial population declines (Gibbons et al. 2000; Gibbs and Shriver 2002; Jochimsen et al. 2004; Ner and Burke 2008; Price et al. 2006, 2011, 2012; Bulte et al. 2010).

Eastern and central North America supports a variety of semi-aquatic freshwater turtle species (Ernst et al. 1994), several of which are in decline (Ernst and Barbour 1989; Lovich 1995; Gibbons et al. 2000), particularly species in the genera *Clemmys*, *Terrapene*, *Sternotherus*, *Kinosternon*, and *Malaclemys* (Bury 1979; Garber 1988a,b; Ernst and Lovich 2009). Many aquatic and riparian environments in urban areas are home to various turtle species, yet these habitats and the associated effects of recreation are among the most collectively understudied (Knight and Gutzwiller 1995). In locations where recreational activities are common throughout the year, there is a lack of comprehensive understanding of the negative effects of human disturbances, especially for semi-aquatic turtles, largely due to their solitary nature and the difficulty of observation. Semi-aquatic turtles often forage, bask, and nest in these high use recreational areas and data on adverse impacts are needed for management, as it is imperative to keep urban ecosystems intact and conserve inhabiting species amidst expansion and increased recreation.

In this study we observed the behavioral responses of basking turtles to the presence of an observer (recreationalist) along the Delaware-Raritan Canal in central New Jersey. Our specific objectives were to 1) observe the basic ecology of the turtle assemblage living within the urban landscape of the canal, 2) determine species differences in response to human presence/recreation, 3) examine what environmental and physical factors influence the turtle(s) response to human presence, and 4) examine what contributes to differences in response distance and time to the first initial response to human disruption (e.g. person walking).

The Delaware-Raritan Canal is highly developed, moderately managed, poorly studied, and used frequently for various recreational activities that differ from previous studies of turtle basking behavior and human disturbance. In our study region walking, jogging, biking, and fishing occur daily throughout the entire year especially in the spring, summer, and fall months (Burger 2001). In the context of disturbance studies, animals most often perceive humans as potential predators, and the costs of avoidance of human presence and activities can directly and indirectly affect fitness and population dynamics (Garber and Burger 1995; Gill et al. 1996; Gill and Sutherland 2000; Frid and Dill 2002; Gill 2007; Hammit et al. 2015).

Examining the behavioral responses of basking turtles will help to better understand the turtle's risk perception of human recreation, habituation, and potential short and long term impacts upon population structure and life history activities in similar urban settings. These data can inform local managers on turtle assemblage, abundances, and habitat uses, and can be incorporated into habitat and recreational management activities along the canal.

Methods

Study site

The Delaware and Raritan Canal (D&R Canal) is a canal in central New Jersey, United States, built in the 1830's that served to connect the Delaware River to the Raritan River. A feeder canal section (which feeds water into the main canal) stretches 35 km from the east bank of the Delaware to Bull's Island near Frenchtown, NJ. The main section of the canal starting in Bordentown, NJ and ending in New Brunswick, NJ runs approximately 71 km and parallels portions of both the Millstone and Raritan Rivers. The D&R Canal is one of the most popular recreational areas in the state for walking, jogging, biking, fishing, and canoeing in central New Jersey (Delaware and Raritan Canal Commission 2015). Many portions of the canal system runs through an urban landscape consisting of commercial and residential areas, as well as large regions of fragmented floodplain forested corridors. The canal and the park areas are part of the National Recreation Trail System serving as valuable wildlife corridors, connecting fields and forests, and is managed by the New Jersey Department of Environmental Protection's (NJDEP) Delaware and Raritan Canal Commission.

Observations were made along the towpath that runs parallel to the canal, approximately a 3,000m stretch in the New Brunswick / Somerset, NJ area (40º32'25.05 º N, 74º30'49.23 ºW), from May to October 2013 (Fig. 1). In this region the width of the canal is relatively narrow (6-12m) and the bank of the towpath generally rises between 0.5-2.0 m above the water level. This region of the canal rarely experiences sudden or drastic changes in flow rate or water depth due to small damns, water outfalls, and spillways. The study area was chosen because of the moderate bike and pedestrian traffic, ease of access, and lack of debris commonly used for basking, causing any available sites to be in short supply.

The towpath varies from 2-3m wide, and the width of the bank from 1-2.5m. Bank and upland vegetation includes hedgerow and thickets of spicebush (Lindera benzoin), Japanese honeysuckle (Lonicera japonica), greenbrier (Smilax), and Virginia creeper (Parthenocissus quinquefolia) among others. Tree canopy species vary in height and density and include Pin Oak (Quercus palustris), Silver Maple (Acer saccharinum), Red Maple (Acer rubrum), White Ash (Fraxinus Americana), Sweetgum (Liquidambar), and Shagbark Hickory (Carya ovata) (Delaware and Raritan Canal Commission 2015). The opposite side of the canal does not have a towpath or recreational park areas, and is comprised of either relatively undisturbed habitat area or private residential property.

Protocol and Data collection

Data were collected along transects from 19 June to 19 September 2013 between either 0730-1000 EST or 1530-1830 EST. Data were collected twice a week, one weekday and one weekend day, depending on weather. Sampling began later in the season because Central New Jersey received greater rainfall than normal, with an average of 22.5 inches over four months, lowering average water temperatures for the canal (NOAA 2015), and turtles were not observed basking until then. Observations were made by walking the canal in only one direction to eliminate the possibility of sampling the same turtles. Turtles were not captured by hand or trapped for any additional data as the purpose was to observe the turtle's natural behavior and response to human presence. The observer walked at a natural constant speed along the towpath (parallel to the canal), and when a turtle(s) was first spotted, its behavior was recorded. Behavioral information included: turtles' distance from the towpath (m) when first observed, height above the water (in), distance of the observer when first responded (m), time to respond (s), type of response (retreat or remain basking), and whether the turtle(s) returned to the basking site after 60 seconds. Brunton Eterna E825 binoculars were used for aide in identifications and distance measurements were obtained using a Bosch GLM 35 Laser Measure. The observer wore natural and dark suited clothing during all observations.

After behavior was observed and recorded, environmental information was recorded, including: time of day, air temperature, water temperature (recorded by USGS station 01403060), cloud cover, canopy cover over the initial location of the turtle(s), canal width (m), bank width (m), percent the turtle(s) visible from the towpath. Turtle and behavioral information recorded included: species, carapace size group, basking location (log, rock, branch, other), distance from the towpath (m), height above the water (in), distance of the observer when first responded(m), time to respond (s), if the turtle(s) returned to the basking site. In addition, all other pedestrians, cyclists, fisherman, or traffic noise were recorded and data was collected whether the disturbance occurred in the presence of a turtle(s) or not.

This study was designed to provide baseline information on immediate and direct effects of human presence. We replicated the more common and least disruptive recreational activity (walking) that occurs along the canal, and observed immediate changes in basking behavior. Presumably, the distance the observer could first see a turtle was the distance the turtle could first see the observer generally. It also documented information on turtle species diversity, habitat preference, and relative abundance. These numbers are an activity index rather than an estimation of population size because individual turtles may have been counted more than once and some species were easier to observe than others. Each census was conducted for an average of one hour.

Statistical Analysis

Regression procedures were used to examine whether environmental variables such as air and water temperature, canopy cover, and cloud cover contributed to differences in the distance that turtle's first responded to disturbance. Likewise, regression procedures were used to examine the significance of turtle characteristics such as group size, percent visible from the towpath, height above the water, and basking distance from the towpath's edge, for differences in the distance and amount of time the turtles first respond to the presence of people (PROC GLM, SAS 2005). This procedure adds the variable that contributes the greatest to explaining variance (R^2) and continues to add the following variables that increases R^2 until all significant variables are included, as well as interaction variables (i.e. distance to the towpath's edge X distance of first response). Wilcoxin X^2 tests were performed (SAS 2005) to determine whether there were differences among variables as a function of species or other categories. Although analyses were completed on all observations, for determining the effect of human presence and disturbance, only the observations made on the towpath side were used.

Results

A total of 524 observations were made on 30 nonconsecutive days throughout the season. During each census an average of 8.3 people/hr were present in the census transect, including walkers, joggers, bikers, and fisherman (not including the observer of the study). Common Snapping Turtles (*Chelydra serpentina*) were only observed twice and therefore eliminated from the analysis. There was variation in turtle assemblage and habitat use among all four species observed: Eastern Painted Turtles (*Chrysemys picta)* (N=307), Red-eared Sliders (*Trachemys scripta elegans*) (N=109), Redbelly Turtles (*Pseudemys rubriventris*) (N=81), and Eastern Mud Turtles (*Kinosternon subrubrum subrubrum*) (N=27) (Table 1). Overall, there were significant differences among all four species for carapace width (X^2=70.8, p=<0.0001) and their basking locations (X^2=40.2, p=<0.0001).

Habitat Use

Among species there were no differences in average air and water temperature during the censuses, indicating that there was no bias in data collection. All four species were more frequently observed on substrate with less than 50% canopy cover regardless of the day of the census throughout the season (X^2=18.2, p=0.03; Table 1). Significant differences were found in the frequency of observations throughout the season, given water temperature categories (Fig. 2) for *C. picta* (X^2=474.1, p=<0.0001) and *T. s. elegans* (X^2=159.1, p=<0.0001). In colder temperatures, turtles were rarely observed basking, except for *C. picta* toward the beginning and end of the summer season. During the middle and end of the summer season at the warmest water temperatures no turtles were observed basking (Fig. 2).

On the towpath side, *C. picta, T. s. elegans* , and *P. rubriventris* averaged similar basking height above water, whereas *K. subrubrum* basked at an lower average height (X^2=51.2, p=<0.0001). Similar averages were determined for the percent visible from the towpath, distance from towpath edge, and distance from bank edge for all species except *K. subrubrum* (Table 1). On the opposite side of the towpath there were significant differences among *C. picta, T. s. elegans* , and *P. rubriventris* in the percent of the turtle that were visible, with *C. picta* averaging the highest (92.4±1.0; Table 1). No *K. subrubrum* were observed on the opposite side of the canal towpath. *C. picta*, *T. s. elegans,* and *P. rubriventris* were found to have significant differences in habitat use as a function of being on the towpath side opposed to the opposite side of the canal. The differences in percent visible from the towpath were greatest among *C. picta* (X^2=131.0, p=<0.0001), but were also significant for the other two species (Table 1). Between the towpath and the opposite side of the canal, there were no significant differences in basking location, carapace width, or canopy cover for C. *picta*, *T. s. elegans*, and *P. rubriventris.*

Response to Human Presence and Factors Affecting Response Along the Towpath

Turtles had two responses to observer presence: no change in basking position or enter the water and swim away (retreating). No turtles basking opposite the towpath side responded to human presence, and for turtles along the towpath side the response of swimming away was the most frequent response for all four species (Table 2). For the turtles that swam away, all four species showed a highly significant correlation between the distances from the towpath the turtle was first seen and the distance at which the turtle first responded to the observer (Fig. 3). *C. picta*, *T. s. elegans*, and *P. rubriventris* had the highest Kendall Tao correlation coefficient (<0.0001) and *K. subrubrum* were also highly correlated (0.0002). The distance at which the turtles were first seen varied significantly among species for the towpath side observations and *K. subrubrum* were first seen at closer distances (X^2=59.1, p=<0.0001). Regardless of how far away the turtle was first seen, there was variation among all four species for the average distances at which they first responded to human presence (X^2=8.6, p=0.04; Table 2). For all turtles that responded by retreating, none returned to their basking location within 60 seconds.

While 100% of *K. subrubrum* responded to observer presence by retreating, not all turtles among the other three species responded by retreating. *C. picta* had the highest frequency of no response (23.6%) and *T. s. elegans* had the second highest (Table 2). For the turtles that did not respond to human presence, the only significant variable was distance of the turtle to the towpath edge. Turtles of the three species that did not respond had a greater average distance from the towpath edge, compared to the turtles that retreated (Table 2).

There were significant models explaining variation in the distance at which turtles first responded to human presence along the towpath side for all species, except P. *rubriventris* where no factors entered (Table 3). Nearly 80% of the variability for *K. subrubrum* was accounted for by the percent canopy cover, percent cloud cover, distance from the towpath edge, and height basking above the water (F=12, p=<0.0001). For *C. picta* percent canopy cover, percent cloud cover, and the distance to the towpath edge entered as factors, however the model only accounted for 20% of the variation (F=4.1, p=0.0001). While percent visible from the towpath contributed significantly for *T. s. elegans*, the other variables did not (5.1, p=0.03; N=63). None of the variables entered for *P. rubriventris*, and none of the interactions (e.g., group size X distance to towpath edge, percent visible X distance to towpath edge) entered the model to explain variation in the distance of response behavior for any of the four species.

For both *C. picta* and *P. rubriventris*, no variables explained the variation for the time elapsed before turtles first responded to observer presence (Table 3). For *K. subrubrum*, the percent visible from the towpath accounted for 50% of the variation in the time elapsed before turtles first responded to observer presence. The basking height above the water was found significant for *T. s. elegans*, however only 37% of the variation the model was accounted for.

The average individual time elapsed before the turtle first responded to human presence varied significantly among species (X^2=43.5, p=<0.0001), with *C. picta* averaging 6.4 seconds compared to *K. subrubrum* at 2.8 secs (Table 2). Similarly, significant differences among all four species were found for number of observations and the duration of time elapsed from when the observer first saw the turtle to the time the turtle first responded to human presence (X^2 68.9, p=<0.0001) (Fig. 4). For *C. picta* and *P. rubriventris* a higher percentage responded after a longer duration of elapsed time, indicating that the observer (disturbance) was closer to the turtle along the towpath during the response. For *K. subrubrum* however, a higher percent responded within 1-3 seconds (75%), indicating that the turtle responded almost immediately once being aware of observer presence.

Discussion

The main findings of this study are 1) there is a diverse turtle community including *K. subrubrum* which was not noted in previous studies, and further research should include population estimates viability 2) turtles were most often observed in groups on logs that extended outward away from the towpath with close to or less than 50% canopy cover, and 3) turtles were vigilant and the majority retreated almost immediately to the presence of the observer.

Basking Behavior

The turtle assemblage in the canal was diverse, with persistent populations, despite frequent recreation and poorly managed habitat (Burger, unpub. data). Our observations corroborate with Duchak and Holzapfel's (2010) study of Emydid turtles across urban to rural habitat gradients in New Jersey, which is the only other known study that has examined turtles within a region of the Delaware Raritan Canal. Duchak and Holzapfel (2010) found *C. Picta*, *T.s. elegans*, and *P. Rubriventris* occurred more frequently together in habitats with higher percent development, and where *T.S. elegans* cohabitated with natives, they were usually outnumbered by any one of the native species, which is consistent with our observations. *C. picta* is one of the most common and abundant species throughout its range and has been found to thrive in urban habitats elsewhere (Baldwin et al. 2004; Connor et al. 2005; Bowen and Janzen 2008). We observed *K. subrubrum* infrequently, and Duchak and Holzapfel (2010) had no observations of this species, which is expected because *K. subrubrum* exhibit lower survivorship and recruitment values in developed areas as a result of their dependence on upland habitat for use in overwintering. This may leave the species more vulnerable to human disturbance and predators that are more abundant in urbanized environments such as our study area (Harden and Dorcas 2008; Harden et al. 2009).

Our observations are an activity index rather than population estimates or indices of annual recruitment and population viability, however they provide insight to the population structure of the four species and warrant further investigations. We observed variation among the body sizes of *C. picta*, and for this species, significant variation in individual juvenile growth rates and average population body size has been found in urban environments elsewhere (Mitchell 1988; Lindeman 1996; Rowe 1997) as well as temporally within *C. picta* populations (Frazer et al. 1991a, 1993). Likewise, for both *P. Rubriventris* and *T. s. elegans* more than half of the turtles observed were large-bodied, and body size greatly contributes to differences in basking duration since heating rates are reduced in larger turtles (Foley and Spotila 1978), which may be the cause for the observed size differences. Further investigation on the size variation and reproductive health of these species, especially *K. subrubrum*, should include additional body measurements, sexing to investigate sex ratios, sexual size dimorphism, and relative sex-biased basking patterns which have been observed for *C. picta*, *T. scripta*, and *P. Rubriventris* elsewhere (Gibbons and Lovich 1990; Forsman and Shine 1995; Carriere et al. 2008).

Habitat Use

Many basking studies have found that the most frequently used basking sites are those located far from shore and in deeper water (Flaherty and Bider 1984; Pluto and Bellis 1986; Lindeman 1999; Cadi and Joly 2003). Our study observed habitat use while basking, not habitat selection. However, for all species except *K. subrubrum,* logs near the bank of the towpath were the most preferred basking substrate (50-60%). Turtles were often observed on logs that extended outwards from the bank and allowed a range of distance from the towpath. Nearly half of the total observations made were of turtles on the opposite side of the canal where there is no towpath, only vegetation and some legs, with little human access. *K. subrubrum* was observed most often basking on rocks, presumably due to the fact that rocks only sit along the banks of the canal in this region in the shallowest of water with soil and wet vegetation adjacent, and this is their preferred habitats. In our study region, except for the cleared bank areas, it was not feasible to get to the water's edge without causing disruption and limiting the ability to study natural basking behavior, as basking turtles are wary and extremely vigilant. Therefore we could not assess the abundance of turtles basking in submerged aquatic vegetation, which often reduces the risk of potential predation from terrestrial organisms (Ernst et al. 1994), and would be an expected behavior for turtles in urbanized habitats with frequent human presence. However, in observing turtles on the opposite bank, we only saw them basking on logs or rocks, and not in any aquatic vegetation.

Similarly, Peterman and Ryan (2009) found that in an extensively managed canal system, also with a towpath where bank vegetation such as downed trees was readily removed, both *C. Picta* and *T.s. elegans* were observed most on emergent deadwood that was distant from the bank compared to the more readily available rock basking sites closer to the bank of the towpath and human disturbance. When bank vegetation was mowed and debris was cleared all turtles species in their study reduced basking in the area, independent of substrate type, because they were less sheltered from human disturbance in adjacent recreational areas (Peterman and Ryan 2009). Likewise, we observed areas along the towpath of the D&R canal where there was little to no bank vegetation acting as a ‘shelter’ and logs were present and extending opposite the towpath, yet no turtles were using the substrate to bask. For both *C. picta* and *T.s. elegans* basking behaviors are variable among populations, and are largely dependent upon the landscape in which the turtles inhabit (Leuritz and Manson 1996; Lefevre and Brooks 1995; Cadi and Joly 2003; Peterman and Ryan 2009). Studies of semi-aquatic turtles in urban areas with high human recreation have shown that, regardless of substrate type, the preferred basking locations were substrates that were more distant from human disturbance (whether foot or road traffic) or increased predation (Connor et al. 2005; Lopez et al. 2005; Moore and Seigel 2006).

Most turtles were observed in groups ranging from 2-7 individuals, and groups varied with different combinations all four species. *K. subrubrum* was usually observed alone. All four species were also observed basking solitarily, which was unexpected for this urbanized area because solitary basking turtles have fewer eyes to watch for potential threats (Auth 1975) and basking substrate distant from the towpath is not plentiful. About a third of the available rock and log substrates along the towpath were unoccupied, while a group of basking turtles were observed basking nearby. The variable basking pattern is comparable to previous findings (Pluto and Bellis 1986), where turtles did not use all available basking sites, and often clustered around specific sites or areas, but there can be several ecological and landscape variables that contribute to this occurrence.

Observing these species basking both in groups and solitarily, but also not utilizing available basking locations nearby, could indicate that competition for basking substrate is not occurring directly or frequently in the population despite limited basking substrate due to previous clearings. Cadi and Joly (2003) found that native pond turtles shifted their basking activity toward lower quality substrates, while the dominant *T.s. elegans* occupied the better basking sites. *T.s. elegans* is a non-native turtle species of New Jersey, and can pose a serious threat to other native species by competing for food and basking sites (Cadi and Joly 2003, 2004; Polo-Cavia et al. 2010). The extent to which *T.s. elegans* interacts competitively in our study region is unclear and the outcome of competition depends on differences in the abilities of each species to use habitat resources. The differences we observed in basking distribution may reflect substrate preferences or a combination of variables (Ernst et al. 1994), and when basking sites are in short supply, emydid turtles will actively compete for them. This should be further investigated as competition may be present and additional basking substrate may be considered in future management options.

The majority of turtles preferred basking in close to or less than 50% canopy cover (Table 1) except for *K. subrubrum* that preferred the least amount of canopy cover, which was expected as they do not bask often and may be in need of greater thermoregulation (Gibbons and Semlitsch 1991; Frazer et al. 1991b). Preferences in canopy cover could reflect a combination of landscape preferences such as the air and water temperature or the amount solar radiation reaching the basking site. On the other hand, canopy cover preferences could serve as a method to reduce predation risk by limiting the detection ability of the predator. The amount of recreational activity along urbanized habitats, such as the towpath, could force turtles to bask under denser canopy cover to remain well hidden. Preferences for high canopy coverage may decrease the ability of an approaching predator to detect the turtle, whereas basking areas under less coverage may allow the turtle to visually detect the predator sooner. This effect of vegetation cover on escape decisions has been found in some lizards (Martín and López 2000a) and chameleons (Cuadrado et al. 2001). In a rapidly developing urban region of New Hampshire, Marchland and Litvaitis (2004) found forest coverage significantly contributed to the basking behavior and general habitat selection for the *C. Picta* population, and their abundances were higher in areas of greater coverage. Similarly, in a highly managed urban canal, Peterman and Ryan (2009) observed reduced usage of basking sites for *C. picta* and *T.s. elegans* when shoreline grass was mowed, because they were less sheltered from human disturbance in adjacent recreational areas.

Effect of Human Presence

Animals should retreat from human presence as they would from predators only when the costs (injury or death) outweigh the benefits of remaining (securing food or a basking location). Short of injury or death, the response of turtles to human presence can be studied in the same way as the response to predation; by studying a change in their behavior in response to people. In our study, turtles reduced their use of basking resources and overall duration of basking time. In the case of the D&R canal, people (especially young children) are often the most important predators: turtles are harassed, moved, collected, or poached. During this study people were observed walking off the towpath down the bank area to view turtles more closely or take pictures. We saw young children throw rocks at the turtles along the towpath (Pittfield pers. obs.). Further, some people collect them to later release them as part of a religious practice and in other occasions outside of the study area some turtles were taken for this purpose (Burger pers. obs.).

When an encounter occurs, either the recreationist sees the turtle first or the turtle detects the recreationalist first. Given the physical vegetation and design of the towpath, we assumed when the observer was first able to see the turtle, the turtle also detected the observer's presence. For all four species there was a strong correlation between the distance the turtle was first seen by the observer and the distance of the observer when the turtle first responded by retreating. Very little distance walked (and time) elapsed before the turtle retreated, regardless of the initial distance the turtle was first seen by the observer. Therefore these turtles were actively alert and vigilant, detected the observer's presence as soon as possible, and perceived the observer as a large enough risk to forfeit a basking location. These findings agree with the optimal escape theory which suggests that prey should not flee immediately upon detection of a predator, but rather wait until the predator approaches closer than the point at which risk is equal to escape costs (Ydenberg and Dill 1986).

Our distance-response correlation is similar to Burger's (2001) study with Northern Water Snakes (*Nerodia sipedon*) and Common Gartersnakes (*Thamnophis sirtalis*) along the D&R canal, which found that individuals fled rapidly when humans were walking by on the tow path, especially when the walkers stopped to watch the snakes instead of walking past. Our response-distance correlations may be similar to the snake's behavior (Burger 2001) because there is greater perceived risk from slower-moving 'predators' since predators are more likely to detect and pursue their prey in that fashion, and turtles perceive slower moving humans as a greater risk than faster moving recreationalist (e.g. bicyclists). This could be further investigated along the towpath by observing joggers and bicyclists at varying speeds as the primary human intruder.

In a habitat-related visibility study on escape decisions, using approaching humans as a predator stimulus, Lopez et al. (2005) found Spanish Terrapin's (*Mauremys leprosa*) abandoned basking sites at the first sign of humans. Approach distances (distance of escaping turtle when first detected by observer) varied depending on the habitat type; approach distances in small stream areas were significantly shorter than in larger habitat regions such as the river or open pond. In habitats with greater probability that a predator could detect the turtle or where the turtle could see the predator sooner, turtles fled more quickly. Lopez et al. (2005) also found that approach distances and responses varied due to the side and distance from the towpath, implying that the probability a predator could access the turtle was greater on the towpath side so turtles fled sooner, which is similar to our study as no turtles opposite the towpath side responded to human presence.

Peterman and Ryan (2009) also found habitat use and basking percentages for *T. s. elegans* and *C. Picta* were altered in areas frequently exposed to human disturbance in the Central Canal of Indianapolis. Basking never occurred within 50 m of any canal-management activities and turtles quickly submerged themselves following minimal human activity. Furthermore, following any vegetation removal, sites that became more exposed to human activities were abandoned as basking locations by all juvenile and hatchling turtles (Peterman and Ryan 2009).

None of the turtles that retreated returned to their basking location during the individual observation period, which was expected because by remaining in the water or swimming to another location, turtles reduce the risk of potential predation from terrestrial organisms (Ernst et al. 1994). The observer only waited 60 seconds after each departure, and turtles may have returned several minutes later to the original basking location. However no turtles were observed moving to another nearby basking location immediately after retreating. The presence of a walking human along the towpath ended basking sessions and therefore the overall daily basking duration was reduced, especially since it should be assumed disturbance from other human recreationalist happens several times every day. Basking is a necessary and vital activity for freshwater turtles (Boyer 1965) , and if basking is continually interrupted, turtles may not be able to reach high body temperatures during the spring and fall months, which could result in negative consequences for energy acquisition and reproduction among other costs (Grayson and Doracs 2004; Gibbons et al. 2000; Selman et al. 2013).

There was a small number (N=49) of turtles along the towpath side that did not respond to observer presence in our study. This could be due to a combination of different variables such as the distance from the towpath or the amount of canopy cover for the turtle, as these were significant for the turtles that did respond. On the contrary, this could suggest possible tolerance to continuous and increasing rates of human recreational activities along the Raritan Canal. Most often tolerance to frequent human disturbances is partial (Burger and Gochfeld 1990; Burger 2001; Frid and Dill 2002), and we assume that repeated exposure to a nonlethal stimulus causes some habituation especially under less threatening conditions, for example greater distances from the disturbance. Tolerance to urbanization and human presence has been found for various turtle species. At a local scale, Hill and Vodopich (2013) observed greater abundances of basking frequencies of Texas River Cooter (*Pseudemys texana*) and *T.s. elegans* in areas of high shoreline modification along a riparian corridor in Texas. Despite being dislodged from basking sites by passing watercrafts, Moore and Seigel (2006) found Map Turtles (*Graptemys flavimaculata)*, tolerated disturbance and reemergence and was common, however nesting behavior was negatively impacted. Bowen and Janzen (2008) found that the intensity of human recreation at a major nesting beach had no effect on the decision of C. *picta* to emerge for nesting habitat selection and further nesting activities.

Given the increasing rates of urbanization, habitat alteration, and human recreation, it is essential to conduct long-term ecological and evolutionary studies on human-influenced populations to better understand habituation or the effects on population dynamics, especially in long-lives species like freshwater turtles Maintaining healthy, viable populations in urban areas is essential to maintain general biodiversity, increase human awareness of wildlife, and engender appreciation for protection and conservation (Burger et al. 2013).

Management Implications

As urbanization continues, especially in coastal areas, our data can serve as a baseline for more complex investigations of the population ecology and potential effects of human recreation on the turtle species for both the D&R Canal and other metropolitan areas. Future research should involve daily sampling and mark-recapture methods to obtain a better understanding of the emydid turtle community composition other local areas of the canal that experience greater recreational use. This is not easily achieved, and we agree with Duchak and Holzafel (2011) that a supplemental New Jersey Fish and Game sponsored program, similar to other citizen science programs (e.g. Christmas Bird Count of Audubon Society) should be established that encourages volunteers to conduct periodic surveys throughout the state, observing turtle species in particular locations to gather insightful information about the abundance, distribution, and overall health of the turtle populations. Citizen science and the involvement of volunteers of all ages is an effective way to educate the public and also collect and evaluate methods of testing data reliability and evaluate information to be used in conservation and management. (Tsipoura and Kelly 2015). Further, such studies should be conducted in other urban and coastal areas along the Atlantic coast where human populations are increasing rapidly (Crosset et al. 2013).

To effectively manage urban habitats, it is important to incorporate the spatial ecology and habitat use of the species utilizing them. We found that basking substrate, canopy cover, and distance from the towpath were all significant factors in habitat use and the disturbance response of turtles, which emphasizes the importance of recognizing the connection between aquatic and surrounding terrestrial habitats, especially in urban ecosystems. Therefore, if maintaining healthy and optimal conditions for basking turtles is a priority of managers of urban parks, then minimal amounts of debris and vegetation should be cleared from bank areas and adjacent terrestrial habitat to provide adequate basking sites. Because this towpath is so frequently used for recreation, we acknowledge that minimal clearing could present a safety hazard in some areas (e.g. Poison Ivy, scratches, ticks), so we also suggest building basking platforms to address this problem. Platforms could be placed on the towpath side, as well as towards the center of the canal under various amounts of vegetation, but also opposite the towpath side so turtles have sufficient places to bask under vegetation without being disturbed by passing pedestrians.

Our results indicate that human recreational activities, such as walking, decrease basking duration in the species studied, and due to the importance of basking and further potential negative consequences, we suggest additional management of this region to minimize the effects of human activities. Because distance from the towpath was a highly significant variable to both habitat use and disturbance, we encourage managers of urban parks to avoid constructing recreational towpaths within a minimum of 3-4 meters from water's edge. We suggest this distance based on the average distance from the towpath that turtles retreated from walking people. Because no turtles that were basking on the opposite bank of the canal responded, our data also indicate if there is sufficient distance between the basking location and recreational activity along a towpath, basking is not disrupted. The exception is boating activities, which may occur at higher rates in other areas of the D&R canal or in other recreational areas. Our results indicate basking turtles are disturbed by minimal human recreation, which warrants further investigation on the threats posed by more intrusive activities on both basking and nesting. Signs should be placed at entry points and along the canal towpath to caution and educate pedestrians on the ecology of turtles, snakes, and other wildlife, especially for basking turtles.

The relationship between human recreation and factors affecting turtle populations are complex, and as urbanization increases, long-term persistence in the face of frequent and increasing disturbances is uncertain. Effective management and conservation of urban wildlife is dependent upon understanding the effects that urbanization and associated activities has on a species. Along the D&R canal and in other recreational areas that are poorly managed, the role of recreational disturbances upon turtles, in both aquatic and terrestrial habitats of urbanized areas must be further evaluated to determine effects on both a local and broad scale (Klemens 2000; Hammit et al. 2015). Understanding the long-term dynamics of long-lived organisms with long generation times such as freshwater turtle populations, it is important to fully understand the impacts of human disturbances in changing urban environments. There may be long delays before population responses are detectable and short term studies of turtle community responses to human induced changes may not reflect ultimate consequences, thus long-term studies should begin promptly to monitor turtle populations in areas of high human activity (Gibbons 1987; Garber and Burger 1995; Smith et al. 2006). Monitoring needs to continue for many years to assess species-specific and demographic responses to disturbance to ensure sound management decisions and the persistence of wildlife in highly modified urban habitats.

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Figure Legends

Figure 1. Map of central New Jersey showing approximate study location along Delaware-Raritan Canal towpath. Study area spans between Middlesex and Somerset County borderline.

Figure 2. Frequency of observations of *K. subrubrum*, *C. scripta*, *T.s. elegans*, and *P. rubriventris* as a function of water temperature (C°) and week of observation during basking season. Given is Chi square and p-values. NS= not significant.

Figure 3. For the towpath side only, correlation between the distances at which each species was first seen by observer by the distance at which turtle first responded to observer presence. Only for turtles that responded to observer presence by retreating (swam away). Given are Kendall Tao values. <0.05=significant.

Figure 4. For the towpath side only, percentage of each species that responded by retreating to observer presence as a function of elapsed time from when the observer first saw the turtle. Given is the Chi square and p value.

Table 1. Comparison of habitat use for four species of freshwater turtles as a function of physical characteristics in the Delaware Raritan Canal in Central NJ . Given are means ± standard error or frequency of observations. NS=not significant, NA=Not Available.

Species	**Painted Turtle**	**Red Eared Slider**	**Redbelly Turtle**	**Mud Turtle**	**Kruskal-Wallis X^2 (p)**
Environmental Variables (All observations)					
n	**307**	**109**	**81**	**27**	
Water Temperature (°C)	25.1 ± 0.1	25.7 ± 0.2	25.0 ± 0.2	26.1 ± 0.4	7.9 (0.05)
Air Temperature (°C)	82.2 ± 0.5	83.1 ± 0.7	81.4 ± 0.8	84.4 ± 1.2	4.0 (NS)
Canopy Cover					
0-25 %	38.4 ~~%~~	37.6 %	23.5%	44.4%	
25-50 %	39.7 %	45.9 %	40.7%	37%	
50-75 %	16.0 ~~%~~	9.2 %	22.2%	18.5%	
75-100 %	5.9 %	7.3 %	13.6%	-	
					18.2 (0.03)
Cloud Cover					
0-25 %	18.2~~%~~	15.6 %	28.4%	18.5%	
25-50 %	32.6%	32.2 %	30.9%	11.1%	
50-75 %	34.9%	38.5 %	27.2%	44.4%	
75-100 %	14.3%	14.7%	13.6%	25.9%	
					13.0 (NS)
Turtle Size Characteristics (All observations)					
Carapace Width					
S (<6 in.)	19.2~~%~~	12.8%	33.3%	51.9%	
M (6-12 in.)	45.0%	73.4%	59.3%	48.2 %	
L (>12 in.)	35.8%	13.8%	7.4%	0%	
					70.8 (<0.0001)
Basking Location					
Rock	35.8%	34.9%	48.2%	48.2%	
Log	60.3%	60.1%	51.9%	25.9%	
Bank	3.9%	4.6%	0%	25.9%	
Submerged Vegetation	0%	0%	0%	0%	
					40.2 (<0.001)

Turtle Variables (Opposite Towpath Side)					
n	**163**	**46**	**36**	**0**	
Percent Visible From Towpath	92.4 ± 1.0	87.8 ± 1.6	86.5 ± 2.0	NA	16.1 (0.0003)
Height Above Water (in)	7.4 ± 0.2	7.4 ± 0.3	7.4 ± 0.3	NA	0.01 (NS)
Distance to Towpath Edge (m)	8.3 ± 0.1	8.3 ± 0.1	8.6 ± 0.1	NA	4.5 (NS)
Distance to Bank Edge of Towpath Side (m)	6.7 ± 0.1	6.8 ± 0.1	6.9 ± 0.1	NA	1.0 (NS)
Turtle Variables (Towpath Side Only Observations)					
n	**144**	**63**	**45**	**27**	
Percent Visible From Towpath	66.5 ± 1.6	65.1 ± 2.2	66.0 ± 2.9	51.3 ± 2.9	14.2 (0.003)
Height Above Water (in)	7.0 ± 0.2	7.0 ± 0.2	6.7 ± 0.2	4.2 ± 0.2	51.2 (<0.0001)
Distance to Towpath Edge (m)	3.0 ± 0.1	3.0 ± 0.1	3.1 ± 0.1	2.0 ± 0.1	47.1 (<0.0001)
Distance to Bank Edge of Towpath Side (m)	1.5 ± 0.1	1.4 ± 0.1	1.4 ± 0.1	0.5 ± 0.3	35.6 (<0.0001)
Kruskal-Wallis X^2 (p) Turtle Variables (Opposite Side vs. Towpath Side)					
Percent Visible From Towpath	131.0 (<0.0001)	42.3 (<0.0001)	27.0 (<0.0001)	NA	
Height Above Water (in)	3.5 (NS)	1.2 (NS)	2.6 (NS)	NA	
Distance to Towpath Edge (m)	231.0 (<0.0001)	80.0 (<0.0001)	60.3 (<0.0001)	NA	
Distance to Bank Edge of Towpath Side (m)	229.0 (<.0001)	79.4 (<0.0001)	60.0 (<0.0001)	NA	

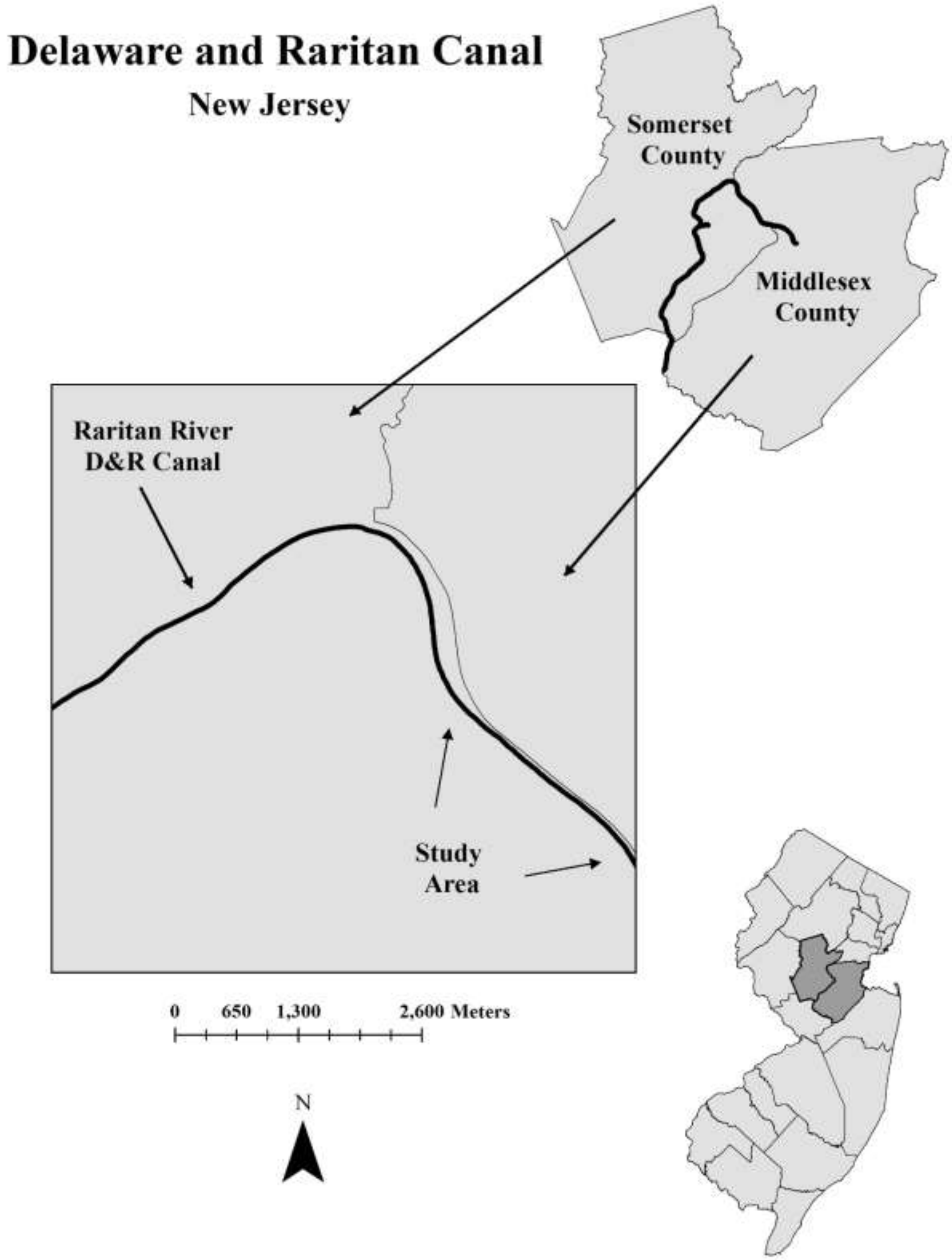
Table 2. Behavioral responses of turtles to human presence (observer). Observations include only turtles on the towpath side. NA=Not available.

Characteristic	**Painted Turtle**	**Red Eared Slider**	**Redbelly Turtle**	**Mud Turtle**	**Kruskal-Wallis X^2 (p)**
n	**144**	**63**	**45**	**27**	
Distance Turtle First Seen by Observer (m)	4.3 ± 0.07	4.5 ± 0.1	4.5 ± 0.1	2.6 ± 0.1	59.1 (<.0001)
Distance of Observer When First Response Occurred (m)	2.1 ± 0.10	2.4 ± 0.2	2.5 ± 0.2	2.1 ± 0.1	8.6 (0.04)
Overall Response Type (%)					
Swim Away	76.4%	85.7%	86.7%	100.0%	
No Response	23.6%	14.3%	13.3%	0%	10.4 (0.01)
Initial Distance of Turtle from Towpath Edge (m)					
Swim Away	2.8 ± 0.1	2.8 ± 0.1	3.0 ± 0.1	NA	
No Response	3.5 ± 0.1	4.1 ± 0.1	4.0 ± 0.4	NA	
X^2	27.0 (<0.0001)	21.2 (<0.0001)	6.5 (p=0.01)		
Time Elapsed Between Turtle First Visible to Observer and Turtle First Response to Observer Presence (sec)	6.4 ± 0.2	5.9 ± 0.3	6.2 ± 0.4	2.8 ± 0.4	43.5 (<.0001)
Percent Return before 60 sec	0%	0%	0%	0%	

Table 3. Model explaining variation in distance and time turtles' responded (m) to human observer for towpath side observations only. NS= not significant

	Painted Turtles		**Red Eared Slider**		**Redbelly Turtle**		**Mud Turtle**	
	Distance to Respond	**Time to Respond**	**Distance to Respond**	**Time to Respond**	**Distance to Respond**	**Time to Respond**	**Distance to Respond**	**Time to Respond**
Model								
F	4.1	2.1	2.6	2.8	1.0	1.5	12	2.1
p	0.0001	0.04	0.02	0.01	0.5	0.2	<0.0001	0.09
r^2	0.21	0.16	0.31	0.37	0.20	0.3	0.80	0.50
Factors entering (F, p)								
Canopy Cover	2.9 (0.04)	2.2 (NS)	0.9 (NS)	2.4 (NS)	0.5 (NS)	2.1 (NS)	20.3 (<0.0001)	0.1 (NS)
Cloud Cover	3.7 (0.01)	0.4 (NS)	0.8 (NS)	0.5 (NS)	0.6 (NS)	2.1 (NS)	3.4 (0.05)	1.0 (NS)
Distance to Towpath Edge (m)	10.8 (0.001)	0.4 (NS)	2.7 (NS)	2.5 (NS)	0.6 (NS)	0.1 (NS)	0.48 (NS)	0.03 (NS)
Percent Visible From Towpath	0.7 (NS)	3.4 (NS)	5.1 (0.03)	10.6 (0.002)	2.1 (NS)	1.4 (NS)	7.0 (0.02)	5.2 (0.04)
Height Above Water (in.)	0.6 (NS)	1.5 (NS)	0	4.0 (0.05)	0.2 (NS)	0.2 (NS)	13.2 (0.002)	0.8 (NS)

Figure 1.



County and river data from NJDEP, 2016.

Figure 2.

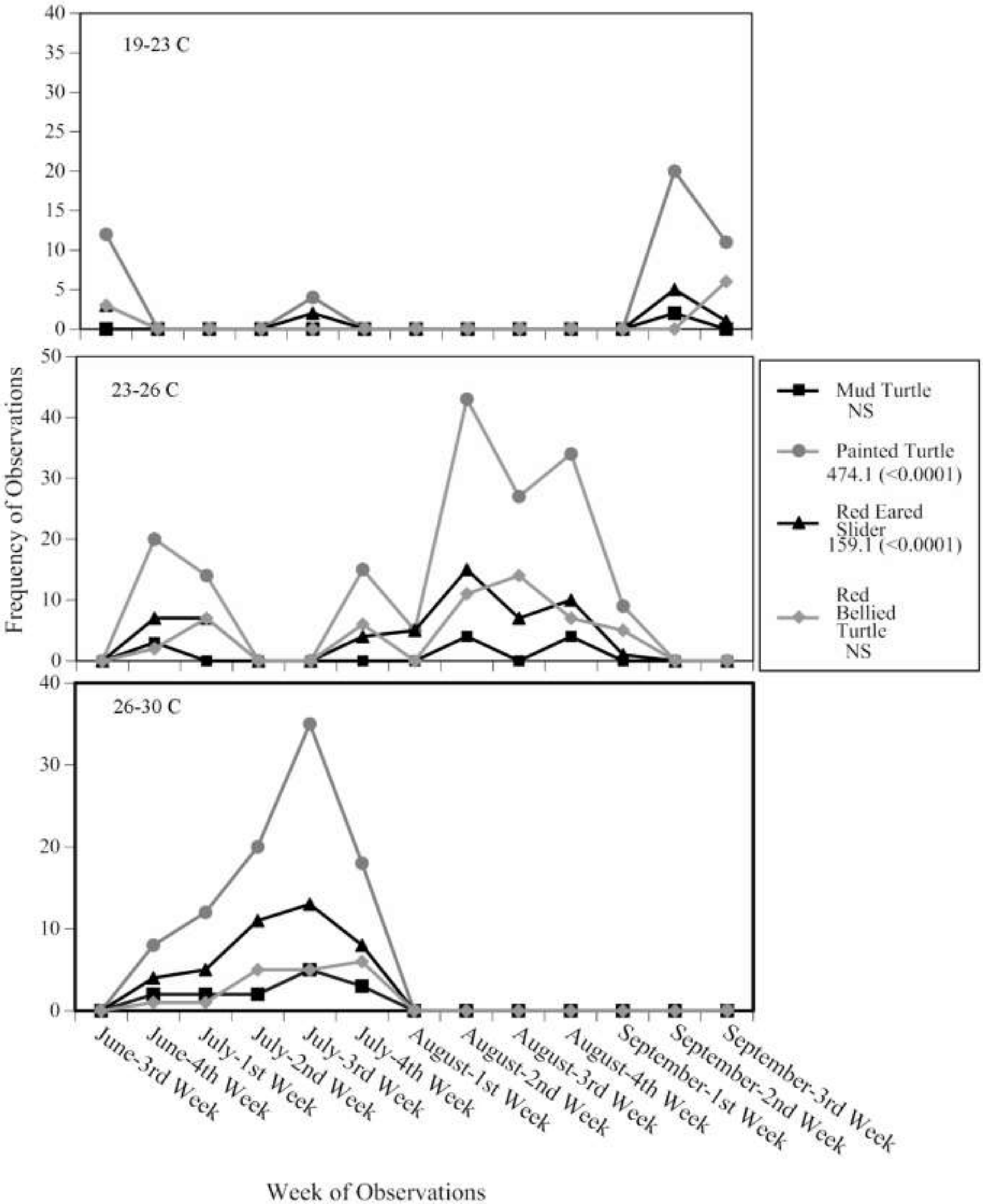

19-23 C
23-26 C
26-30 C
Frequency of Observations
Mud Turtle NS
Painted Turtle 474.1 (<0.0001)
Red Eared Slider 159.1 (<0.0001)
Red Bellied Turtle NS
June-3rd Week
June-4th Week
July-1st Week
July-2nd Week
July-3rd Week
July-4th Week
August-1st Week
August-2nd Week
August-3rd Week
August-4th Week
September-1st Week
September-2nd Week
September-3rd Week
Week of Observations

Figure 3.

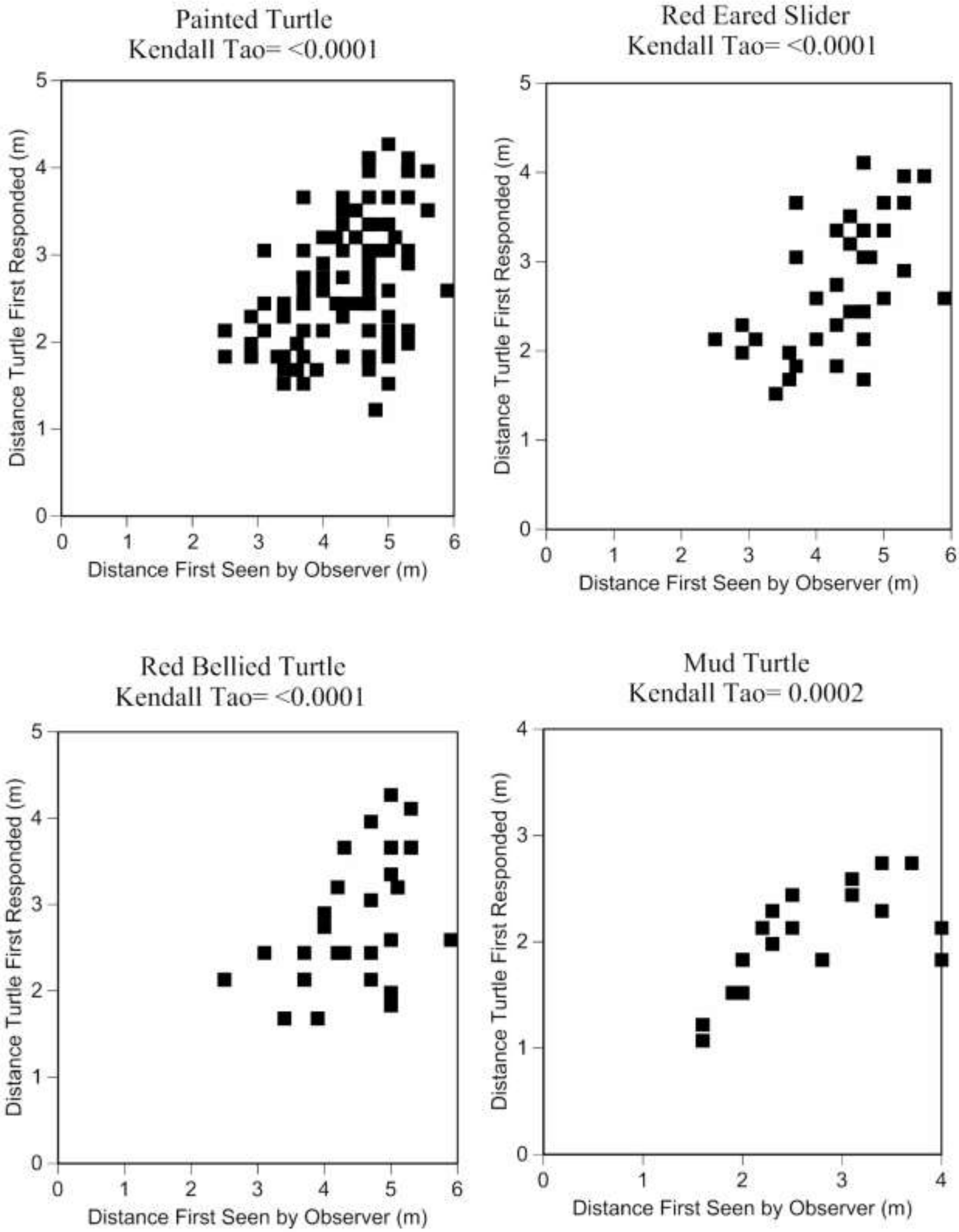
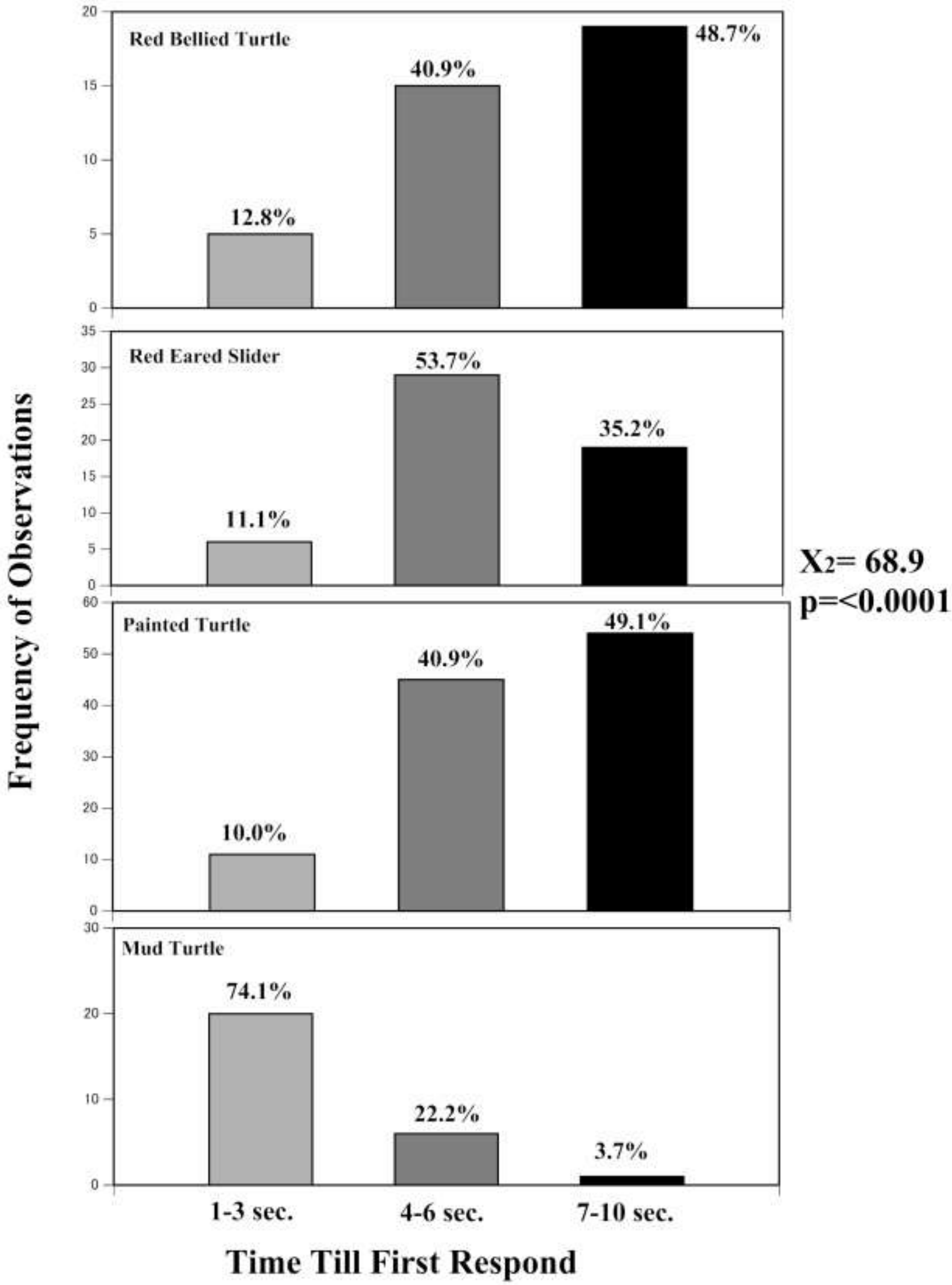

Painted Turtle
Kendall Tao= <0.0001
Distance Turtle First Responded (m)
Distance First Seen by Observer (m)
Red Eared Slider
Kendall Tao= <0.0001
Distance Turtle First Responded (m)
Distance First Seen by Observer (m)
Red Bellied Turtle
Kendall Tao= <0.0001
Distance Turtle First Responded (m)
Distance First Seen by Observer (m)
Mud Turtle
Kendall Tao= 0.0002
Distance Turtle First Responded (m)
Distance First Seen by Observer (m)

Figure 4.


Red Bellied Turtle
12.8%
40.9%
48.7%
Red Eared Slider
11.1%
53.7%
35.2%
Painted Turtle
10.0%
40.9%
49.1%
Mud Turtle
74.1%
22.2%
3.7%
Frequency of Observations
1-3 sec.
4-6 sec.
7-10 sec.
Time Till First Respond
X2= 68.9
p=<0.0001