

Factors affecting leech parasitism on four turtle species in St. Lawrence Islands National Park

by

Nikki Reshke

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University of Ottawa

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Supervisor: Dr. Blouin-Demers

Abstract:

Parasitism is a very common symbiotic relationship in nature where one organism draws its energy for reproduction and survival at the detriment of a host. The goal of this study was to look at the temporal patterns (month of capture) and host susceptibility (species, size and body condition) in the host-parasite interaction between four turtle species found in St. Lawrence Islands National Park and their associated leeches. During the months of May to August 2008, leeches were counted and measured to determine their prevalence and biomass respectively on a total of 324 turtles from four turtle species: Map Turtles (*Graptemys geographica*), Blanding's Turtles (*Emydoidea blandingii*), Common Musk Turtles (*Sternotherus odoratus*) and Painted Turtles (*Chrysemys picta*). Leech prevalence and biomass followed the same trends for each characteristic studied. They both varied significantly by species, but showed no difference over the course of the four months when turtle species were pooled. Within a species, there was no correlation between leech prevalence and biomass and a turtle's size or body condition. The results from my study indicate that turtle species, due to the interaction of habitat and basking tendencies, plays the biggest role in affecting host-parasite dynamics between turtles and leeches. These results add to the limited information currently available on this topic and demonstrate the need for further investigation on the same turtle species both at similar and different habitats and geographic locations to broaden our understanding of host-parasite interactions.

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Introduction:

Symbiotic relationships, where different species closely interact, are very common in nature. These interactions can be classified as: mutualism, where both organisms in the relationship benefit; parasitism, where the relationship is beneficial for one organism and harmful for the other; and commensalism, where one organism benefits and no harm is done to the other organism (Redman et al, 2001). Parasitism, defined as a relationship where one organism draws its energy for reproduction and survival at the detriment of a host (Heeb et al, 1998), is a common relationship seen in many organisms. Parasites can be one of several types, be it an endoparasite which survives within the host or an ectoparasite which survives on the outer surface of the host. In both cases parasites have the potential to reduce immensely the fitness of their host, which is a function of the virulence of the parasite (Heeb et al, 1998). In this study, I examined the parasitic relationship between leeches and turtles found in the St Lawrence Island National Park.

Two species of leeches, *Placobdella Parasitica* and *Placobdella Ornata* are the main leech species infecting North American turtles (Maloney and Chandler, 1976). These species of leech are a type of ectoparasite which can depend on several different organisms for their survival including vertebrates such as reptiles and fish, or invertebrates such as crustaceans and water snails, but their preferred hosts are turtles (Sawyer, 1972). Parasitic leeches have the capacity to cause major reduced fitness in their hosts and even death depending on environmental conditions and leech abundance (Berven and Boltz, 2001). These leeches are most often found in the shallow waters of highly productive, eutrophic lakes. They are sometimes seen swimming freely in the

water column, but are more often associated with the benthic community where they attach to the substrate and submerged vegetation, stones and logs (Sawyer, 1986). While *P. Ornata* is often found free-living in the environment, *P. Parasitica* is more often found attached to a host and will often stay attached to the host after a blood meal (Maloney and Chandler, 1976). It has been suggested that leeches preferentially attach to turtles near soft tissue under the scutes. This placement would offer more protection and an easy access to a blood meal (McCoy et al, 2007; Readell et al, 2008).

There have been several previous studies looking at leech parasitism on turtles which provide some insight into the factors influencing leech load on their turtle host. Basking tendencies has been proposed to play a major role in the leech load, whereby it is suggested that leeches will preferentially choose to parasitize bottom dwelling species rather than those who bask frequently (Ryan and Lambert, 2005) to avoid desiccation (McCoy et al, 2007; Readell et al, 2008). Sawyer (1972) indicated that leeches leave their host and become free living during the months of July and August when they begin brooding. McCoy et al (2007) suggested that the size of a turtle plays a role in leech load where the larger a turtle, the more surface area for leech attachment and thus a higher leech load. To date, there has been very few studies looking at leech load and body condition of a turtle.

Each of these previous studies, as well as some others, used the leech-turtle parasitism model to study host parasite relationships. This relationship has several advantages that make it a good one to study. First, turtles are relatively easy to capture, handle and manipulate. Secondly, as leeches are an ectoparasite, they are easy to visualize and quantify. Most previous studies examining the leech-turtle relationship

looked at only one or two turtle species' interaction with leeches and considered only a few factors each affecting this relationship. My study on the other hand, looked at four turtle species and several factors affecting leech parasitism on turtles. This allowed me to have a more detailed look into the host-parasite dynamics of this relationship and compare my results to several previous studies.

The goal of this study was to look at the temporal patterns (month of capture) and host susceptibility (species, size and body condition) in the host-parasite relationship between four turtle species found in the St Lawrence Islands National Park and their associated leeches. I studied leech parasitism on four of the five turtle species inhabiting this park, of which three are considered to be species at risk according to COSEWIC. The turtles I studied were Map Turtles (*Graptemys geographica*), Blanding's Turtles (*Emydoidea blandingii*), Common Musk Turtles (*Sternotherus odoratus*) and Painted Turtles (*Chrysemys picta*). Blanding's turtles and Common musk turtles, both threatened species, are found in swampy habitats with high productivity and little to no current. These species are both bottom dwellers that rarely leave the water to bask (Bonin et al, 2006). Map turtles, a species of special concern, and Painted turtles, a species not considered to be at risk, are found in river habitats with open waterways and slight currents. These species, though both highly aquatic, spend a significant time aerially basking on sunny rocks and logs (Bonin et al, 2006).

I expected that leech load, including leech prevalence and biomass, as determined as the number of leeches and the total length of leeches respectively, would be affected by the turtle species, the month of capture, the turtle's size, and the turtle's body condition in Map turtles, Blanding's turtles, Common Musk turtles and Painted turtles

found in St. Lawrence Islands National Park. Based on what is already known about leech parasitism on turtles, I had the following expectations: 1) the bottom dwelling Blanding's and Common Musk turtles should have higher leech loads than the aerial basking Map and Painted turtles 2) there should be a parasitism low during the months of July and August when leeches become free-living 3) larger turtles, due to a larger surface area for attachment, should have higher leech loads and 4) turtles in poor body condition, either because they have a weakened immune response or because the parasites themselves divert energy from them, should have a higher leech load.

Methods:

Study Location and Study Species

During the months of May through to the end of August 2008, I trapped Map turtles, Common Musk turtles, Painted turtles and Blanding's turtles on and around Grenadier Island in St. Lawrence Islands National Park. This national park has 21 islands and close to 90 islets within the St. Lawrence River spanning from Brockville to Kingston, Ontario. Grenadier Island, located in Mallorytown, Ontario is one of the park's largest islands and has an inland swamp in the centre of the island called Brooker's pond (Figure 1).

The Blanding's population, a species designated as a Threatened in Canada (COSEWIC), is highly localized around the Great Lakes-St Lawrence region, and was located exclusively in Brooker's pond in the centre of the island. The Common Musk turtles, though abundant in Eastern United States, are at the northern extent of their range in the St Lawrence River and are designated as a Threatened species in Canada

(COSEWIC). The Common Musk turtles were found mainly in the waters along the south shore of the island. The Map turtles, also abundant in the Eastern United States are at the northern extent of their range in the St Lawrence River. Map turtles are designated as a species of special concern in Canada (COSEWIC), and were found in the waters surrounding the island mainly in the west end. The Painted turtle population, not considered to be at risk in Canada (COSEWIC), is wide-spread in all of the United States and Southern Canada and were found in all of the above mentioned locations (Figure 1 inset).

Turtle Capture and Processing

Each turtle was captured using different techniques based on the turtle species basking habits. Blanding's turtles were trapped in sardine baited hoop nets, whereby the turtles swam into the nets but were then unable to swim back out again, or they were caught by hand as I walked through the bog mat. Map turtles were trapped in basking traps whereby the turtles basking on the plank in the middle of the trap jumped into the trap upon our approach. Painted turtles were trapped in both the basking traps and the baited hoop nets. Common musk turtles were caught by hand when they were found floating at the surface of the water, often under lily pads.

Upon capture, each turtle was brought back to the lab for processing. All turtles had their carapace length, width and height, and plastron length measured using callipers to the nearest 0.5 cm. Each turtle was weighed to the nearest 1 g using a spring scale. The sex of each turtle was determined based on their secondary sexual characteristics: male Blanding's turtles have a concave plastron compared to the females; male Painted turtles

have front claws at least twice the length of females; male Map and Common musk turtles have a much longer and thicker tail than do their respective females. The body condition of all turtles were the residuals from a regression of carapace length on mass (both log transformed) for each species. Each turtle was given a unique code drilled into their marginal scutes using a hand-held drill and a yellow paint blotch to identify the 2008 recaptures. All turtles spent the night in the lab in Tupperware containers with 3 cm of water and were released the following day at their capture locations.

Leech Data Collection

All leeches were counted and measured. As well, leech location on the turtle was noted directly upon capture of the turtle in the field. This ensured that the leeches did not fall off or move location on the turtle during transportation to the laboratory. Leech load was determined as leech prevalence and biomass. Leech prevalence was determined as the number of leeches on the turtle. The total length of leeches on the turtle was used as the proxy for leech biomass. Location of leeches was determined for four attachment sites on the turtles: carapace, plastron, anterior tissue and posterior tissue.

Statistical Analysis

All statistical analyses were performed using JMP 5.0.1. A two-way ANOVA test was performed to determine if turtle species and the season played a role on leech prevalence and biomass. A second two-way ANOVA test was performed to determine if turtle size and body condition within species had an effect on leech prevalence and biomass. Results were considered significant at $P=0.05$. If there was a significant effect

by any of the factors, a Tukey's HSD test was performed to determine significant differences between the groups.

Results:

All captured Blanding's turtles had leeches attached whereas very few Map turtles had leeches attached. About half of the Painted and Common Musk turtles had leeches attached. Most of the leeches were attached to turtles whose habitat preference was swampy areas and those with bottom-dwelling habits (Table 1).

For all turtle species, the leeches were mainly attached to the plastron and carapace (Figure 2). Those attached to the carapace of the map turtles and common musk turtles were often found under the marginal scutes near the flesh at the posterior end of the turtle. Those attached to the Blanding's and swamp inhabiting Painted turtles were found everywhere on the turtles, but primarily on the exposed carapace and plastron (Figure 3). At this location, some large leeches were found carrying broods of small leeches ventrally.

Species

There was a significant difference in leech prevalence ($R^2=0.21$, $F_{(3,323)}=27.91$, $p<0.0001$) and leech biomass ($R^2=0.40$, $F_{(3,323)}=73.10$, $p<0.0001$) by species. Tukey's HSD tests revealed that Blanding's had a significantly higher leech prevalence and biomass than the other three species; Map turtles had a significantly lower leech prevalence and biomass than the other three species; Painted and Stinkpot turtles did not differ significantly from each other, but had a significantly higher leech prevalence and

biomass than the Map turtles and significantly lower leech prevalence and biomass than the Blanding's turtles (Figure 5).

Painted turtles were the only turtle species that I studied that were found in both Brooker's pond, the swamp habitat, and the St. Lawrence River, the river habitat. Those captured in the swamp had a much higher average leech prevalence and biomass than those captured in the river habitat (Figure 4).

Season

There was no significant difference in leech prevalence ($R^2=0.01$, $F_{(3,323)}=0.84$, $p=0.469$) or leech biomass ($R^2=0.01$, $F_{(3,323)}=1.43$, $p=0.233$) between the months when all turtle species were pooled for each month (Figure 6). However there were different trends when looking at each species separately. There appeared to be no month effect on leech prevalence for the Map turtles. There appeared to be an increase in prevalence of leeches on Blanding's throughout the summer, with the highest prevalence in August. For Painted and Common Musk turtles, it appeared that leech prevalence was highest during June and decreased over the course the summer (Figure 7).

Size

Within a species, there was no significant correlation between size of turtle, as determined from the carapace length, and the prevalence of leeches (Blanding's: $R^2=0.01$, $F_{(1,31)}=0.12$, $p=0.732$; Common Musk: $R^2=0.03$, $F_{(1,62)}=2.13$, $p=0.15$; Map: $R^2=0.01$, $F_{(1,146)}=1.13$, $p=0.29$; Painted: $R^2=0.01$, $F_{(1,78)}=0.80$, $p=0.37$) as seen in Figure 8, and the size of turtle and biomass of leeches (Blanding's: $R^2=0.05$, $F_{(1,31)}=1.93$, $p=0.18$; Common Musk: $R^2=0.04$, $F_{(1,62)}=2.46$, $p=0.12$; Map: $R^2=0.01$, $F_{(1,146)}=2.00$, $p=0.16$; Painted:

$R^2=0.02$, $F_{(1,77)}=1.32$, $p=0.25$) as seen in Figure 9. Within a species, a small turtle was just as likely as a large turtle to have a high leech prevalence and biomass.

Body condition

Within a species, there was no significant correlation between the body condition of the turtle and the prevalence of leeches (Common Musk: $R^2=0.01$, $F_{(1,62)}=0.01$, $p=0.97$; Map: $R^2=0.01$, $F_{(1,146)}=0.08$, $p=0.78$; Painted: $R^2=0.01$, $F_{(1,77)}=0.42$, $p=0.52$) as seen in Figure 10, and the body condition of the turtle and biomass of leeches (Common Musk: $R^2=0.01$, $F_{(1,62)}=0.01$, $p=0.98$; Map: $R^2=0.01$, $F_{(1,146)}=0.08$, $p=0.78$; Painted: $R^2=0.01$, $F_{(1,77)}=0.52$, $p=0.47$) as seen in Figure 11. Within a species, a turtle in better condition was just as likely as a turtle in poor condition to have a high leech prevalence and biomass. The exception being that it appeared that there was a weak correlation between body condition and leech prevalence and biomass in the Blanding's turtle (Prevalence: $R^2=0.17$, $F_{(1,31)}=5.8$, $p=0.02$; Biomass: $R^2=0.22$, $F_{(1,31)}=8.51$, $p=0.007$). For this species, it appeared that both leech prevalence and biomass increased as the body condition of the turtles increased.

Discussion:

Some of my results are consistent with findings from previous studies whereas some do not match the results from previous studies. Here, I will discuss how some of my results differ from those previously set forth. In all cases, the results for leech biomass (total length of leeches) matched leech prevalence (number of leeches). This means that leech infestation followed the same trends within turtle species keeping leech prevalence and biomass trends matching.

Leech Occurrence

There are no previous results regarding leech prevalence on Blanding's, however my results indicated that all except one Blanding's sampled had at least one leech attached. My results for leech prevalence on the Common musk turtle, where half of all sampled Common Musk turtles were parasitized by at least one leech, were higher than that found by Readle et al (2008), but much lower than that found by Ryan and Lambert (2005). Ryan and Lambert (2005) also found that about 50% of the Map turtles they sampled were parasitized by at least one leech, whereas I found that only about 5% of the Map turtles I sampled had a leech present. Finally, I found that slightly over half of the Painted turtles pooled for each habitat were parasitized by at least one leech, a finding supported by Readle et al (2008) and McCoy et al (2007). However, the painted turtles sampled from the swamp habitat had leech prevalence closer to 90% whereas those sampled from the river habitat had a leech prevalence of only about 35%. These findings, along with the results from the other studies looking at leech parasitism on different species of turtles from different locations suggest that an important factor in the occurrence of leeches on turtles has to do with the prevalence of leeches themselves in the habitat of the turtle. So, if there are more leeches in a certain environment, there will also be more leeches associated with turtles in this environment.

Leech Attachment Sites

Contrary to most of the other studies on leech parasitism on turtles, I found that there were relatively few leeches present on the turtle's integument for all four species. Previous studies indicate that leeches are most often found attached to the inguinal area

of turtles (Readel et al, 2008; McCoy et al, 2007), which the authors suggest is because this location allows easy access to a blood meal and protection from the environment. I found, on the other hand, that on the Map turtles, Common Musk turtles and river-dwelling Painted turtles, most leeches were attached to the underside of the marginal scutes at the posterior end of the turtle, as seen in Figure 3 a & b. At this site, there was maximum protection from environmental conditions and nearby fleshy spots for feeding. This location might also have been preferred by the leeches versus the inguinal area as they would not have been disturbed by the movement of the turtle's limbs for locomotion. There may also have been a higher number of leeches at the posterior end versus the anterior end of the turtle, as the turtles themselves were less of a threat to the leeches at this location. Turtles may be able to remove leeches and subsequently feed on them (Brooks et al, 1990), so their presence at the posterior end suggested the turtles could not reach them there to remove them as a meal. Most of the leeches attached to the Blanding's and the swamp-dwelling Painted turtles chose to attach to both the exposed carapace and plastron. At this location, there was no protection from the environment, nor was there easy access to fleshy areas for feeding. Siddall and Gaffney (2004) found that *P. Ornata* is able to draw a blood meal from the bony carapace and plastron of snapping turtles, so it is possible that the leeches found on the carapace and plastron in my study were able to gain access to a blood meal from this location as well.

Species

Species had the biggest effect on the leech prevalence and biomass, also seen in other studies (McCoy et al, 2007; Readel et al, 2008; Ryan and Lambert, 2005).

However, within the species, there was the interaction of basking tendencies and habitat selection.

Blanding's turtles are highly aquatic, bottom dwelling turtles, spending most of their time in the swamp water or basking amongst the bog mats (Bonin et al, 2006). This habitat selection is also the one primarily chosen by the leech species that parasitize them (Sawyer, 1986). This means that there was a higher density of *P. ornata* and *P. parasitica* present at this location to parasitize the Blanding's turtles. On the other hand, Map turtles are also highly aquatic, but prefer to aerial bask on exposed rocks and logs (Bonin et al, 2006). Their habitat is primarily in open waters with a slight current. *P. ornata* and *P. parasitica*, though sometimes found in this habitat, are not as likely to be found in these areas (Sawyer, 1986), which means that there were fewer leeches present at this location to parasitize the Map turtles. The Common Musk turtles prefer shallow, murky, slow moving waters (Bonin et al, 2006). All the Common Musk turtles in this study were captured in this type of environment in the St. Lawrence River where there were fewer *P. ornata* and *P. parasitica* than in the swamp on the island. The few leeches that were present in the river would tend towards the shallower, slow moving waters (Sawyer, 1986), where the Common Musk turtle was found. The results from the Painted turtles provided strong evidence that habitat does play a large role within the species. The high prevalence and biomass of leeches on the swamp-inhabiting Painted turtles as compared to the river-dwelling Painted turtles suggest that the reason there is different levels of parasitism on this species is due to where the specific turtles were found. For example if the turtle preferred the swamp, it was more likely to come into contact with leeches, and

therefore have higher leech loads as compared to those preferring the river, where leech levels were lower.

The basking tendencies of the turtles might also have played an important role in the difference in prevalence and biomass seen between the species. Blanding's and Common Musk turtles' bottom dwelling habits put them in direct contact with the substrate, where many leeches could be found. In fact, Sawyer (1986) found that both *P. ornata* and *P. parasitica* swim very rarely as juveniles and not at all as adults. This means the adult leeches move along the bottom substrate where upon meeting a turtle or other host, they can attach. Therefore, if a turtle species spends more time in contact with the substrate, as do the Blanding's and Common Musk turtles, it has a higher chance to be parasitized. On the other hand, Map turtles and Painted turtles spend very little time in contact with the substrate which means the non-swimming leeches will not have access to them. Map and Painted turtles also spend a significant time aerially basking, so leeches may be preferentially avoiding species that aerially bask (Ryan and Lambert, 2005).

Body Condition and Size

I had expected that turtles in poor body conditions would be more highly parasitized than turtles in better body conditions for two reasons. One possibility is that leeches might be able to better parasitize a host in poor condition, who is unable to avoid leech attachment in the first place or has less energy to dispose of the leeches once they are attached. The second possibility is that turtles that are highly parasitized might have worse body conditions due to their energy being diverted from the host to the parasite. In fact, from the Blanding's results the opposite appeared to be true. A weak positive

correlation, where leeches were attaching to turtles in better body condition was observed. However, very little of the variation was explained by this model, suggesting that it is likely not body condition playing a very important role in leech prevalence and biomass on the turtles. In all other turtle species, there was no difference between the leech prevalence and biomass on healthy turtles compared to those in poor health, suggesting two things: leeches do not preferentially attach to turtles in poor health, nor do they reduce the fitness of the hosts by a significant amount.

I had expected that within a species, smaller turtles would be less parasitized than larger turtles due to a smaller surface area for leech attachment (McCoy et al, 2007; Readell et al, 2008). My results indicated that this is not the case. There is in fact no correlation between leech prevalence and biomass and the size of the turtle. A small turtle was just as likely as a large turtle to be heavily parasitized.

Season

The season did not appear to have an effect on leech prevalence and biomass. Sawyer (1972) noted that *P. parasitica*, which is most often found associated with the host, leaves their turtle host and become free-living during July and August to breed, which would suggest a higher leech load in May and June as compared to July and August. My results indicated, however, that when all turtle species were pooled, there was no significant difference in leech prevalence and biomass between the four months in this study.

However, when looking at each species individually, different trends seemed to emerge. Map turtles had consistent leech prevalence throughout the study period, which

is likely due to the very low number of turtles with leeches to begin with. Blanding's turtles had the highest leech prevalence in August. The increase in leech prevalence and biomass on the Blanding's turtles in August was likely due to brooding leeches. Two of the four Blanding's turtles caught in August had a parent leech with young leeches attached to the parent's venter, which increased both the prevalence and biomass. Sawyer (1986) indicates that brooding individuals rarely occur on turtles, but from the Blanding's results, it appears that it may not be as uncommon as originally thought to find brooding individuals attached the turtle hosts (Brooks et al, 1990). Painted and Common Musk Turtles had the highest leech prevalence in June, which is consistent with the observations made by Sawyer (1972). None of these turtle species had brooding leeches attached during any of the study period, which kept the prevalence and biomass much lower than seen in the Blanding's.

Future Studies and Areas of Improvement

Overall, I was able to complete a thorough study on leech parasitism on four turtle species found in the St Lawrence Islands National Park. That being said, there are a few areas in which this study could have been improved. Sample sizes posed a problem in some instances. For example, I did not catch any Painted turtles and only seven Common Musk turtles during the month of May. I also caught only 33 Blanding's turtles, with only four turtles per month for June, July and August. This made it difficult to determine any significant findings based on the month of capture. Also, I caught very few swamp-dwelling Painted turtles compared to the river-dwelling turtles, which made it difficult to compare the two populations.

After completing this study, I became aware of a follow-up study that is needed for the species of turtles I examined. I observed differences in leech prevalence and biomass between the species, but was unable to confirm if these differences were due to the turtle species themselves, or due to habitat and basking tendencies. A re-colonization experiment, similar to that done by Ryan and Lambert (2005), both in the turtles' natural habitat and in a lab setting, would allow me to determine what else is interacting with species to get the observed leech prevalence and biomass trends.

It is also important to note that there is variation between the results from previous studies and my own study. Though all studies found that there was a significant relationship between leech loads and species, the prevalence for the same species at different locations was not consistent. Different species and different locations of capture also showed differences in leech load based on month. Further studies on the same species both at similar habitats and geographic locations as well as at different habitats and geographic location are needed to compile a larger pool of data to observe the overall trends in host-parasite dynamics.

Conclusions

In conclusion, while my results support some of my expectations, they do not support them all. As I expected, the species of turtle does affect leech prevalence and biomass. On the other hand, my results did not support what I had expected for the effect of month of capture, turtle body condition and turtle size on leech prevalence and biomass. These findings indicate that turtle species, due to the interaction of habitat and basking tendencies, plays the biggest role in affecting leech loads, including prevalence

and biomass. My study on leech prevalence and biomass, including data for parasitism on four turtle species in the St Lawrence Island National Park, adds to the limited information currently available on this topic and demonstrates the need for further investigation on these and other turtle species in both similar and different habitats and geographic locations to broaden our understanding of host-parasite interactions.

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Table 1: Percent of turtles parasitized by at least one leech.

Turtle Species	n	Number parasitized	Percent parasitized	Location caught	Basking tendencies
<i>Graptemys geographica</i>	148	8	5.4		
Female	82	5	6.1	River	Aerially basking
Male	66	3	4.5		
<i>Chrysemys picta</i>	59	21	35.6		
Female	40	13	32.5	River	Aerially basking
Male	19	8	42.1		
<i>Chrysemys picta</i>	21	19	90.5		
Female	6	6	100	Swamp	Aerially basking
Male	15	13	86.7		
<i>Sternotherus oderatus</i>	63	34	53.9		
Female	35	20	57.1	Swamp	Bottom dwelling
Male	28	14	50		
<i>Emydoidea blandingii</i>	33	32	97		
Female	15	14	93	Swamp	Bottom dwelling
Male	18	18	100		

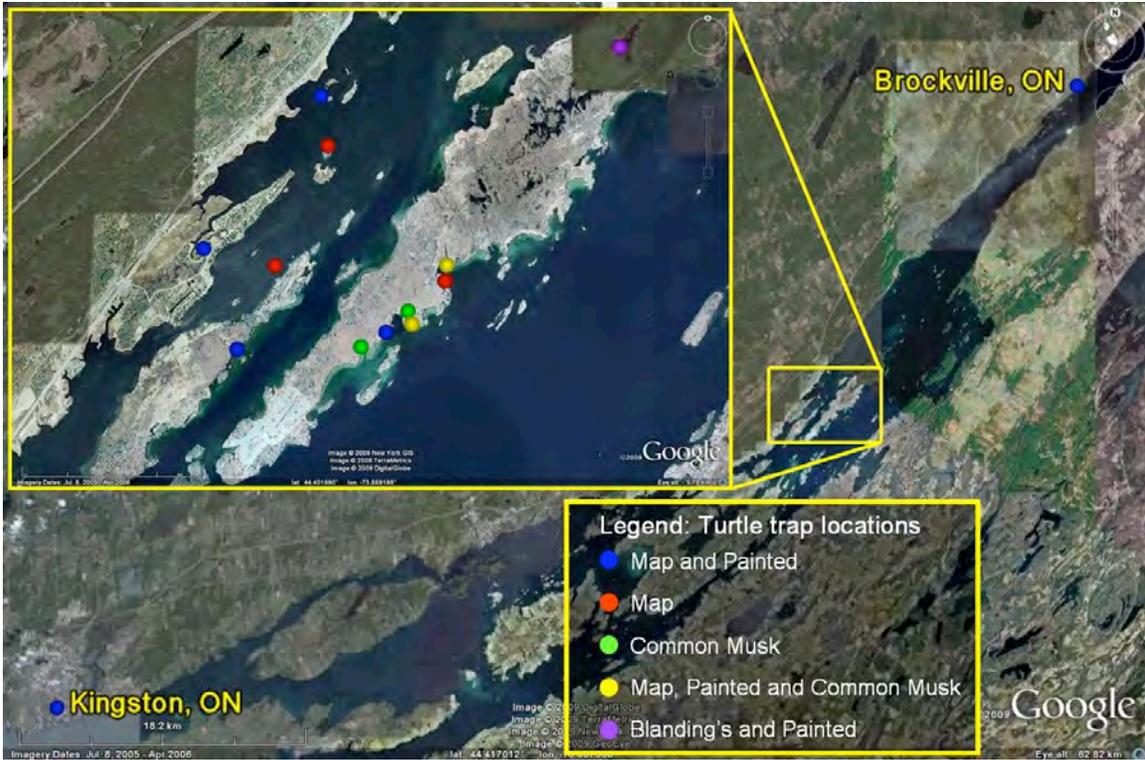


Figure 1. Map of Grenadier Island located in the St. Lawrence River, Ontario, Canada generated by Google Earth. Inset shows the locations of turtles captured on and around the island by turtle species.

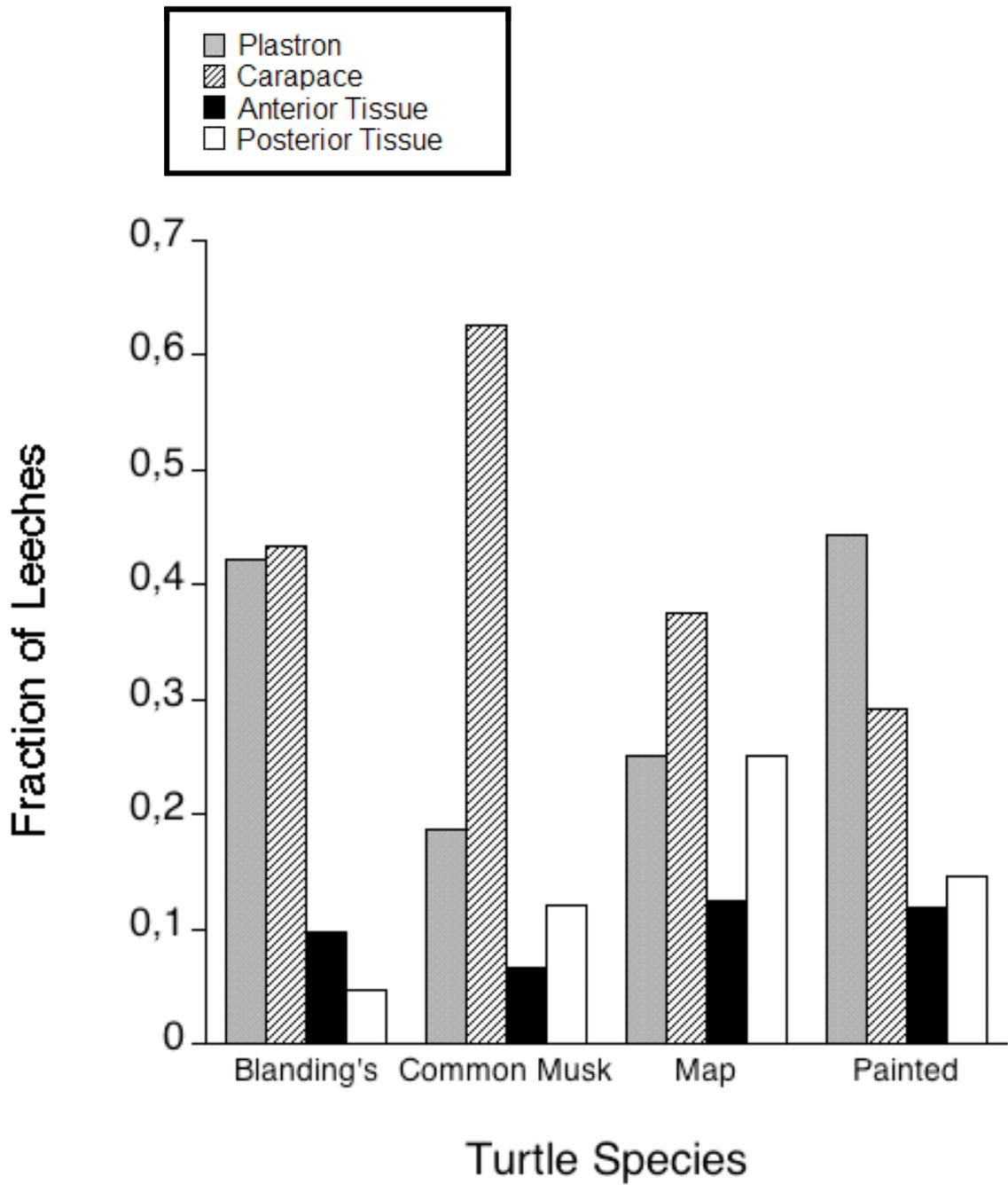


Figure 2. Leech attachment site for each turtle species. Each bar represents the number of leech observations at each region out of the total number of leeches found on each species.

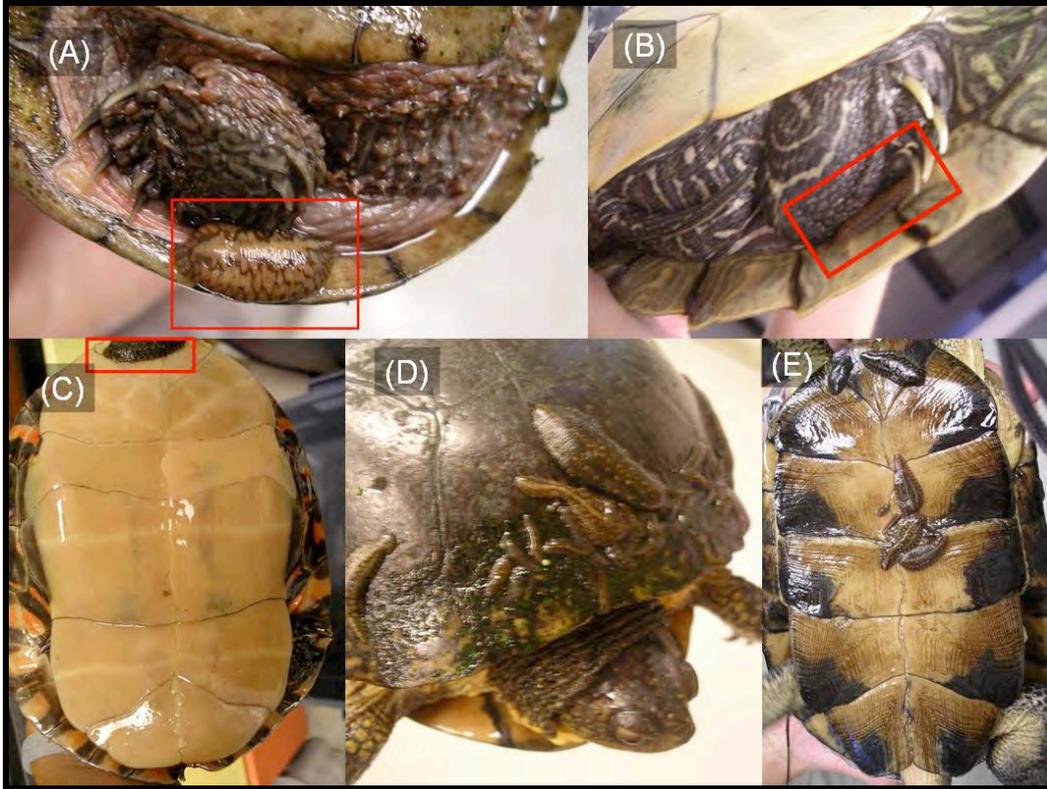


Figure 3. Primary location of leech attachment by turtle species. (A) Attachment to Common musk turtle beneath the posterior marginal scutes. (B) Attachment to Map turtle beneath the posterior marginal scutes. (C) Attachment to Painted turtle on the outer surface of the plastron. Attachment to Blanding's turtles on the outer surface of the (D) carapace and (E) plastron.

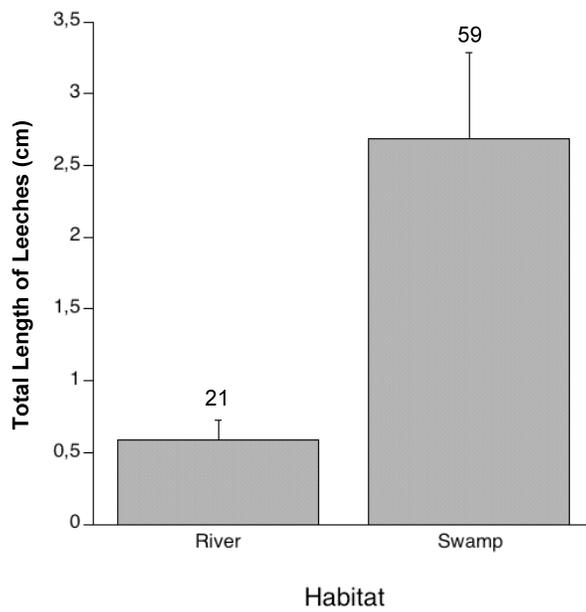
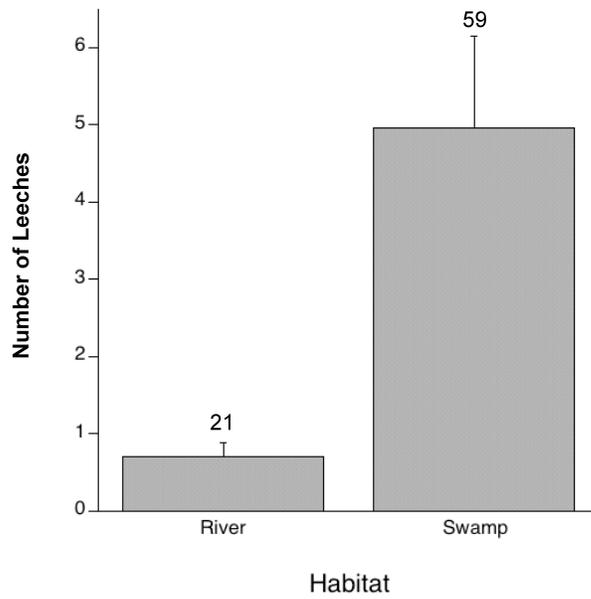


Figure 4. Leech prevalence (number of leeches) and biomass (total length of leeches) on painted turtles in two different habitats. Numbers represent sample size (number of turtles). Averages (+SE) are presented.

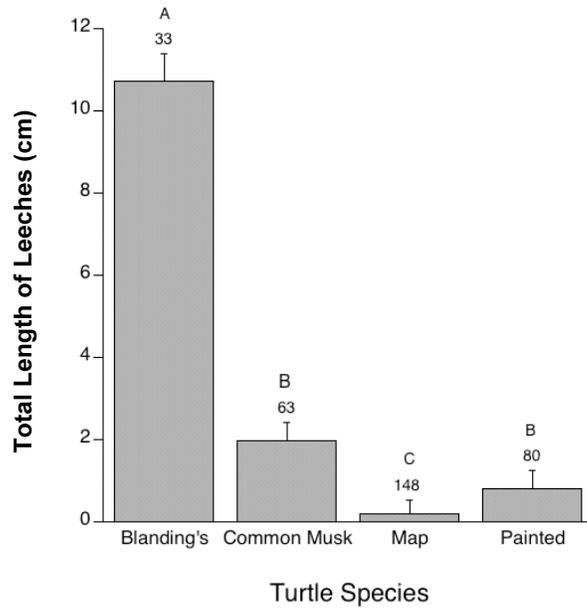
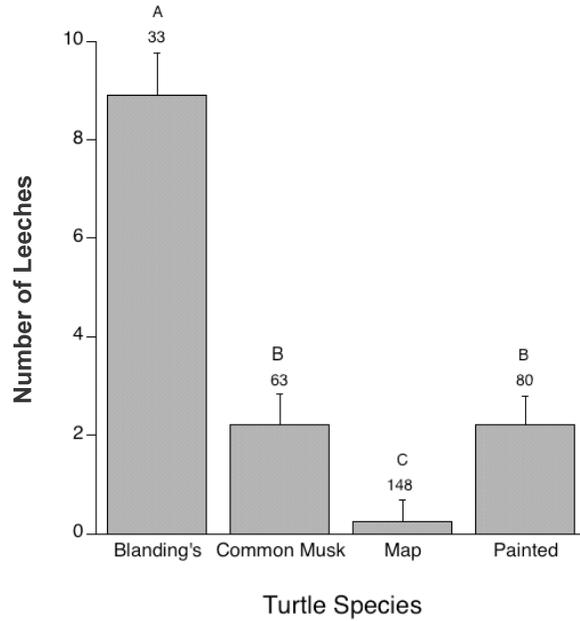


Figure 5. Leech prevalence (number of leeches) and biomass (total length of leeches) on each turtle species. Intensity is the number of leeches on the turtles and biomass is the total length of leeches on the turtles. Least square means (+SE) are presented. Numbers represent sample size (number of turtles) and the letters represent significant differences between the groups.

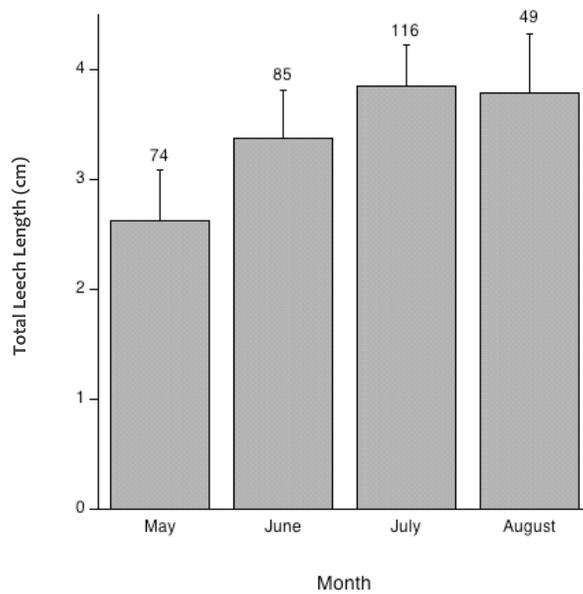
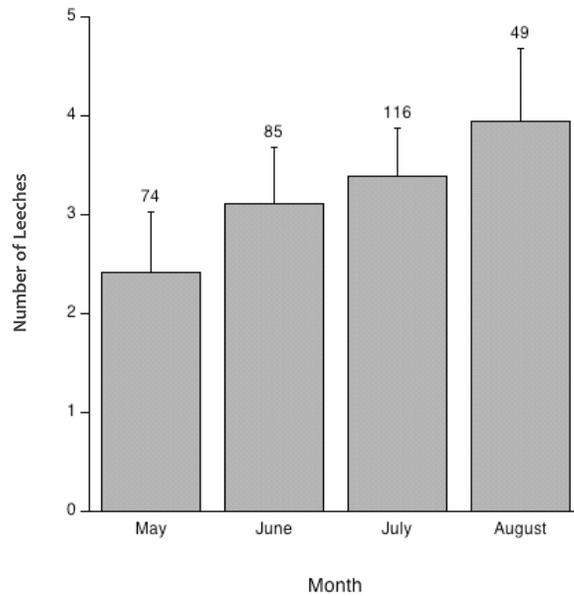
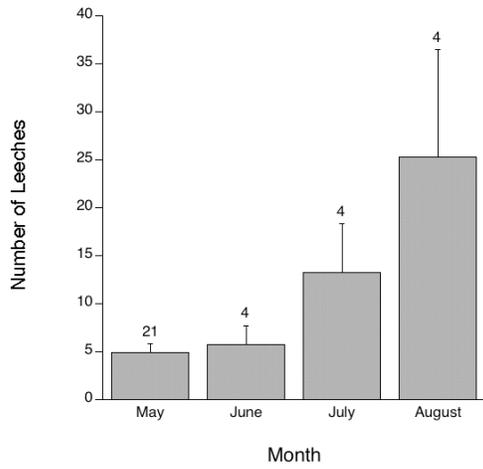
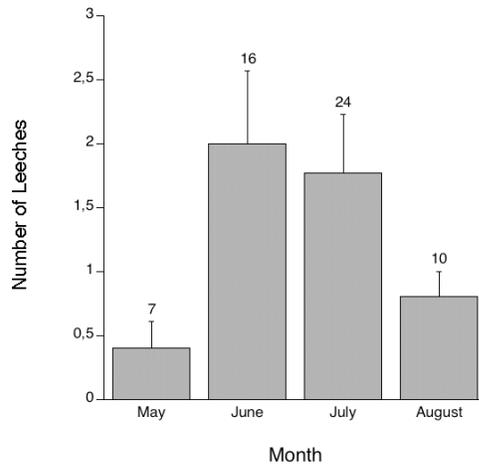


Figure 6. Leech prevalence (number of leeches) and biomass (total length of leeches) by month. Data from all four turtle species is pooled. Numbers represent sample size (number of turtles). Least square means (+SE) are presented.

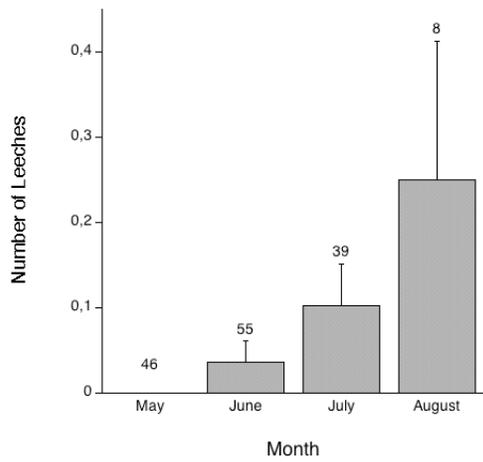
Blanding's Turtles



Common MuskTurtles



Map Turtles



Painted Turtles

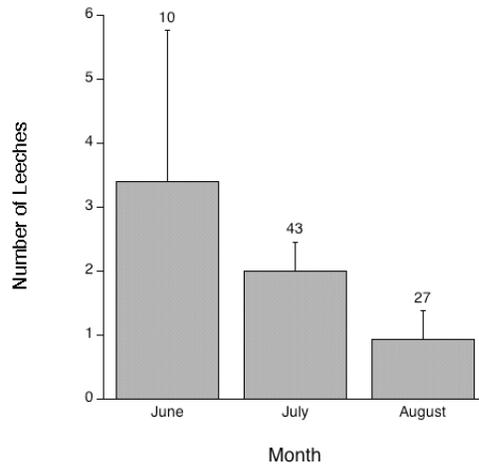
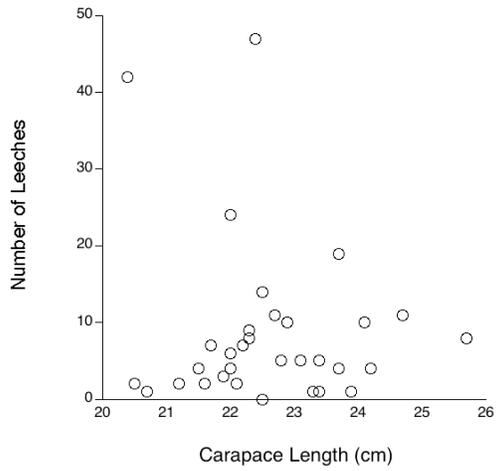
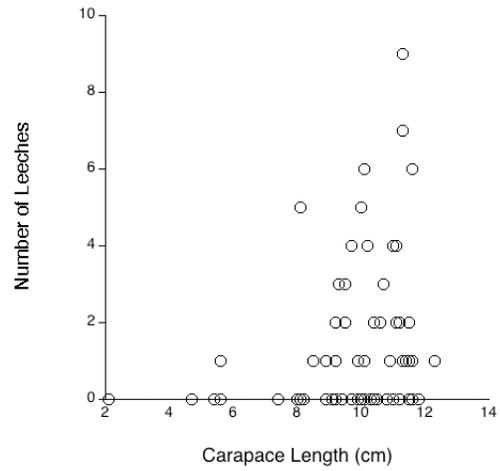


Figure 7. Leech prevalence (number of leeches) by species by month. Numbers represent sample sizes (number of turtles). Averages (+SE) are presented. One outlier (an individual with over 50 leeches) has been omitted from the Common Musk turtle plot to preserve proper scale.

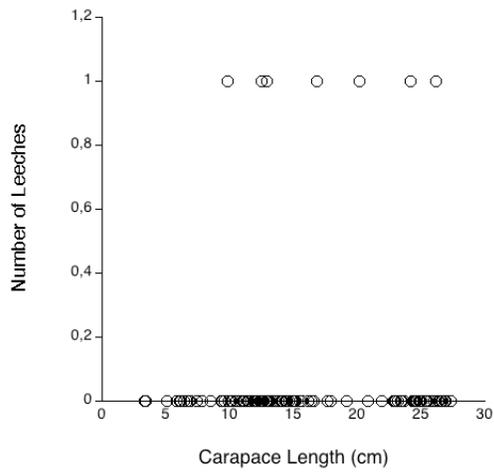
Blanding's Turtles



Common Musk Turtles



MapTurtles



Painted Turtles

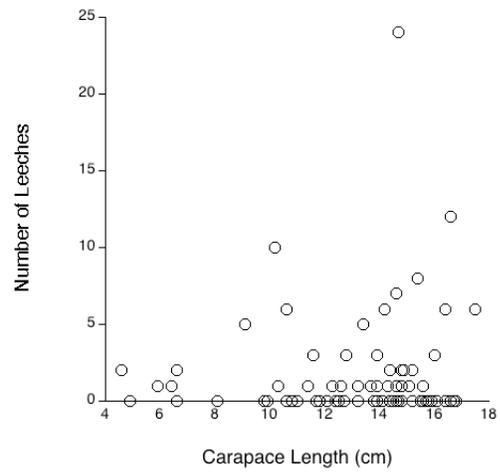
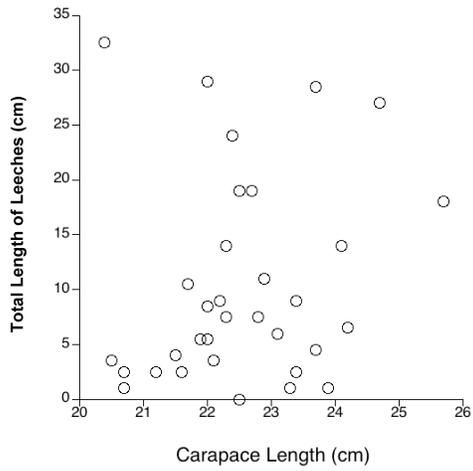
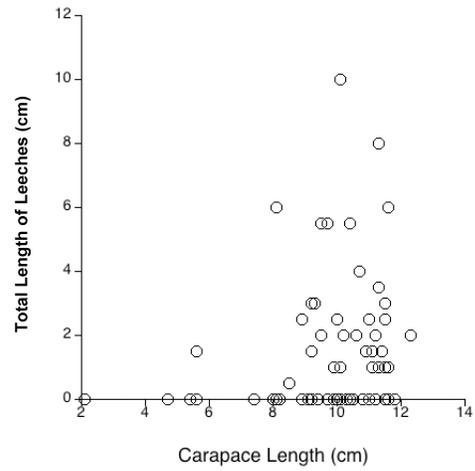


Figure 8. Relationship between carapace length and leech prevalence (number of leeches). One outlier (an individual with over 50 leeches) has been omitted from the Common Musk turtle plot to preserve proper scale.

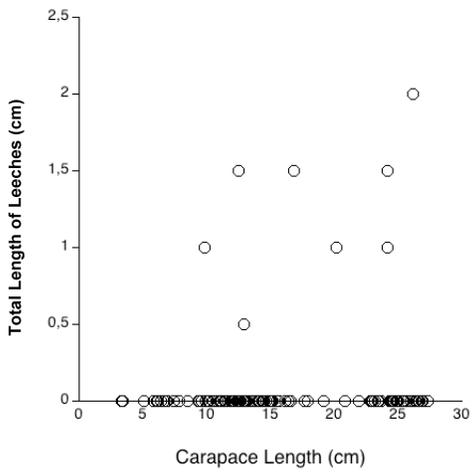
Blanding's Turtles



Common Musk Turtles



Map Turtles



Painted Turtles

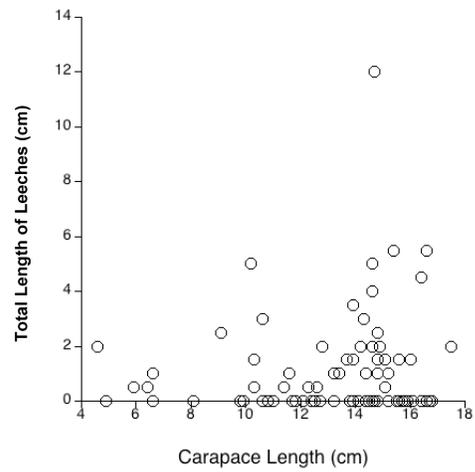
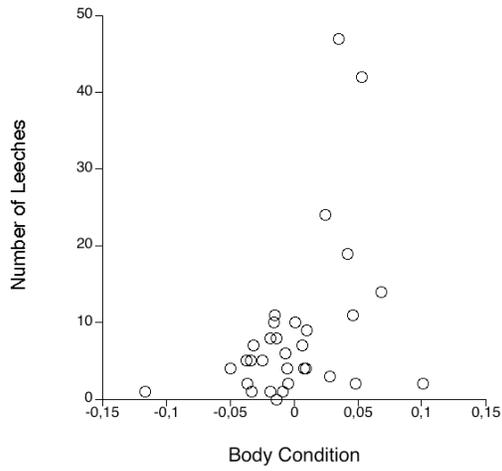
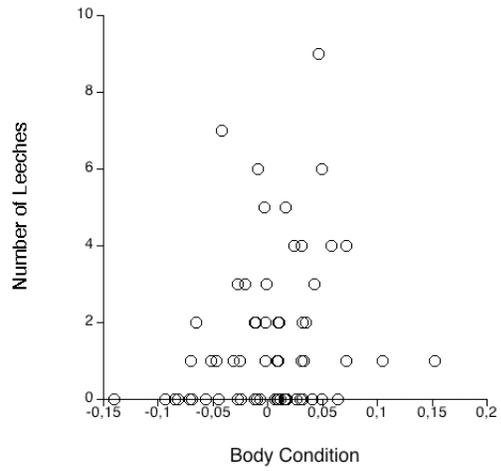


Figure 9. Relationship between carapace length and leech biomass (total length of leeches). One outlier (an individual with over 50 leeches) has been omitted from the Common Musk turtle plot to preserve proper scale.

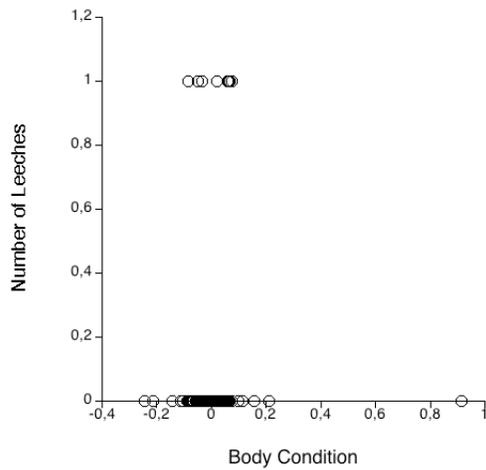
Blanding's Turtle



Common Musk Turtles



Map Turtles



Painted Turtles

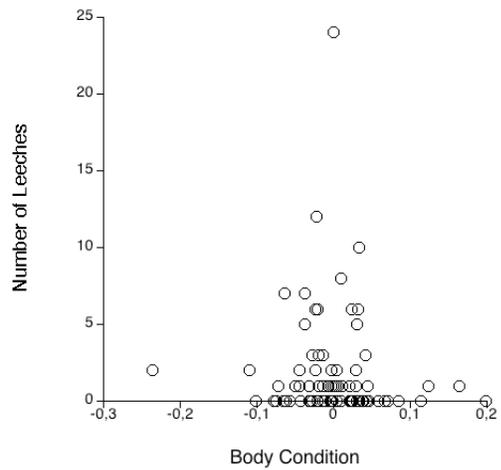
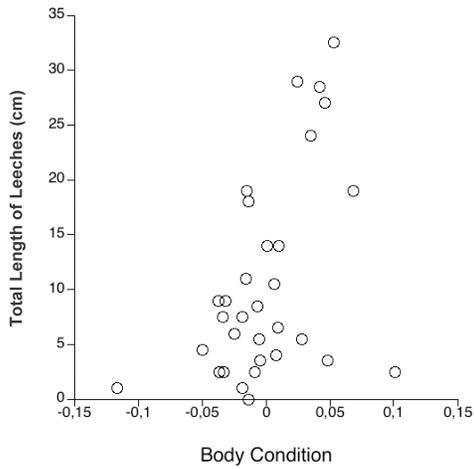
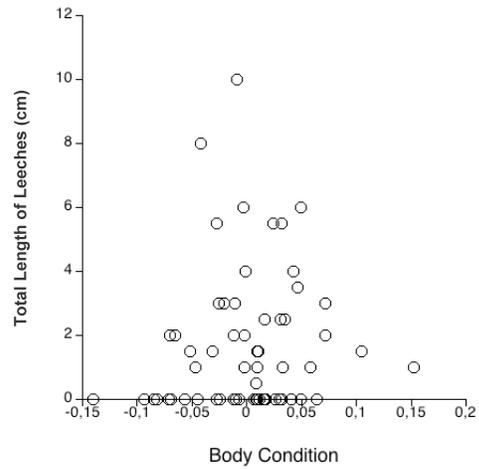


Figure 10. Relationship between body condition and leech prevalence (number of leeches). One outlier (an individual with over 50 leeches) has been omitted from the Common Musk turtle plot to preserve proper scale.

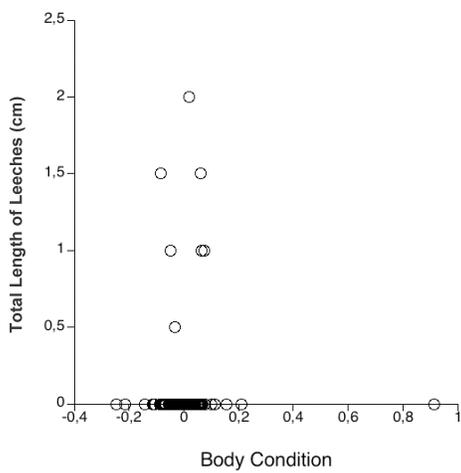
Blanding's Turtles



Common Musk Turtles



Map Turtles



Painted Turtles

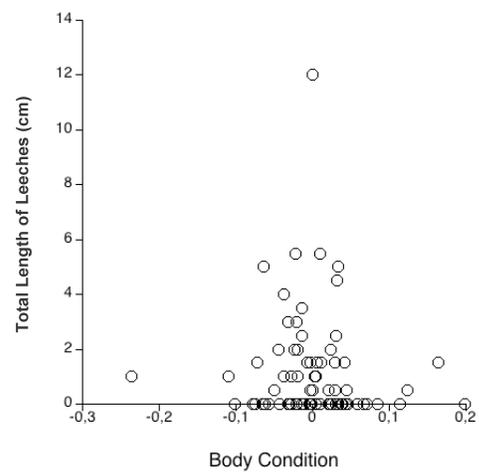


Figure 11. Relationship between body condition and leech biomass (total length of leeches). One outlier (an individual with over 50 leeches) has been omitted from the Common Musk turtle plot to preserve proper scale.