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Relationship between instream habitat characteristics, emergent insects, and riparian bird communities

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THE RELATIONSHIP BETWEEN INSTREAM HABITAT CHARACTERISTICS, EMERGENT INSECTS, AND RIPARIAN BIRD COMMUNITIES

By

Kyle D. Forgette

A THESIS

Submitted in partial fulfillment of the requirements for the degree of

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This thesis, “The Relationship between Instream Habitat Characteristics, Emergent Insects, and Riparian Bird Communities,” is hereby approved in partial fulfillment of the requirements for the Degree of MASTER OF SCIENCE IN BIOLOGICAL SCIENCES.

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Date ________________________________

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1. ABSTRACT

Streams and riparian areas can be intricately connected via physical and biotic interactions that influence habitat conditions and supply resource subsidies between these ecosystems. Streambed characteristics such as the size of substrate particles influence the composition and the abundance of emergent aquatic insects, which can be an important resource for riparian breeding birds. We predict fine sediment abundance in small headwater streams directly affects the composition and number of emergent insects while it may indirectly affect riparian bird assemblages. Streams with abundant fine sediments that embed larger substrates should have lower emergence of large insects such as Ephemeroptera, Plecoptera and Trichoptera. Streams with lower emergent insect abundance are predicted to support fewer breeding birds and may lack certain bird species that specialize on aquatic insects. This study examined relationships between streambed characteristics, and emergent insects (composition, abundance and biomass), and riparian breeding birds (abundance and richness) along headwater streams of the Otter River Watershed. The stream bed habitats of seven stream reaches were characterized using longitudinal surveys. Malaise traps were deployed to sample emergent aquatic insects. Riparian breeding birds were surveyed using fixed-radius point-counts. Streams differed within a wide range of fine sediment abundances. Total emergent aquatic insect abundance increased as coverage by instream substrates increased in diameter, while bird community was unresponsive to insect or stream features. Knowledge of stream and riparian relationships is important for understanding of food webs in these ecosystems, and it is useful for riparian forest conservation and improving land-use management to reduce sediment pollution in these systems.

2. INTRODUCTION

Streams and riparian areas (RAs) are often tightly coupled ecologically. RAs function to protect, maintain, and create stream habitat as well as to reciprocally subsidize consumers in both habitats via the transfer of inorganic and organic materials and food resources (Naiman and Decamps 1997; Nakano and Murakami 2001). Disturbance from natural forces (i.e. wildfires and flooding events) as well as human activities (i.e. logging, road construction, pollution, dam construction, and artificial channelization) can alter the linkages within and among streams and RAs (Northcote and Hartman 2004). Forestry practices, in particular, near streams can have a strong influence on stream characteristics. For example, Northcote and Hartman (2004) noted that factors such as road construction, timber harvesting, scarification, slash burning, fertilization, and chemical applications can impact stream characteristics. These factors can influence channel morphology (Gottesfeld et al. 2008); nutrient regimes, water chemistry, vegetation community composition (Moore and Bull 2004) and invertebrate/vertebrate community (Burns 1972). Sediment pollution is a common result of RA disturbance caused by forest practices, which has prompted much research on the effects of fine sediment abundance in streams and its influence on the biotic community in adjoining aquatic and terrestrial habitats (e.g., Beaubien 1999; Brown and Timms 2002; VanDusen et al. 2005; Pinto et al. 2006; Molinos and Donohue 2011).

Fine sediment abundance can greatly influence the physical and behavioral biology of aquatic life (Brusven and Prather 1974; Merritt and Cummins 1996; Harrison et al. 2008). Many emergent insect taxa, especially those from the orders of Ephemeroptera, Plecoptera, and Trichoptera (EPT), require streams with low fine sediment abundance (i.e. sand depth and coverage) to survive. The loss of interstitial spaces between coarse sediments (boulders, cobbles, pebbles, and gravels), due to deposition of sand or other fine materials, reduces areas for insect development, feeding, and protection from predators (Brusven and Prather 1974).

Bub et al. (2004) surveyed breeding bird assemblages along headwater streams in Michigan's Upper Peninsula and studied the relationship between time since forest thinning and bird community composition. One question that was not specifically addressed in their work was how riparian breeding bird assemblage related to the availability of emergent aquatic insects as well as stream habitat characteristics (i.e. fine sediment abundance).

The transfer of insects between streams and RAs are greatly impacted by stream sedimentation. Terrestrial and emergent aquatic insects, namely EPT, are important sources of food for aquatic and terrestrial consumers (Nakano and Murakami 2001). Aquatic insects, in particular, can have a strong influence on terrestrial food webs (Ormerod 1986; Carlisle 2004; Paetzold 2006; Uesugi and Murakami 2006; Smith et al. 2007; Hagar and Saintours 2008). They supply food for terrestrial predators (i.e. birds, bats, lizards, and spiders) and compose 25 to 100% of the daily diet for some terrestrial species (Iwata 2006; Malison et al. 2010a). Baxter et al. (2005) emphasized the importance of emergent aquatic insects as a food source to riparian breeding birds after they conducted a literature review on studies dated back to 1966 focusing on emergent aquatic insects and riparian birds of temperate zones. Baxter et al. (2005) concluded that emergent insects provided 26 to 86% of overall breeding bird diets along the riparian area of streams. Murakami and Nakano (2001) noted that aquatic insect prey accounted for over 25% of the energy demand of temperate deciduous riparian forest bird communities along the Horonai Stream in the Tomakomai Experimental Forest of Hokkaido, Japan.

The objective of this study was to examine relationships between stream habitat characteristics (i.e. fine sediment abundance), emergent aquatic insects (i.e. EPT), and riparian bird assemblage. Here, my main hypothesis is that breeding bird abundance and species richness will be greatest in RAs where emergent aquatic insect abundance (Ephemeroptera, Plecoptera, Trichoptera) and dry mass are greatest. The secondary hypothesis states that the detection abundance and species richness of breeding birds will be greater adjacent to headwater streams with higher coarse sediment abundance (i.e. boulder, cobble, pebble, gravel coverage). Finally, detection abundance of birds such as the Winter wren (*Troglodytes troglodytes)* and American redstart (*Setophaga ruticilla),* that have been shown to prefer emergent aquatic insects as food (Nakano and Murakami 2001), will show the greatest sensitivity to differences in emergent aquatic insect abundance and biomass as well as to instream coarse sediment abundance. Streams containing high fine sediment abundances (i.e. sand depth and coverage) will have lower abundances and biomass of larger emergent aquatic insects such as EPT, as well as lower riparian breeding bird abundances and species richness.

3. METHODS

3.1 Study Area

The Otter River Watershed (ORW) is located in Michigan's Upper Peninsula (UP), USA. The 40,040 ha watershed is situated on the western end of the UP within Houghton, Baraga, and Ontonagon counties (Sturgeon/Otter River Watershed Council 2000), which contain 96%, 3%, and 1% of the watershed, respectively. The bedrock of the ORW was formed in the Keweenaw sub-epoch of the Pre-Cambrian era (ca. 1 bya) and is primarily of the Jacobsville sandstone formation (Beaubien 1999). This layer was overlaid by a thick layer of sediment deposited when the last glaciers receded 10,000 years ago (Price 2011). The sediment layer was composed of lacustrine sand and poorly sorted gravel. Top soils were moderate to well drained sandy loam or loams as referenced in Schwenner (1991) and VanDusen et al. (2005). Forested land comprises 80.3% of the total watershed, followed by 9.9% wetlands, 3.4% agriculture, 2.1% grassland, 1.4% urban roads, 0.3% shrub/scrub, and 0.1% barren land (UPRCD 2008). Forested land is comprised mostly of northern hardwoods, including sugar maple (*Acer saccharum),* eastern hemlock (*Tsuga Canadensis)*, American basswood (*Tilia Americana),* yellow birch (*Betula alleghaniensis),* red maple (*A. rubrum),* and tag alder (*Alnus rugosa)*. Elevations of the watershed range from 260 to 355m (VanDusen et al. 2005).

3.2 Study Site Characteristics

3.2.1 Stream Habitat

Seven streams in the ORW such as West Branch of the Sante River, Thirteen Mile Creek, Deer Camp (also known as Thirteen Mile Creek), Otter Siding River (also known as

West Branch Otter River), Pike Lake Curve (also known as Lake Fifteen), Ogre (also known as Beaver Creek), and Lake Fifteen Creek, comparable to Bub et al. (2004), were sampled in the early summer of 2011 (June 6^{th} to June 16^{th}) (Appendix Figure 9.1). Acronyms will be used when referring to these streams: WBS (West Branch of the Sante River), THM (Thirteen Mile), DEC (Deer Camp), OSR (Otter Siding River), PLC (Pike Lake Curve), OGR (Ogre), and LKF (Lake Fifteen).

Habitat characteristics were assessed along 11 cross-stream transects, separated by 50m, of a 500m reach within each stream (Figure 3.1). Each transect was subdivided into five segments according to Bain and Stevenson (1999). Within each segment, substrate composition was classified under one of eight substrate categories (bedrock (B), boulder (BO, >254mm), cobble (CO, 63.5 –> 254mm), pebble (P, 15.9 –> 63.5mm), gravel (G, 1.59 –> 15.9mm), sand (S), organic (O, silt, detritus, muck), and clay (C)) (Cummins 1962). Coverage by primary, secondary, and tertiary substrates within each segment was visually assessed (Casey Huckins, pers. comm.). Surveys were performed in the upstream direction. Surveyors walked on dry land from transect to transect, when possible, to minimize disruption of stream habitat.

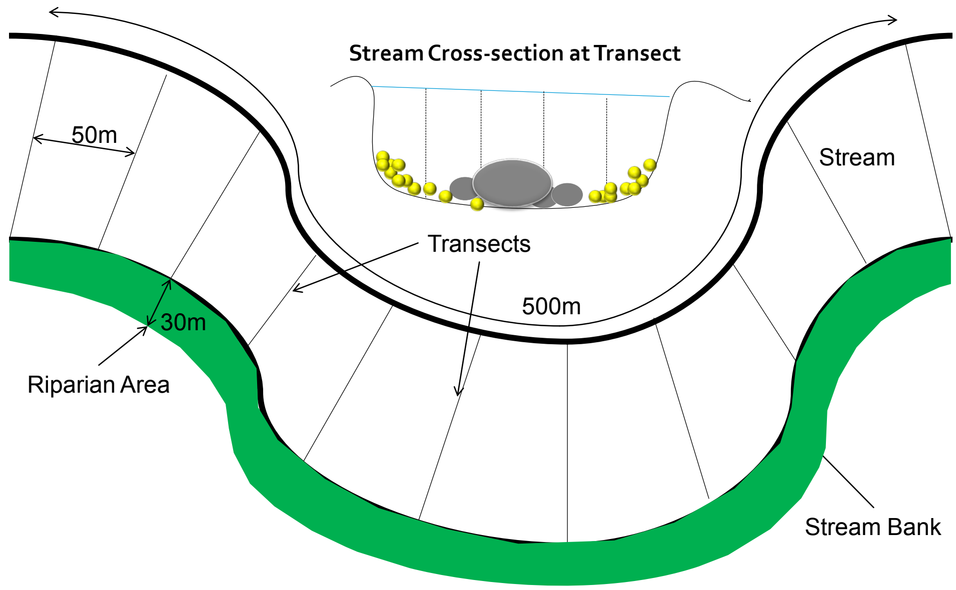


Figure 3.1: Headwater stream study reach separated into 11 lateral transects to longitudinally profile streambed habitat.

For each reach, average substrate coverage according intermediate diameter was calculated as the mean of all 11 transects. Sand depth for each segment was estimated by measuring the depth to which a 0.64 cm steel rod penetrated the sand before hitting a hard substrate. The mean sand depth along each transect was calculated then averaged across all transects of each stream. To characterize stream particle size, mean and median pebble diameters were estimated from pebble counts conducted along the entire length of each reach (Bain and Stevenson 1999). Stream wetted width was measured at each transect. Discharge was estimated for each stream reach using a Marsh-McBirney flow meter attached to a wading rod to measure water depth and velocity at 10 evenly spaced points along a wetted-channel transect (procedure in Bain and Stevenson, 1999) in early-summer (June 6th – June 16th).

3.2.1.1 Riparian Vegetation Density and Canopy Cover

Methods for measuring riparian vegetation density and canopy cover followed procedures from the Bureau of Land Management (1996). Riparian forest density was estimated using a density board at four equally spaced plots (Figure 3.2) along each stream. Mean riparian forest density was calculated as an average across all four plots. Canopy cover within the riparian area of each stream was estimated with a sighting device (i.e. ocular tube). At each transect, ten equally spaced points were established within 30 meters perpendicular from the stream. At each point, canopy cover readings were taken at 4 cardinal directions. A total of 440 ocular tube readings were recorded for each study site. Mean canopy cover was calculated as the total number of hits (points where ocular tube cross hairs intersected vegetation) divided by total number of readings taken.

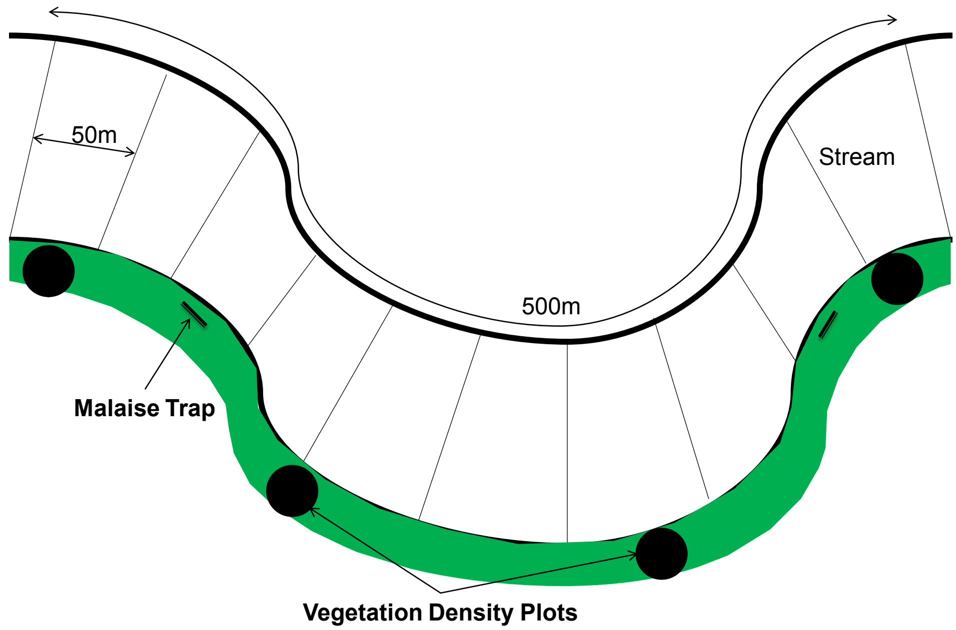


Figure 3.2: Headwater stream reach with designation of riparian vegetation plots used to survey riparian vegetation density and Malaise traps to sample emergent aquatic insects along headwater streams in Michigan's Upper Peninsula, USA.

3.2.2 Insect Community Characteristics

Emerging aquatic insects were sampled near peak emergence for our region from June 6th to June 18th (Baxter et al. 2005) using Malaise traps deployed along stream banks. To capture a snap shot of the riparian insect community, Malaise traps were located at two sampling locations along each stream (Figure 3.2). Traps were approximately 1.83 meters long *1.22 meters high and constructed of charcoal-colored, fiberglass mosquito screen based on configurations and dimensions described in Uesugi and Murakami (2006) (Appendix Figure 9.2). From initial stream observations of the previous fall (2010), in-stream productivity was assumed to be relatively uniform since uniform streambed habitat along each reach was observed. Therefore, at each site, two traps were placed in the RA on the stream bank within 10m of the stream, any further and adult insect abundances exponentially decline (Baxter et al. 2005) and perpendicular to areas where insect flight tends to be concentrated (along borders of dense vegetation, in openings between trees, across wide trails, etc). Traps were deployed for twelve nights from June 6th to June 18th and checked every two days. Intercepted insects were funneled into plastic containers partially filled with anti-freeze (Ethylene glycol), a killing agent. Insects were field preserved in ethyl alcohol and later separated into terrestrial and aquatic groups. They were further identified to order using identification guides from Borror and White (1970) and Arnett (2000). Abundance and order richness was derived. Wet mass was obtained after insects were blotted with a dry paper towel for 10 seconds then weighed to the nearest 0.0001mg. To obtain dry mass, insects were placed in a drying oven at 55°C for 72 hours then weighed to the nearest 0.0001g, a technique modified from Landeiro et al. (2010).

3.2.3 Breeding Bird Surveys

Bird surveys followed procedures described in Howe et al. (1997) and Bub et al. (2004). Four 25-meter fixed radius point-count surveys were conducted along each study reach within the breeding season (June 6st to June 19th). Fixed-radius plots limited bird detections to the riparian area. Each plot was located 25 m from the stream bank to reduce noise interference from flowing water. Each plot was separated 150 m from each other (Figure 3.3). Surveys were conducted between 30 min before sunrise and ended 5 hours later (approximately 9:30am) (Howe et al. 1997). Birds detected by sight or sound were recorded within a 10-minute period. Bird abundance, species richness, and abundance of emergent insect-preferred species was later derived.

To control and account for surveyor presence during surveys, the surveyor waited 2 minutes after approaching a plot to acclimate birds to the surveyor's presence. Surveys continued for 10 minutes thereafter while limiting movement and noise.

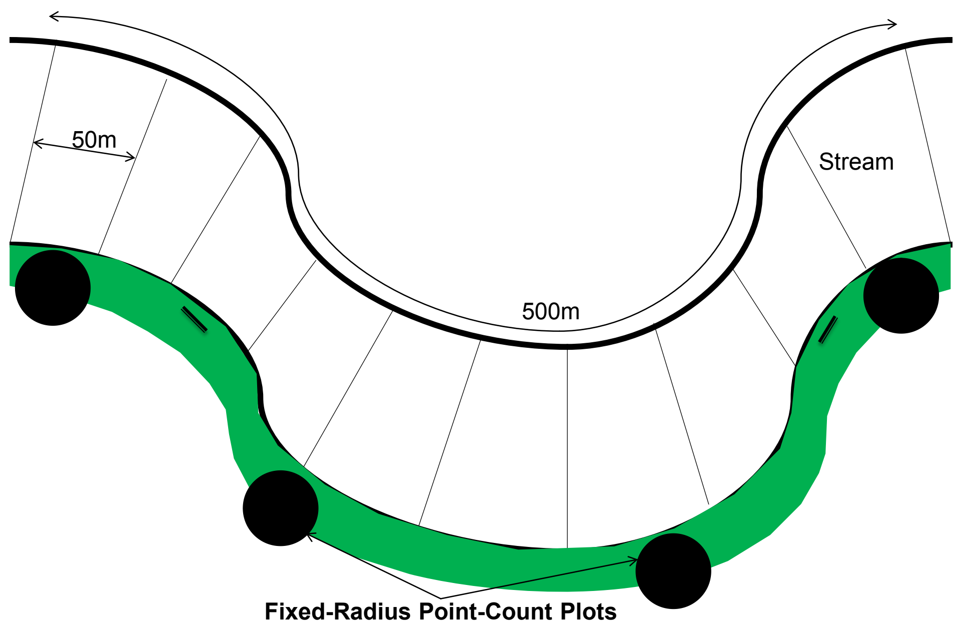


Figure 3.3: Headwater stream reach with designation of fixed-radius point-count plots used to survey riparian bird community along headwater streams in Michigan's Upper Peninsula, USA.

3.3 Data Analysis

3.3.1 Statistical Methods

Data was analyzed in Excel. Analysis of variance (ANOVA) was calculated ($\alpha = 0.05$) to identify streams of different fine sediment abundances (i.e. sand depth) (Table 3.1). Pearson correlations (r) were used to measure the intensity of association between stream, insect, and bird variables (Zar 1999). Pearson correlation values that fell between ±1.0 and ±0.6 were interpreted as explaining sufficient variation for consideration of a relationship (U of S 2011). A Tukey multiple comparison test was used to compare stream groups regarding sand depths (Figure 3.4; Appendix Table 9.1).

Table 3.1

Analysis of Variance (ANOVA) among seven headwater streams in MI Upper Peninsula regarding sand depth.

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	2.47	6	0.412	17.7	2.3E-12	2.23
Within Groups	1.63	70	0.0233			
Total	4.10	76				

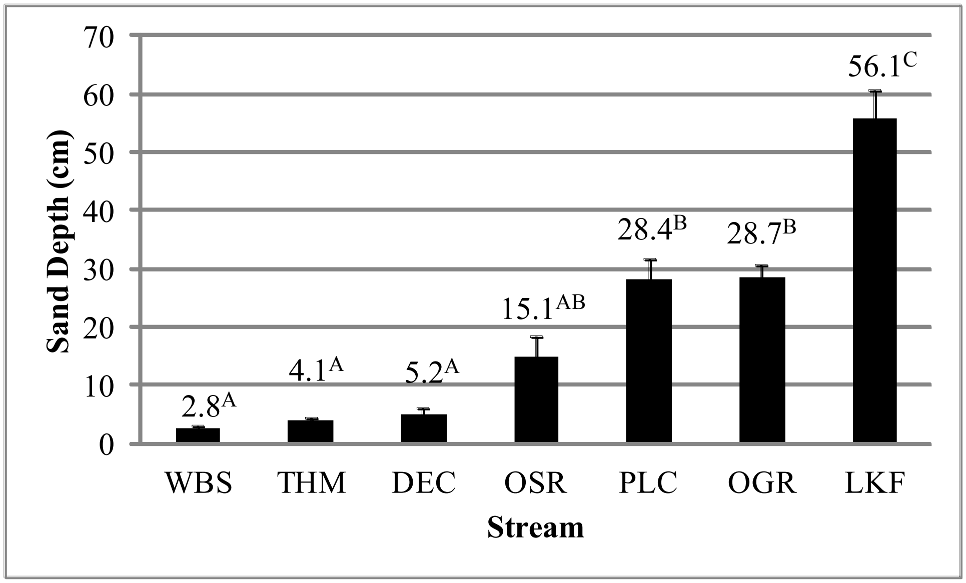


Figure 3.4: Results of measurements of sand depth for seven streams, with numbers showing mean depth of error bars showing standard error. Streams with the same letters are those having depths that do not differ significantly (P>0.05), when compared with a Tukey Multiple Comparison (Zar 1999).

4. RESULTS

4.1 Stream and Riparian Habitat

Stream Habitat: Stream habitat condition characterized by metrics of substrate size and composition varied greatly among the 7 stream reaches where sand depth differed spatially between streams (Appendix Table 9.2). An analysis of variance (ANOVA) indicated that our seven stream reaches were significantly different (P = 2.3E-12, Table 3.1). Stream reaches at PLC, OGR, and LKF had significantly higher sand depths than WBS, THM and DEC (P ≤ 4.42E-8). OSR was not significantly different from WBS, THM and DEC nor from PLC and OGR (Figure 3.4).

Coverage by predominant stream substrates varied between streams (Figure 4.1). I estimated that streambeds of reaches PLC, OGR, and LKF were 60% or more composed

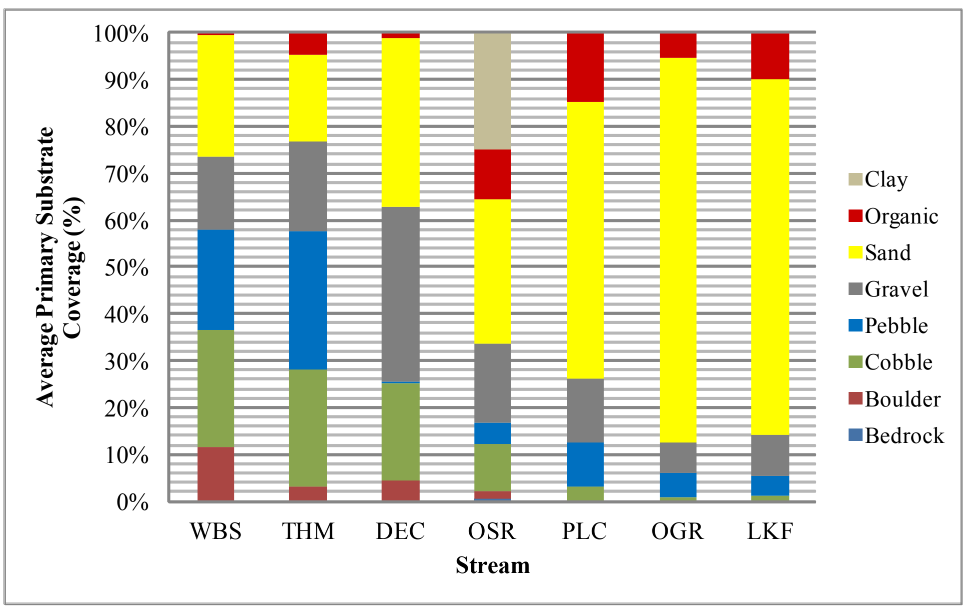


Figure 4.1: Average percent coverage of primary stream substrates of n = 11 transects along seven 500m headwater stream reaches in Michigan's Upper Peninsula. Streams in order of increasing sand depth.

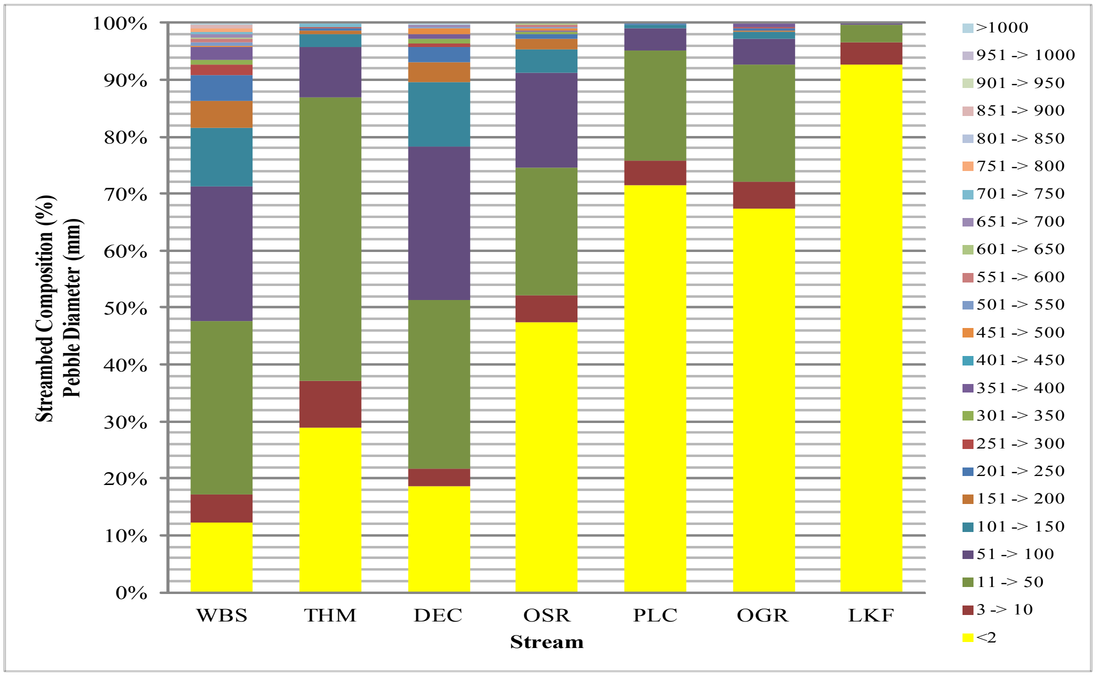


Figure 4.2: Composition of streambed substrates based on particle diameter from pebble counts (n = 331 counts) in seven headwater streams in MI's Upper Peninsula.

of fine substrates (i.e. sand), whereas WBS, THM, DEC, and OSR had 32% or less of their streambeds composed of sand.

Substrate particle sizes based on pebble counts differed between the study stream reaches. Streambed substrate composition in WBS, THM and DEC contained less than 30% fine sediments (≤ 2mm in diameter); whereas substrate composition in OSR, PLC, OGR, and LKF contained 47% or more of fine sediments (≤ 2mm in diameter) (Figure 4.2). Median pebble diameters also show some differences between streams (Appendix Figure 9.3).

Riparian Vegetation: Riparian vegetation density within the first 2m from ground level along the study reaches was not significantly different between streams (P = 0.74; Appendix Figure 9.4). However the study sites did differ in percent canopy cover (P =

3.77E-6). Few stream habitat metrics correlated with riparian vegetation density and canopy cover. Riparian vegetation density was negatively correlated with boulder coverage (r = -0.73) while canopy cover was negatively correlated to stream wetted width (r = -0.90).

4.2 Insect Community Characteristics

A total of 285 individual insects were captured from fourteen traps within the riparian area of our seven study streams (Appendix Table 9.3a). Captured insects were numerically dominated by aquatic emergent whereas terrestrial insects accounted for most of the dry mass. Emergent aquatic insects comprised 58% of the total insects captured across all sites and the other 42% were classified as terrestrial insects. Of the total emergent aquatic insect assemblage, members of Ephemeroptera, Plecoptera and Trichopter combined (EPT) comprised 11% while Dipterans comprised the other 47%.

Total insect abundance was negatively correlated with sand depth (r = -0.46) and sand coverage (r = -0.48) (Appendix Figure 9.5). Abundance of total aquatic insects and EPT insects were negatively correlated to sand depth (r = -0.63, r = -0.22, respectively; Figure 4.3). Total EPT abundance was also negatively correlated with % sand coverage (r = -0.50, Appendix Figure 9.6).

It follows that total aquatic insect abundance was positively correlated with the percent coverage by larger substrates such as boulders (r = 0.68), cobbles (r = 0.5), and pebbles (r = 0.28) (Figure 4.4). Correlations between EPT abundance and coverage by larger substrates such as boulders (r = 0.34), cobbles (r = 0.53), and pebbles (r = 0.88) were also positive (Appendix Figure 9.6).

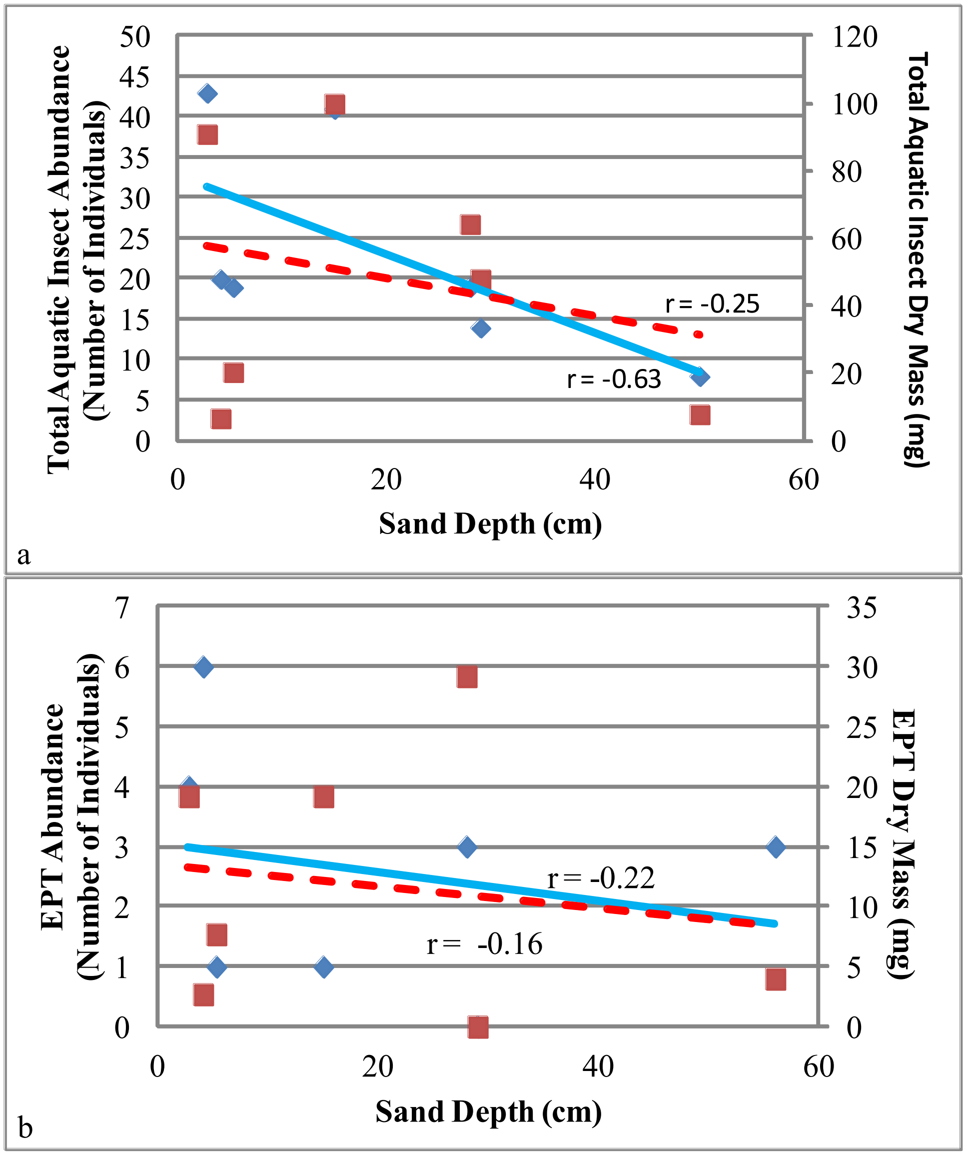
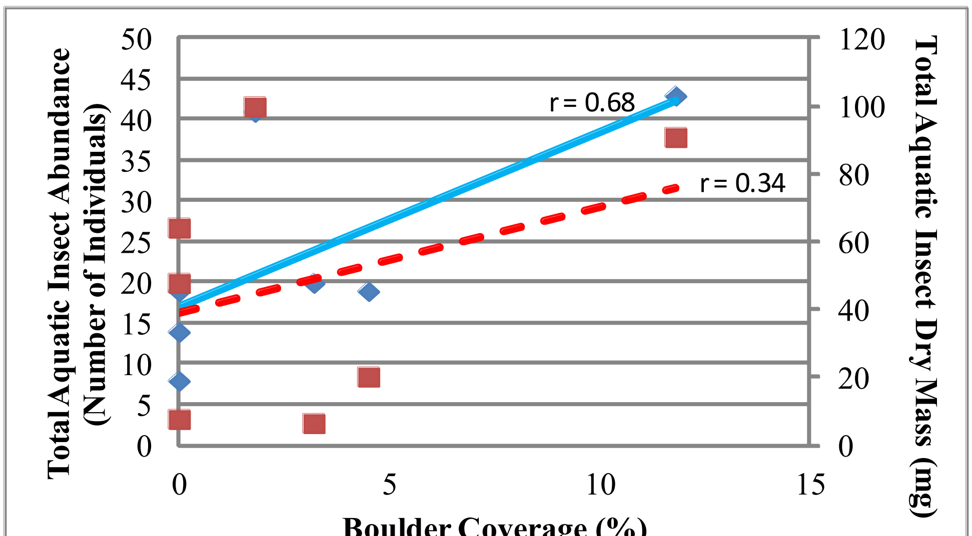


Figure 4.3: Total emergent aquatic insects (a) and emergent EPT (b) abundance (◆) and dry mass (■) relative to sand depth of n = 11 transects within seven headwater streams of Michigan's Upper Peninsula, USA. Pearson Correlation Coefficient (r). Coefficients (r) between ±1.0 & ±0.6 indicates sufficient relationship.

Total dry mass of insects was 769.5mg (Appendix Table 9.3b). Approximately 44% of the total dry mass of the insects collected were emergent aquatic insects. Within the aquatic insects 24% of the dry mass was from EPT individuals and the rest were Dipterans.

Total riparian insect dry mass was negatively correlated with sand depth (r = -0.28) and sand coverage (r = -0.37; Appendix Figure 9.5). Total aquatic dry mass was negatively correlated with sand depth (r = -0.25, Figure 4.3a). EPT dry mass was also negatively correlated with sand depth (r = -0.16, Figure 4.3a) and sand coverage (r = -0.24; Appendix Figure 9.6d).

Positive correlations were found between both total aquatic and EPT dry mass with coverage by boulders (r = 0.34 and r = 0.20, respectively; Figure 4.4a and 9.6a). Total aquatic insects were slightly negatively correlated with pebble coverage (r = -0.043), whereas EPT was slightly positive (r = 0.0021). Low negative correlations of total aquatic insects, including EPT, were found with coverage by cobbles (r = -0.018 and r = -0.019, respectively) (Figure 4.4b and 9.6b).



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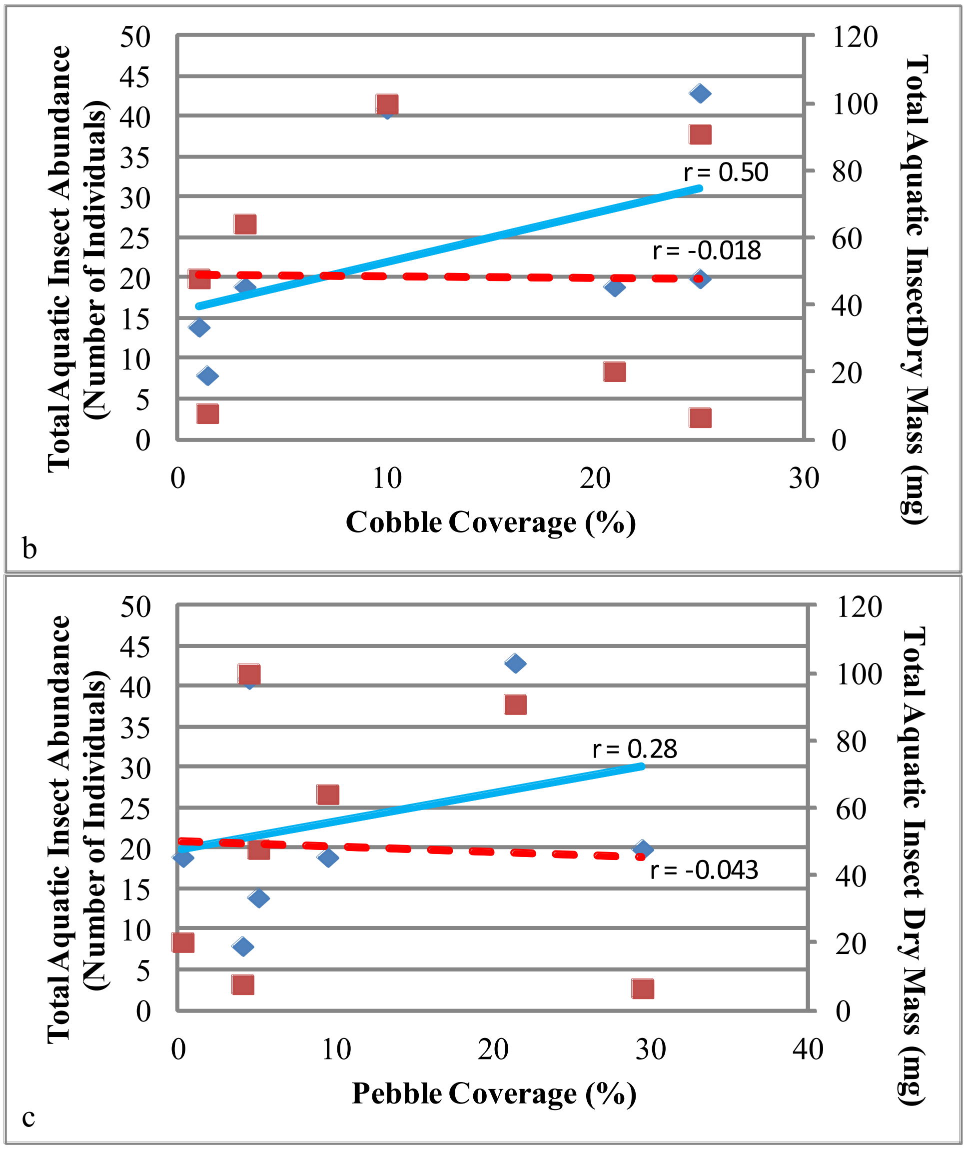
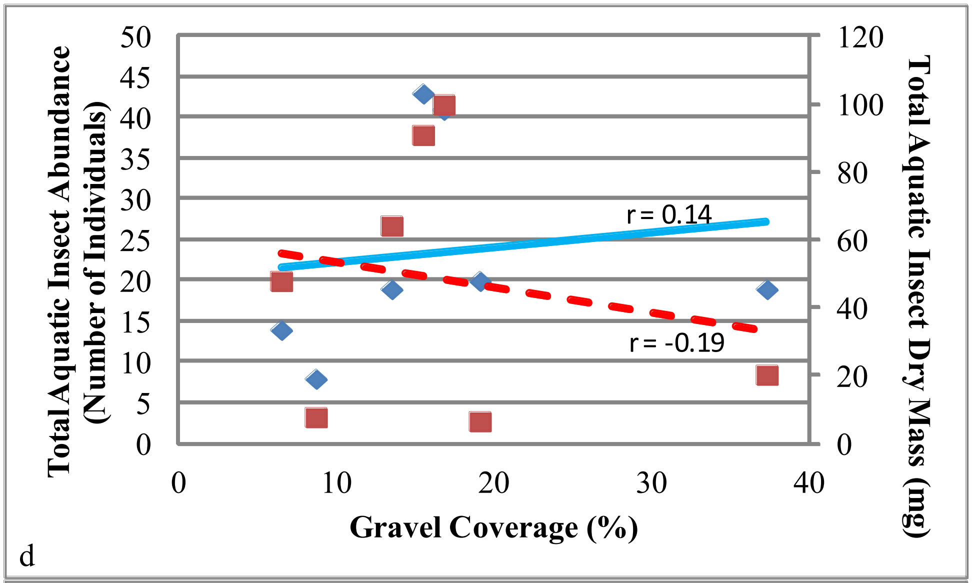
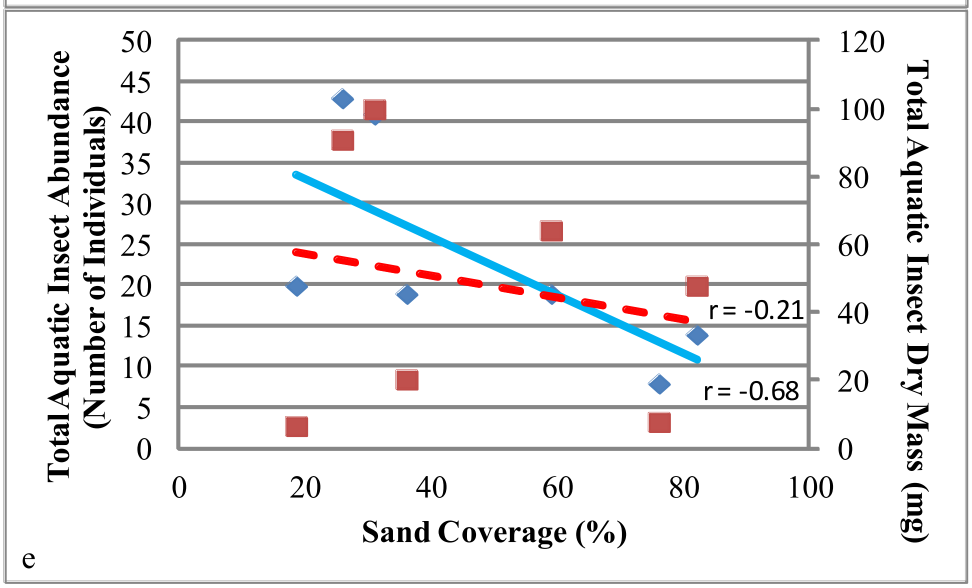


50
45
40
35
30
25
20
15
10
5
0
120
100
80
60
40
20
0
0
10
20
30
Total Aquatic Insect Abundance (Number of Individuals)
Total Aquatic InsectDry Mass (mg)
Cobble Coverage (%)
r = 0.50
r = -0.018
b
50
45
40
35
30
25
20
15
10
5
0
120
100
80
60
40
20
0
0
10
20
30
40
Total Aquatic Insect Abundance (Number of Individuals)
Total Aquatic Insect Dry Mass (mg)
Pebble Coverage (%)
r = 0.28
r = -0.043
c



Total Aquatic Insect Abundance (Number of Individuals)
Total Aquatic Insect Dry Mass (mg)
Gravel Coverage (%)
r = 0.14
r = -0.19
d



Total Aquatic Insect Abundance (Number of Individuals)
Total Aquatic Insect Dry Mass (mg)
Sand Coverage (%)
r = -0.21
r = -0.68
e

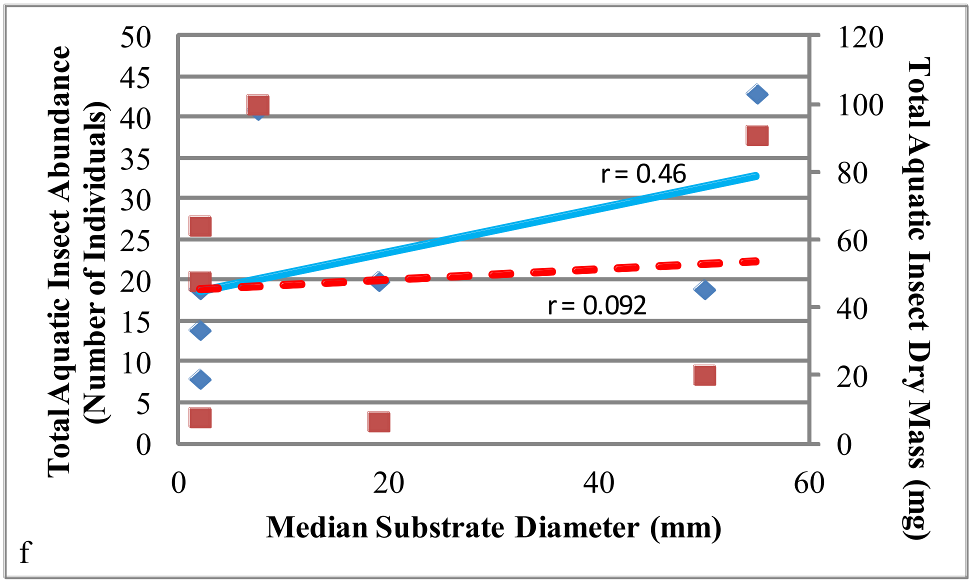


Figure 4.4: Relationships between coverage by various stream substrates (a) boulder, b) cobble, c) pebble, d) gravel, e) sand within n = 77 stream transects and f) median stream substrate diamter from pebble counts (n = 2317 counts), to total emergent aquatic insect abundance (◆) and dry mass (■) along riparian areas of headwater streams in Michigan's Upper Peninsula, USA. Pearson correlation coefficients (r) between ±1.0 & ±0.6 indicates sufficient relationship.

4.3 Breeding Bird Surveys

I detected substantial variation in the abundance and the species composition of breeding birds in the riparian zones of the study streams (Figure 4.5, Table 9.4). A total of 487 individual birds from 50 species were detected. Bird detection abundance and species richness was lowest at DEC (22 individuals, 8 species) and greatest at OSR (56 individuals, 24 species). Emergent insect-preferred species (Winter Wren (WIWR) (*Troglodytes troglodytes*) and American Redstart (AMRE) (*Setophaga ruticilla*)) abundances also varied between streams. No Winter wrens or American redstarts were detected at DEC, whereas five wrens were detected at OSR and six redstarts at OSR and THM (Figure 4.5 and Appendix Table 9.4). Study sites were I detected greater total bird abundance also had greater species richness (r = 0.946).

Although the species richness of the breeding birds did not appear to be related to the total abundance of emergent insects (r = -0.21, Figure 4.6a), richness of the bird community was greater in the streams that supplied more emergent EPT abundance (r = 0.79, Figure 4.6b).

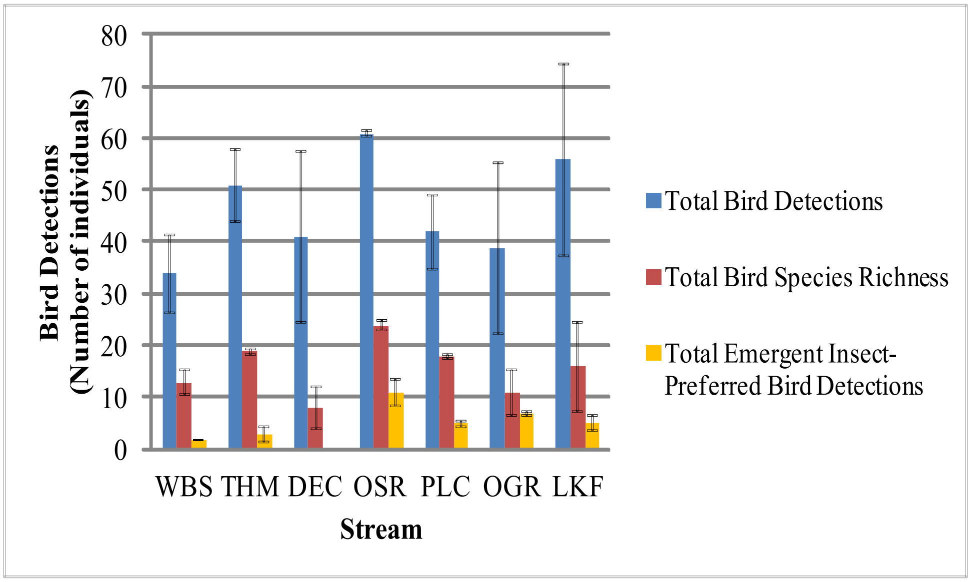


Figure 4.5: Total riparian bird detection abundance (n = 487 birds), species richness (n = 50 species), and detection abundance of emergent insect-preferred species (n = 2 species), in the riparian area along seven headwater streams in Michigan's Upper Peninsula, USA. Standard error bars are shown.

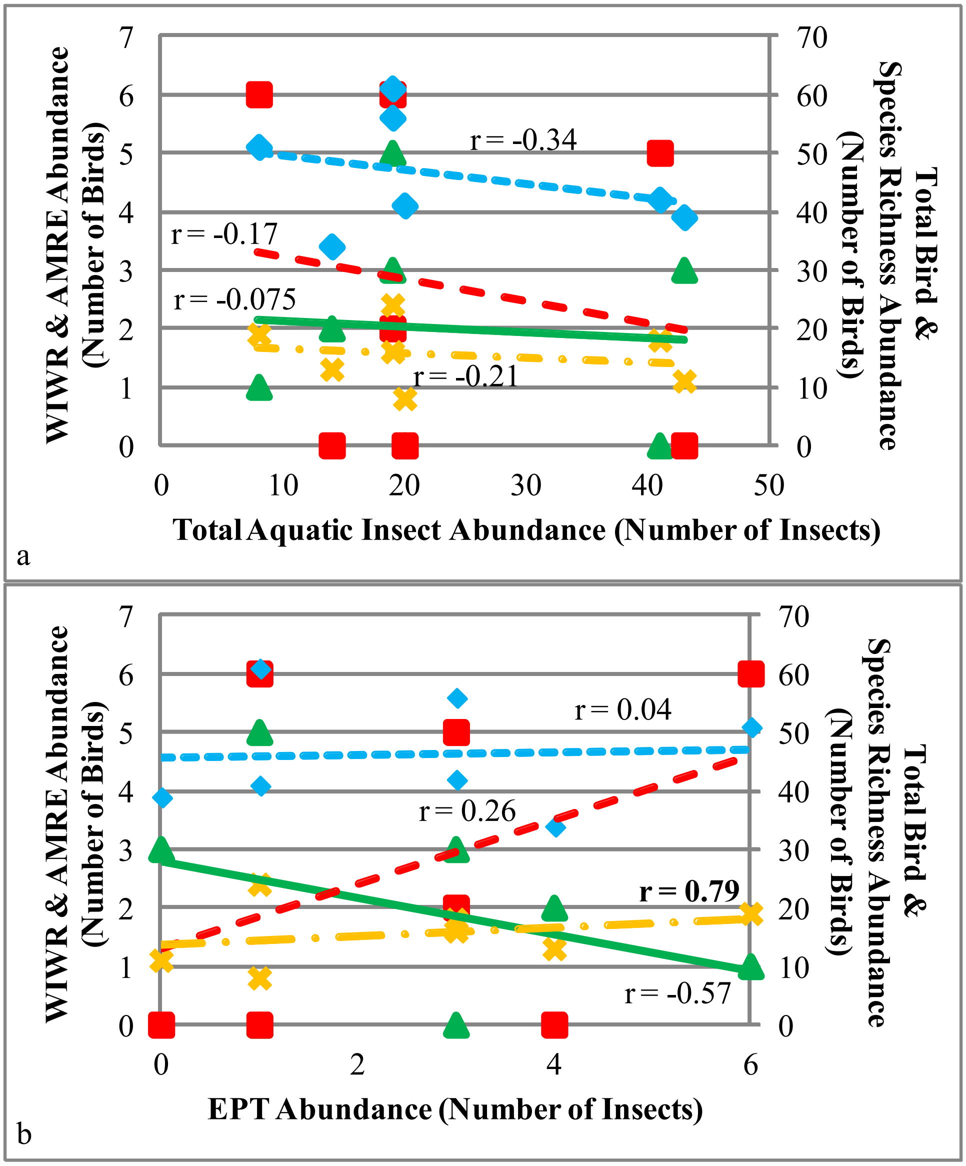


Figure 4.6: Total bird detection abundance (n=487) (◆), species richness (n=50) (✖), and emergent insect-preferred bird abundance (n=33) (Winter Wren (WIWR) (▲) and American redstart (AMRE) (■)) in relation to total emergent aquatic (a) and EPT (b) insect abundance (n=18) in riparian areas along headwater streams of Michigan's Upper Peninsula, USA. Pearson Correlation Coefficients (r) between ±1.0 & ±0.6 indicates sufficient relationship in bold.

Relationships between ripairan bird abundance and richness with total emergent aquatic insect abundance were weak (Figure 4.6a). Total birds detected were negatively correlated to total aquatic insect abundance (r = -0.34) and slightly positive to EPT abundance (r = 0.04). Bird richness was sharply positively correlated with EPT abundance (r = 0.79, Figure 4.6b). Winter wren abundance was slightly negative to total aquatic insect abundance (r = -0.075), but more strongly negative to EPT abundance (r = -0.57). American redstart abundance was slightly negatively correlated to total aquatic insect abundance (r = -0.17), but positively correlated with EPT abundance (r = 0.26).

Relationships between riparian bird abundance and richness with total emergent aquatic insect dry mass was weak (Appendix Figure 9.8a). Total abundance of birds detected was negatively correlated to emergent aquatic insect dry mass (r = -0.33) and EPT dry mass (r = -0.10) while species richness was weakly correlated to total aquatic insect dry mass (r = -0.097) and sharply positively correlated with EPT dry mass (r = 0.88, Appendix Figure 9.8b). Winter wren abundance showed very little correlation to either total aquatic (r = -0.011) and EPT (r = -0.080) dry mass. American redstart abundance was negatively correlated to total aquatic insect dry mass (r = -0.18) while positively correlated with EPT dry mass (r = 0.25).

Relationships between stream characteristics and riparian bird community assemblage (abundance and richness) were largely weak (Appendix Table 9.5). The few correlations that were strong were comparisons between bird species richness and streambed coverage by clay (r = 0.69) and organic material (r = 0.66). A wide range of correlations between total bird abundance to substarte coverage was observed with bouders (r = -0.51), cobbles (r = -0.25), pebbles (r = -0.15), gravel (r = -0.12), sand (r = -0.051), clay (r = 0.66), and organic material (r = 0.51).

5. DISCUSSION

In this comparative study I investigated relationships between stream habitat, emergent aquatic insects, and riparian breeding birds in headwater streams of Michigan's Upper Peninsula. Overall, streams with less sand and larger substrates in the wetted channel appeared to supply more emergent aquatic insects to the riparian area than streams with more fine sediments. Likewise, streams contributing higher EPT abundances to the riparian area showed higher bird species richness.

5.1 Stream and Insect Relationships

Past logging practices of forest stands adjacent to our streams (VanDusen et al. 2005) (Appendix Figure 9.9) is most likely the cause for the presence of an apparent overabundance of fine sediments (i.e. sand) observed in some of our study sites. Streams that contained high sand depths resulted in lower abundances of emergent aquatic insects in the riparian area, whereas streams with shallower sand depths had greater abundances. This relationship is likely due to the effects of streambed smothering caused by increased inputs of sand. Brusven and Prather (1974) discussed the harmful effects of sediment pollution to stream biota, and Merritt and Cummins (1996) explained the importance of rough streambed structures, such as boulders, cobbles, and pebbles, to support insect emergence from streams for many species in the orders of Ephemeroptera, Plecoptera, and Trichoptera. If large amounts of sand wash into a stream, larger substrates become embedded and cannot properly support insect emergence.

In this study, streams predominantly covered by larger substrates such as boulders, cobbles, and pebbles supplied greater abundances of emergent aquatic insects to the riparian area than streams that were predominantly covered by finer substrates such as gravel and sand. These results were corroborated by other studies (Rabeni et al. 2005; Gomi et al. 2010; Long et al. 2011), especially Brusven and Prather (1974) who studied substrate preferences of five species of aquatic stream insects belonging to the orders of Ephemeroptera, Plecoptera, Trichoptera (EPT), and Diptera. They concluded that streams containing larger substrates such as large pebbles (12 – 25mm) and cobbles (64-256mm in diameter) had higher macroinvertebrate abundances over streams with half or fully embedded cobble or no cobble at all. Therefore, we expected to find higher abundances of emergent aquatic insects, as well as EPT assemblage, in the riparian area along streams that were predominantly covered by larger substrates.

The number of Malaise traps and timing of insect surveys with peak insect emergence for our region are a few major limiting factors which may have prevented us from observing stronger relationships between instream habitat characteristics and emergent aquatic insects. The number of traps deployed along stream banks may have underrepresented emergent aquatic insects in the riparian area. Budget constraints and material costs limited us to two traps per stream. According to Baxter et al. (2005), peak emergence of aquatic insects occurs in the later spring/early summer in temperate regions. Abiotic conditions, such as air and water temperature, if altered, can influence timing of emergence and flight activity of aquatic insects (Harper and Peckarsky 2006; Fin and Poff 2008). Due to a cold, late spring the timing for peak insect emergence for our region may have been pushed outside of our sampling timeline.

5.2 Insect and Bird Relationships

The emergence of aquatic insects from streams has been understood to provide an abundant source of food that attracts large numbers of insect consumers (i.e. birds, bats, lizards, spiders) from upland areas located away from the stream (Murakami and Nakano 2002; Baxter et al. 2005; Iwata 2006). A strong positive correlation between bird abundance and the flux of emergent aquatic insects into the riparian area was found in the literature review by Baxter et al. (2005). In this study we detected weak relationships between bird abundance and total emergent insect abundance, but found a very strong relationship between EPT abundance with bird species richness. Such a strong relationship between emergent EPT and bird species richness has been supported by work from Murakami and Nakano (2002). They observed that insectivorous birds who fed on both aquatic and terrestrial insects were more frequently detected in the riparian forests than in upland forests because they are attracted to the overabundance of allochthonous prey input from streams.

Insectivorous birds, Winter wrens and American Redstarts in particular, are generally more prevalent in riparian forest habitats and prefer to consume emergent aquatic insects over terrestrial insects (Waterhouse et al. 1990; Keast et al. 1995; Wiebe and Martin 1998; Murakami and Nakano 2001). One main reason for this behavior is due to high energy demands made on parents when rearing nestling young. So it is at this time where parents try to synchronize rearing of young with the emergence of aquatic insects (Martin 1987; Gray 1993). In the current study, there was a weak relationship between the Winter wren and the ratio of aquatic to terrestrial insect availability in the riparian area (r

= 0.046, Appendix Figure 9.7). American redstarts however were found to correlate positively with Trichopteran abundance (r= 0.6412). We may not have detected a relationship regarding Winter wrens because of a low average abundance detected per stream (mean = 2).

In this study, I chose not to look at individual bird diets, but instead to look at the community of potentially available emergent aquatic insects as prey to riparian consumers, namely insectivorous breeding birds. The aquatic prey captured in this study belonged to orders that have been shown to make up a significant proportion of riparian bird diets (Rosenberg et al. 1982; Nakano and Murakami 2001; Yard et al. 2004; Baxter et al. 2005; Kirkpatrick and Conway 2006; Uesugi and Murakami 2006). All insects captured were assumed to be an available food source for all riparian birds detected. Dipterans, which made up a large proportion of the abundance and dry mass of total emergent aquatic insects captured, were assumed to have originated from the stream.

The timing of insect surveys as well as the timing of bird surveys were likely limiting factors preventing observation of stronger relationships between emergent aquatic insects and the riparian bird community. Bird surveys were conducted within the breeding season (June 1st to July 15th) and during the morning hours of the day when birds are most active. Within the daily time frame of the most bird activity (singing/detectable by plain sight), there existed distinct periods of lower and higher activity. Lower periods of activity typically occurred between one half hour before sunrise until about 6:00am and then after 8:30am, whereas higher periods of activity occurred between 6:00am and

8:30am. Accounting for the lower periods of activity most likely skewed our results which showed weaker relationships then there may have existed.

6. FUTURE WORK

6.1 Questions that Remain

More work beyond the scope of this study is needed to enhance this type of approach to studying stream and riparian forest relationships. Firstly, comparing headwater streams to higher orders of the same stream will help further elucidate how stream size and changes in substrate composition related to larger stream orders, influences the patterns we found. This information would broaden understanding of the relationships between stream habitat and riparian bird community relative to headwater streams in north temperate forests. Lastly, studying seasonality trends of streambed characteristics, emergent insects, and bird community would provide information on relationship dynamics between stream and riparian habitats as the seasons change. Pursuing seasonality studies would allow forest managers to put into consideration time of year when planning harvesting operations in order to optimize timber harvest yield while at the same time minimizing impact to streams and riparian bird communities.

6.2 Theoretical Implications

This study's approach to exploring the intricately interconnected relationships shared between stream and riparian areas aimed to identify and analyz key relationships between instream fine sediment abundance, emergent aquatic insects, and riparian bird community. This approach will help increase understanding of stream and riparian food web for ecologists and other researchers. Forest resource managers that harvest timber near headwater streams can use this study to build a more complete understanding as to the importance of stream habitat for riparian bird community. Therefore, future forest management plans should be evaluated and/or updated to conserve stream habitat condition in order to benefit aquatic macroinvertebrates as well as riparian breeding birds. This approach will also help to promote protection of streams from excessive input of fine sediments which will benefit stream and riparian forest biota.

7. CONCLUSION

As a comparative study, relationships between stream habitat, emergent aquatic insects, and riparian breeding birds were investigated in headwater streams of Michigan's Upper Peninsula. Streams containing low fine sediment abundance (i.e. sand depth and coverage) as well as coarse sediment abundance (i.e. boulder, cobble, and gravel coverage) expressed stronger correlations with emergent aquatic insect abundance in the riparian area than with streams containing higher fine sediment and lower coarse sediment abundances. There were insufficient and weak considerations of a relationship between riparian breeding bird community and either stream habitat or emergent aquatic insects. Work beyond the scope of this study is needed to further this type of approach to studying stream and riparian forest relationships.

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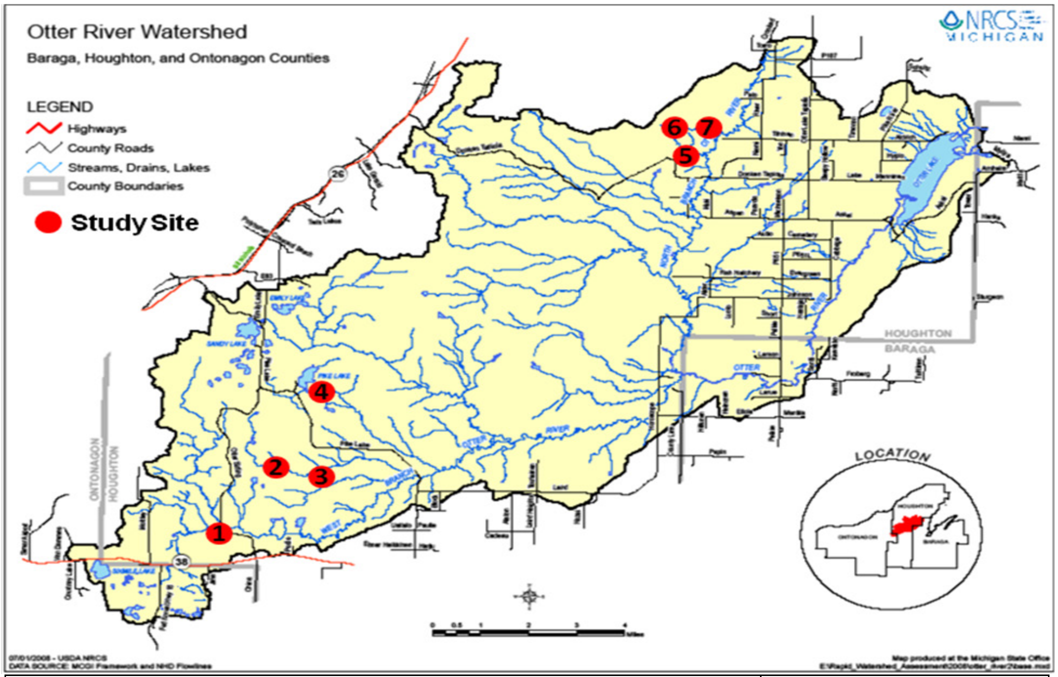
9. APPENDIX A



Study Site	GPS (WGS 84)
Otter Siding Creek (1)	N 46°46'32.0" W 88°51'49.3"
Lake Fifteen (2)	N 46°47'55.2" W 88°50'42.6"
Pike Lake Curve (3)	N 46°48'10.6" W 88°49'33.1"
Ogre (4)	N 46°48'44.2" W 88°48'45.3"
West Sante River (5)	N 46°57'36.4" W 88°44'02.4"
Thirteen Mile Creek (6)	N 46°57'45.6" W 88°43'23.5"
Deer Camp (7)	N 46°57'41.3" W 88°43'01.2"

Figure 9.1: Map designating seven headwater stream study sites (with GPS position listed below) in the Otter River Watershed of Michigan's Upper Peninsula. Map from *www.uprcd.org/downloads/****otter_river****_rwa_****news****letter.pdf* ***(UPRCD, 2008).***

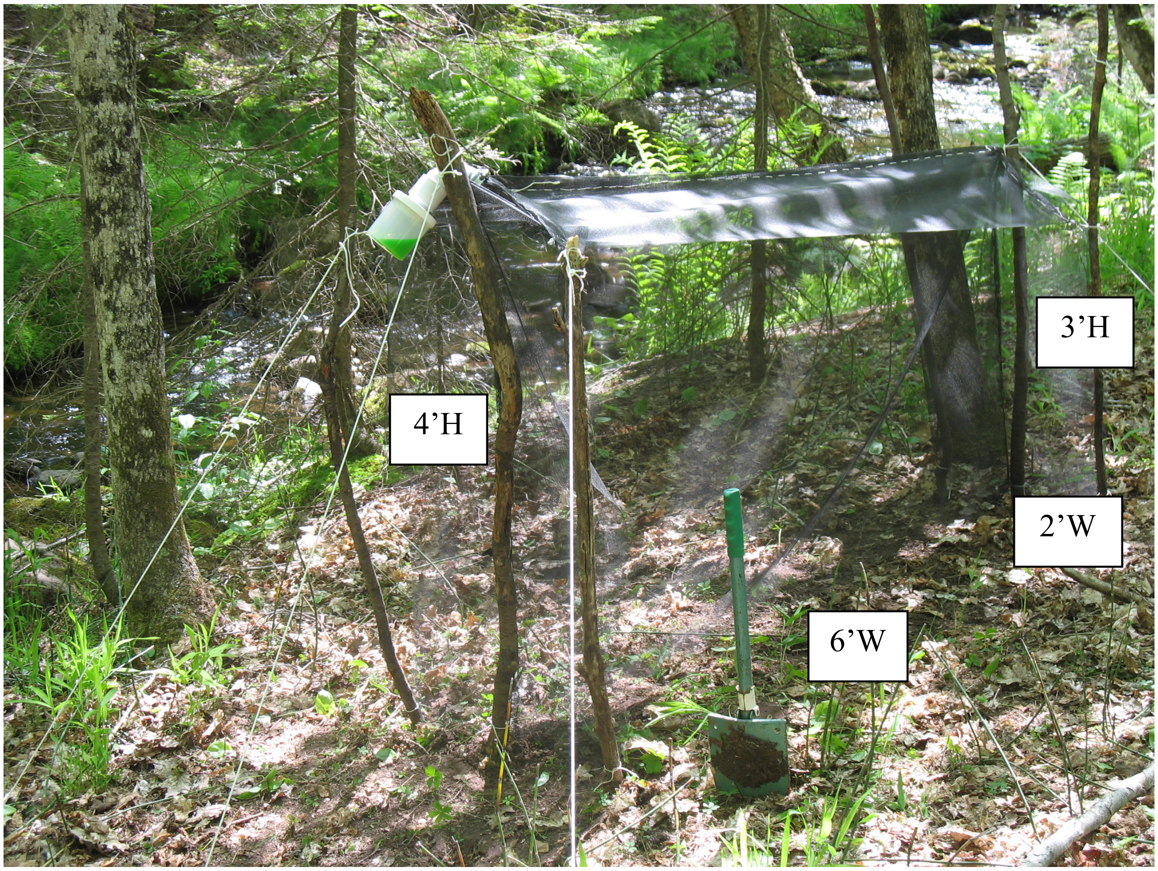


Figure 9.2: Design and dimensions of Malaise traps used to sample flying insects in the riparian areas along headwater streams of Michigan’s Upper Peninsula, USA.

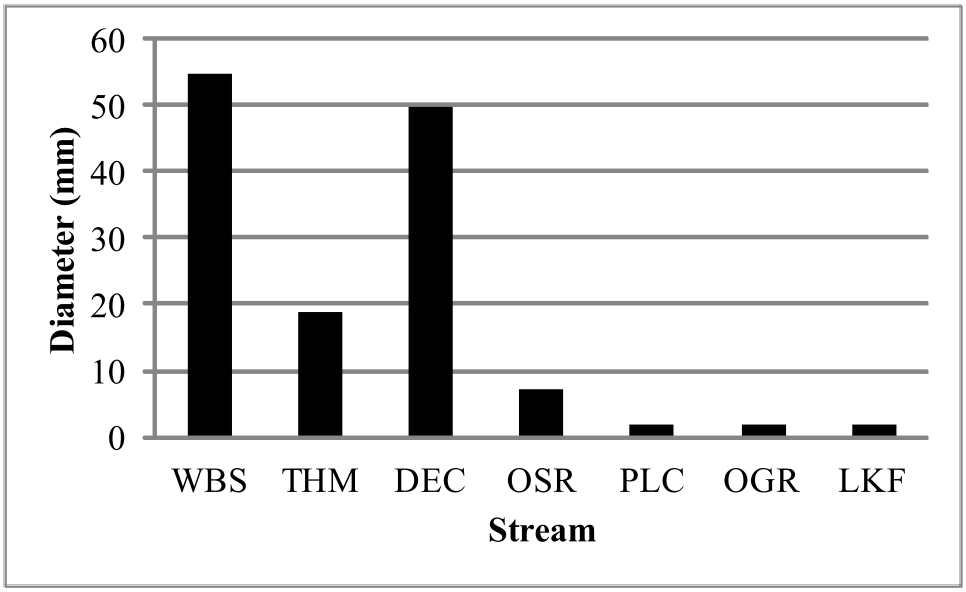


Figure 9.3: Median pebble diameter based on pebble counts (n = 331 counts) in seven headwater streams of Michigan's Upper Peninsula, USA.

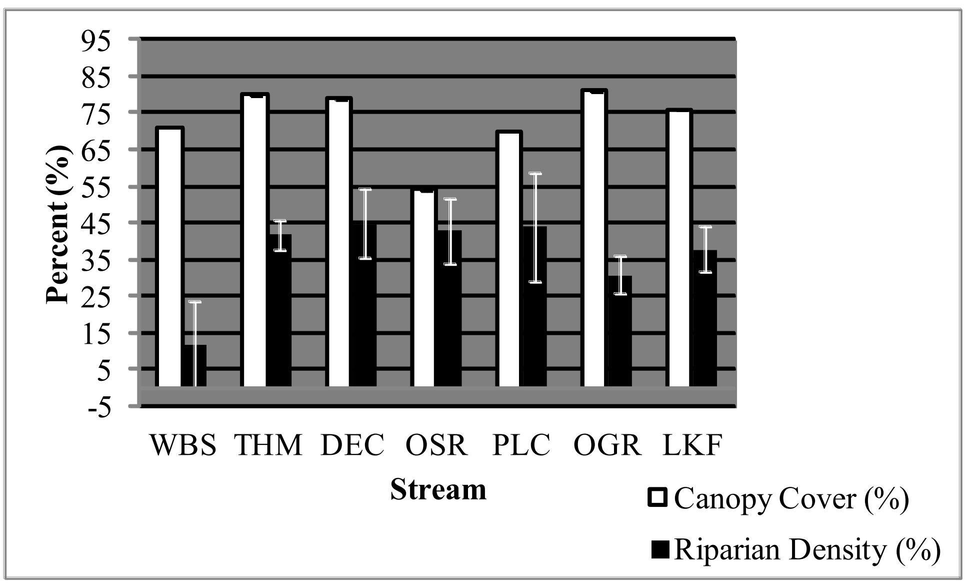


Figure 9.4: Mean canopy cover and riparian vegetation density along seven headwater streams in the Otter River Watershed of Michigan's Upper Peninsula. Standard error bars are displayed.

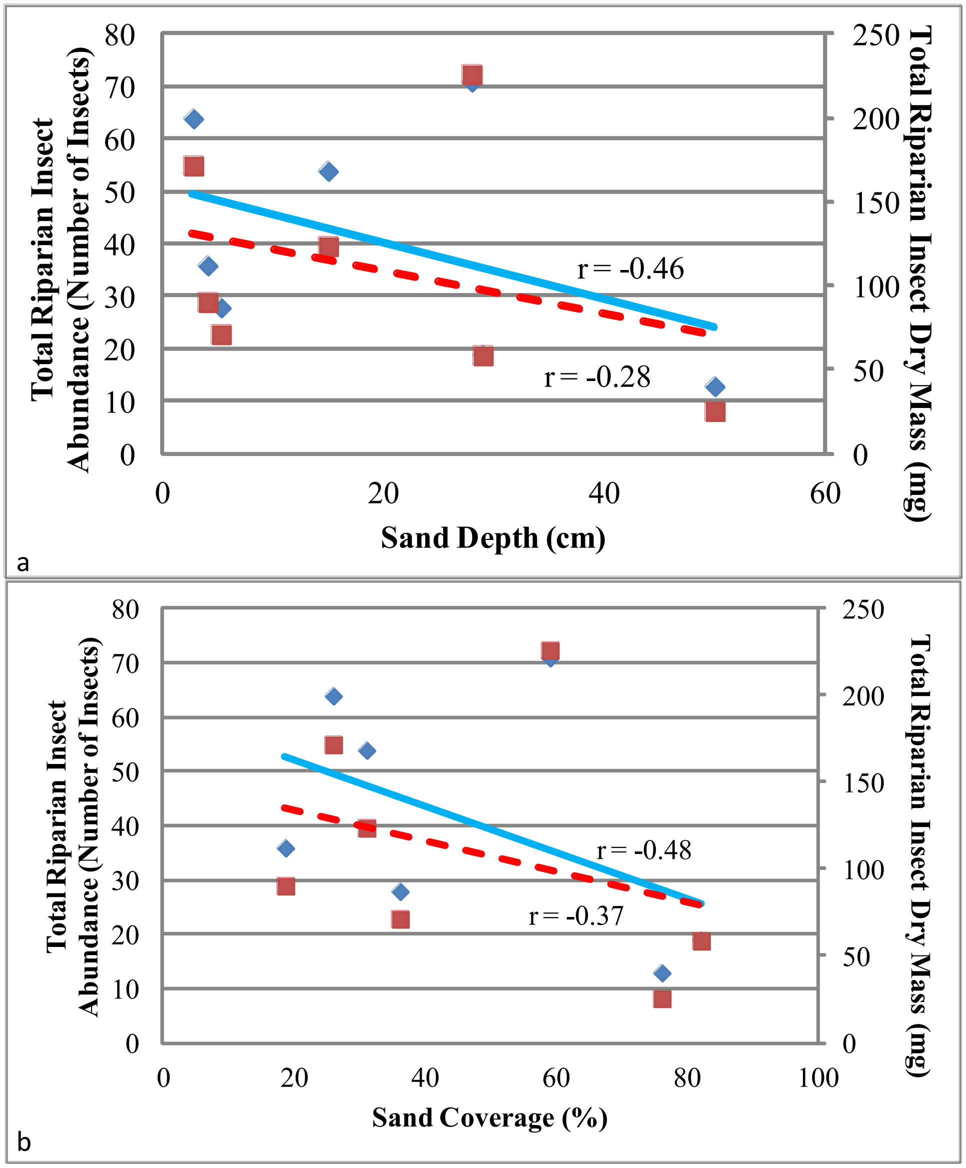
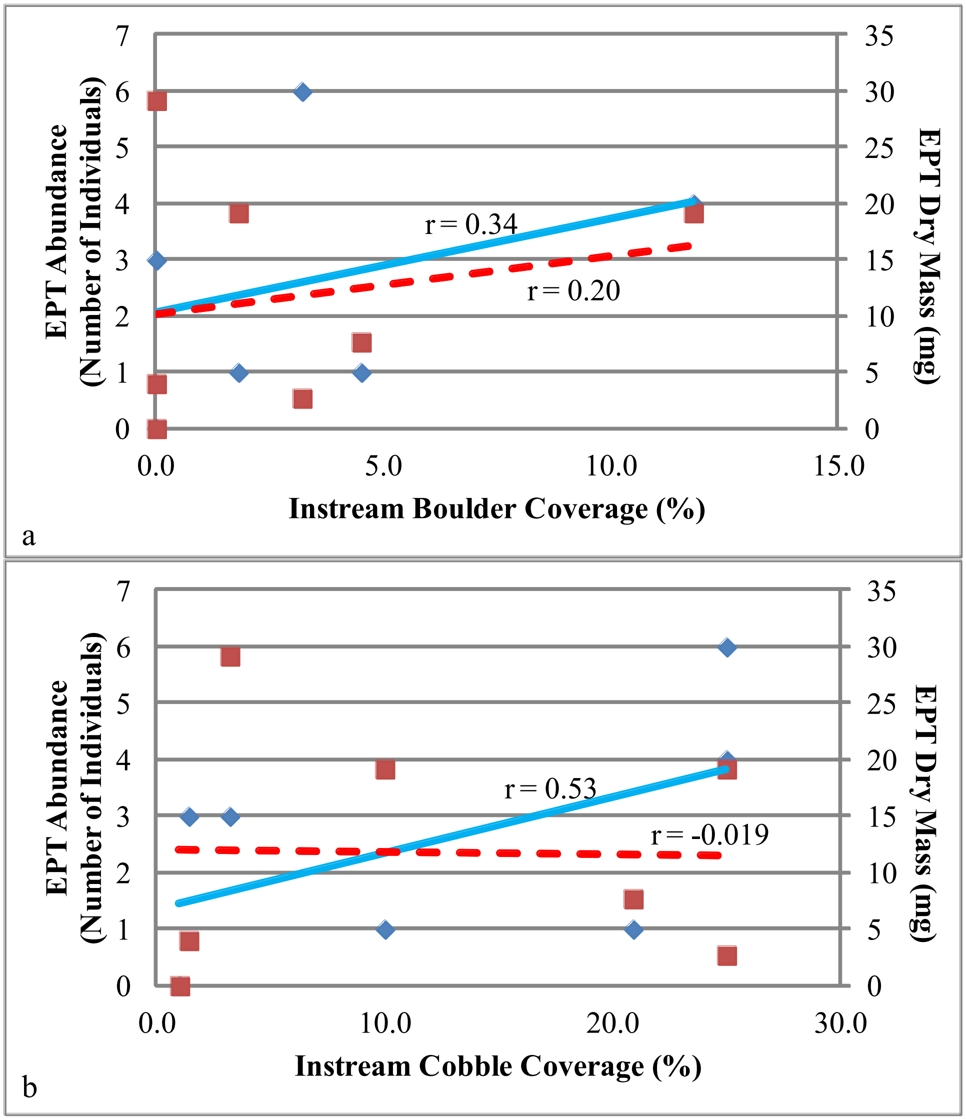
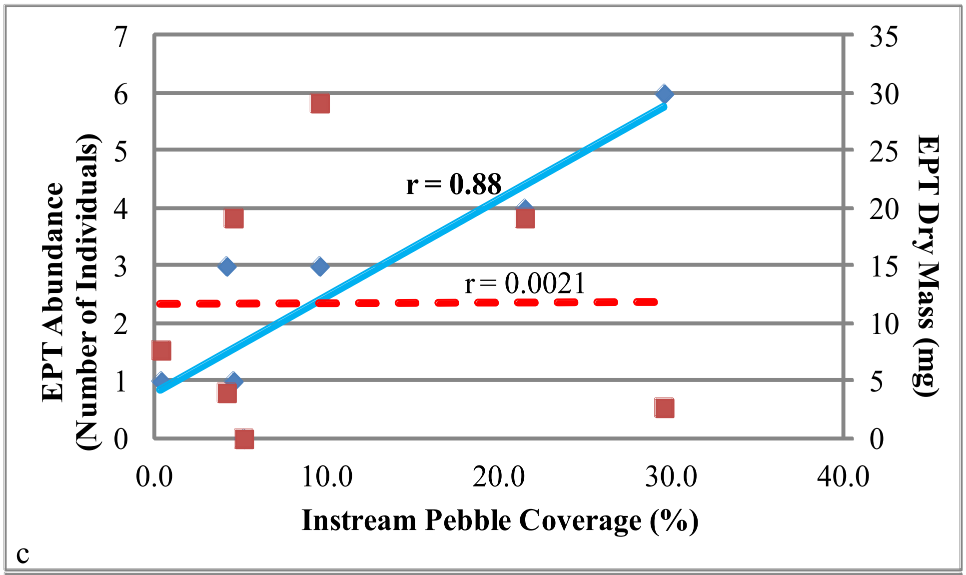
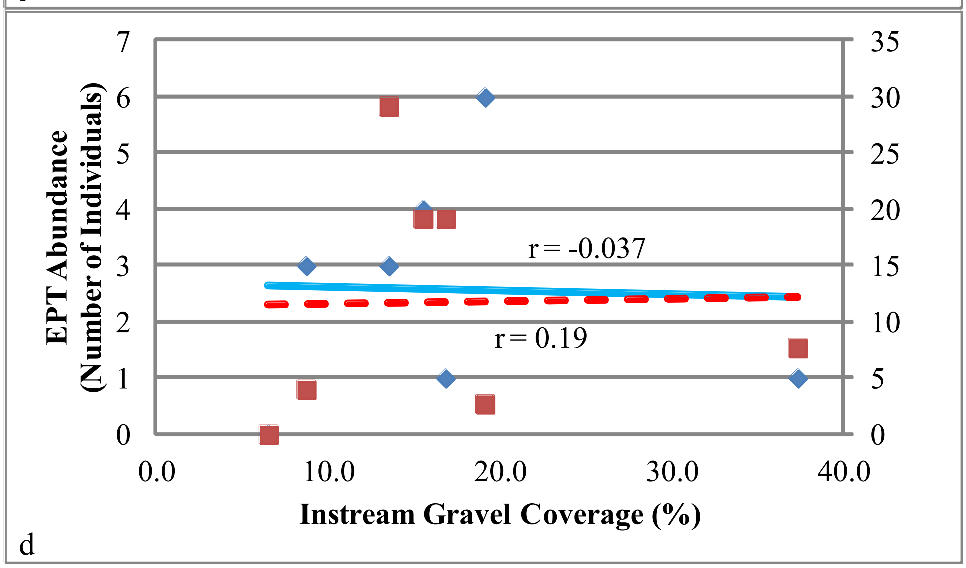


Figure 9.5: Total riparian insect abundance (◆) and dry mass (■) relative to instream sand depth (a) and coverage (b) along Seven headwater streams in the Otter River Watershed.


EPT Abundance (Number of Individuals)
EPT Dry Mass (mg)
r = 0.34
r = 0.20
Instream Boulder Coverage (%)
a
EPT Abundance (Number of Individuals)
EPT Dry Mass (mg)
r = 0.53
r = -0.019
Instream Cobble Coverage (%)
b


EPT Abundance (Number of Individuals)
EPT Dry Mass (mg)
r = 0.88
r = 0.0021
Instream Pebble Coverage (%)
c


EPT Abundance (Number of Individuals)
r = -0.037
r = 0.19
Instream Gravel Coverage (%)
d

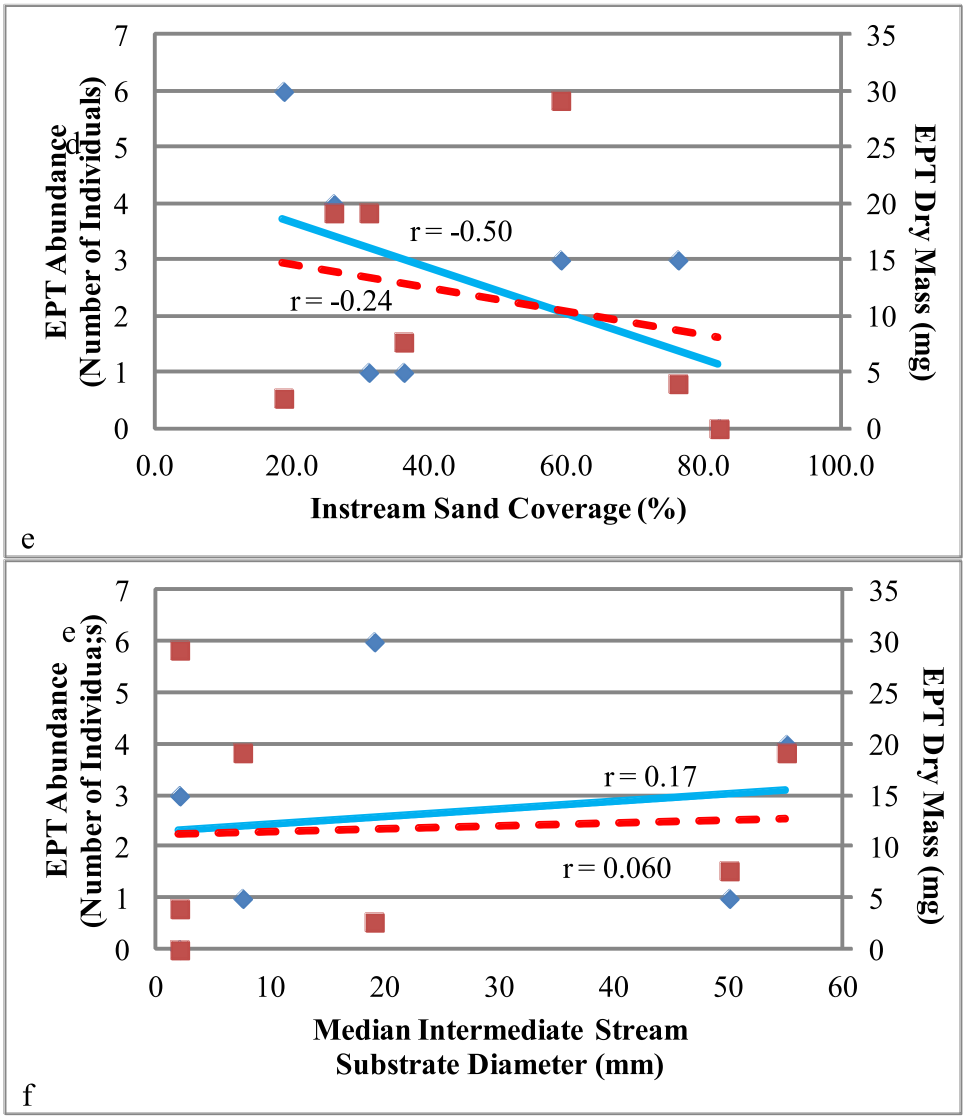


Figure 9.6: Relationships between coverage by various stream substrates (a) boulder, b) cobble, c) pebble, d) gravel, e) sand within n = 77 stream transects and f) median stream substrate diamter from pebble counts (n = 2317 counts), to emergent aquatic insects (EPT) abundance (◆) and dry mass (■) along riparian areas of headwater streams in Michigan's Upper Peninsula, USA. Pearson correlation coefficients (r) between ±1.0 & ±0.6 indicates sufficient relationship.

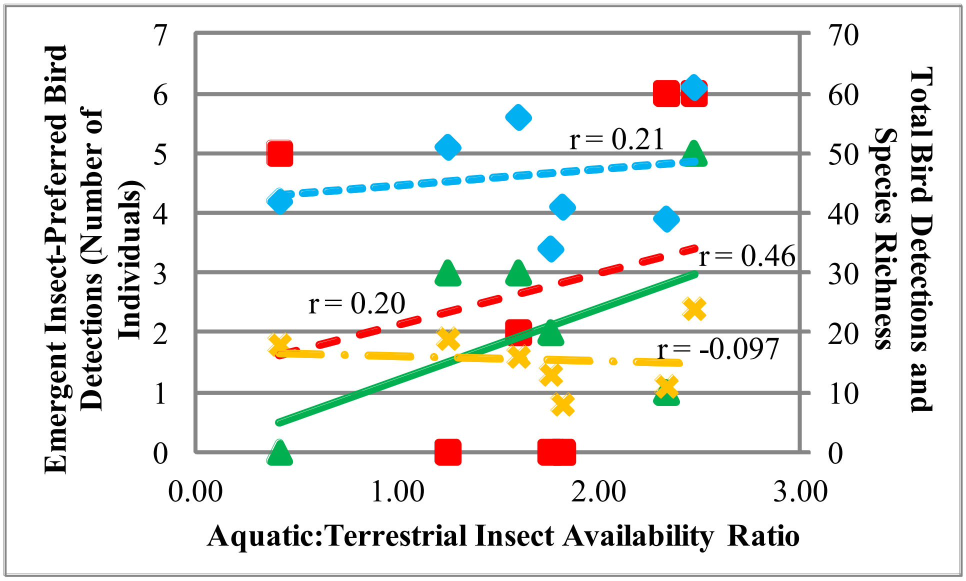


Figure 9.7: Total bird abundance (◆) (n=487), species richness (✖) (n = 50), and emergent insect-preferred bird abundance (n=33) (Winter wren (▲) and American redstart (■)) in relation to the ratio of aquatic/terrestrial insect availability in the riparian area along seven headwater streams in Michigan's Upper Peninsula, USA. Pearson Correlation Coefficients (r) between ±1.0 & ±0.6 indicates sufficient relationship.

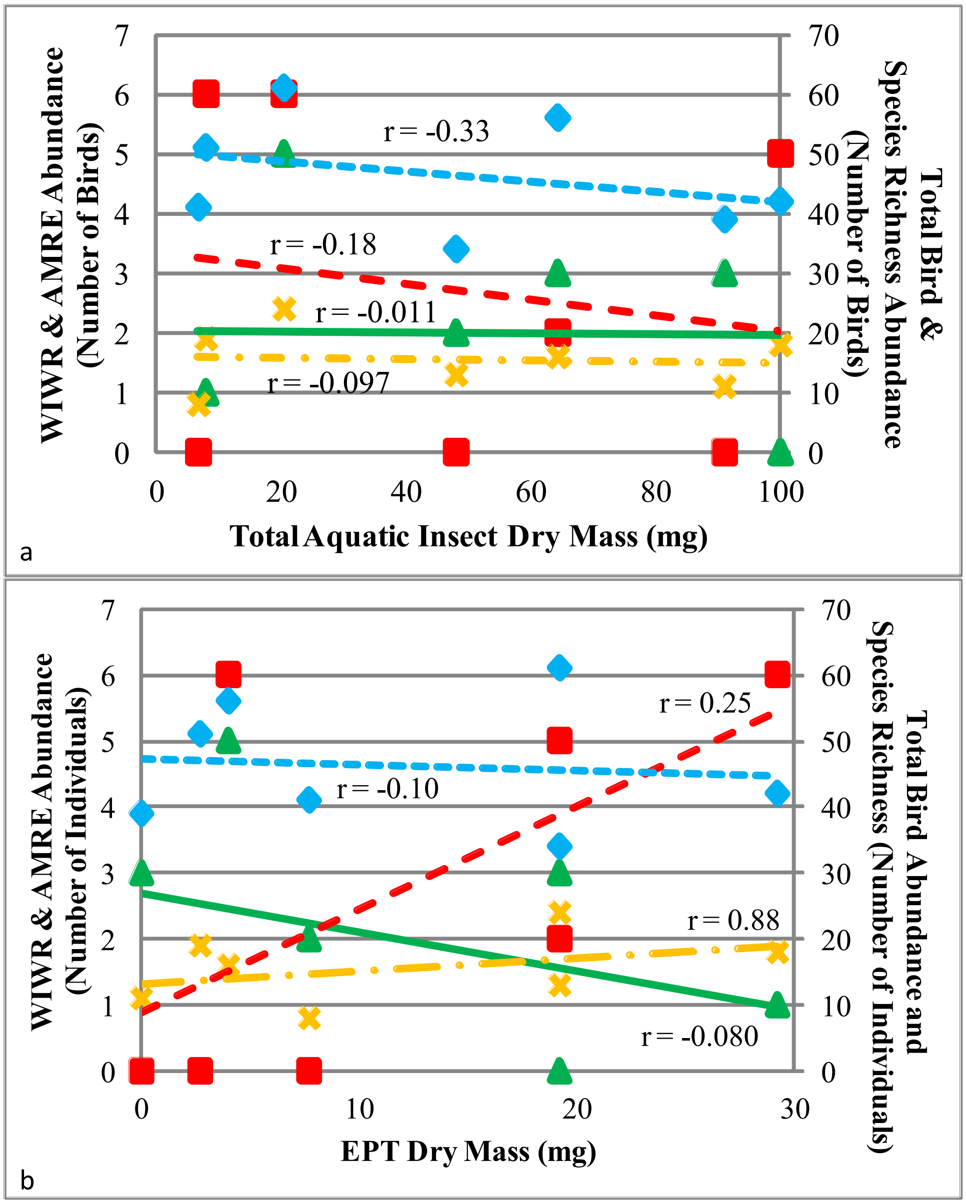


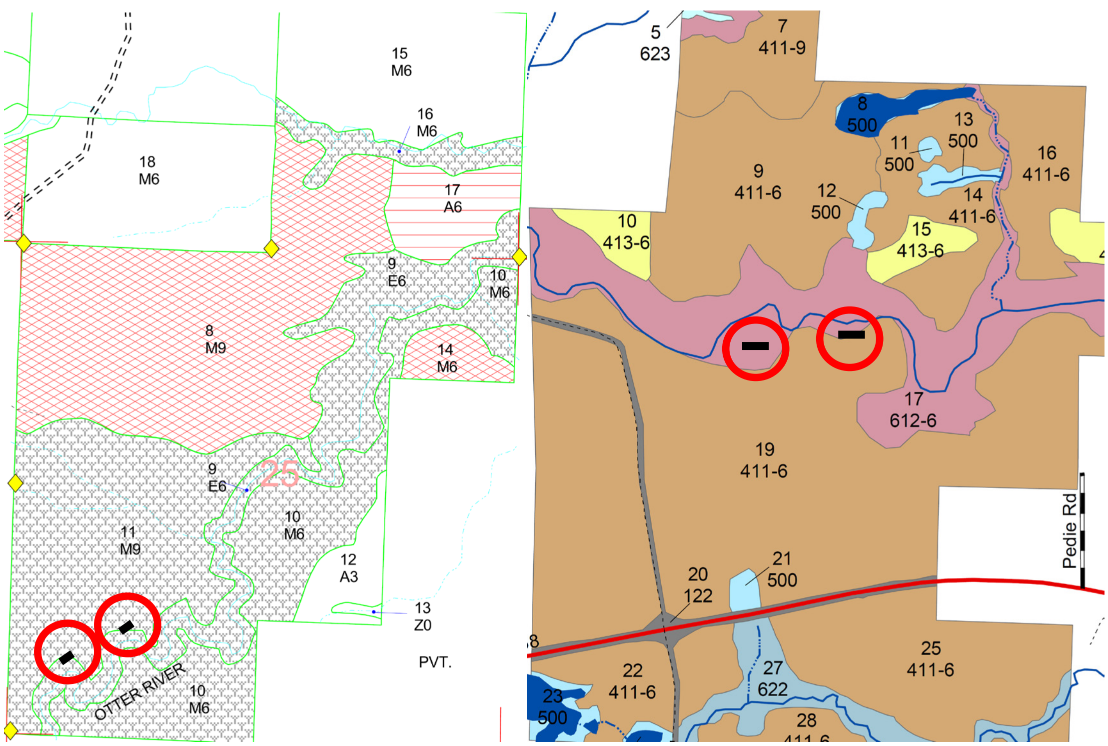
Figure 9.8: Total bird detection abundance (n=487) (◆), species richness (n=50) (✖), and emergent insect-preferred bird abundance (n=33) (Winter Wren (WIWR) (▲) and American redstart (AMRE) (■)) in relation to total emergent aquatic (a) and EPT (b) insect dry mass in riparian areas along headwater streams of Michigan's Upper Peninsula, USA. Pearson Correlation Coefficients (r) between ±1.0 & ±0.6 indicates sufficient relationship in bold.

Pike Lake Curve (PLC)
Owner: State of Michigan

COMPARTMENT 46
T51N, R36W, SEC. 23-25
COUNTY: HOUGHTON
UNIT: BARAGA
FOREST: COPPER COUNTRY
YOE: 2004
ACRES: 1,225 GIS CALCULATED
MAP REVISED: 8/28/2002
STAND EXAMINER:
Owner: State of Michigan

Otter Siding Creek (OSR)
Owner: State of Michigan

Compartment 47
T51N, R36W, Sec. 27, 34, 35
County: Houghton
Unit: Baraga
YOE: 2008
Acres: 1,125 GIS Calculated
Stand Examiner: Fred Hansen
Map Revised: 9/25/2006
Map Phase: Pre-review

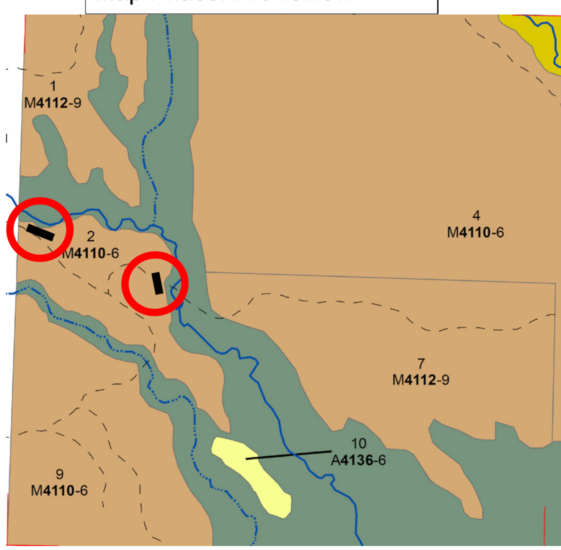


a b

Unpublished DNR inventory data (Price 2011).

Deer Camp (DEC)
Owner: State of Michigan

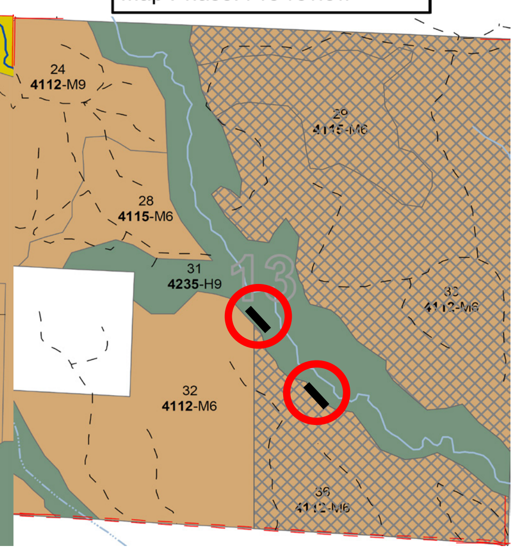
Compartment 35
T53N, R35W, Sec. 24, 25, 26
County: Houghton
Unit: Baraga
YOE: 2009
Acres: 1,766 GIS Calculated
Stand Examiner: Fred Hansen
Map Revised: 8/02/2007
Map Phase: Pre-review



c

Ogre (OGR)
Owner: State of Michigan

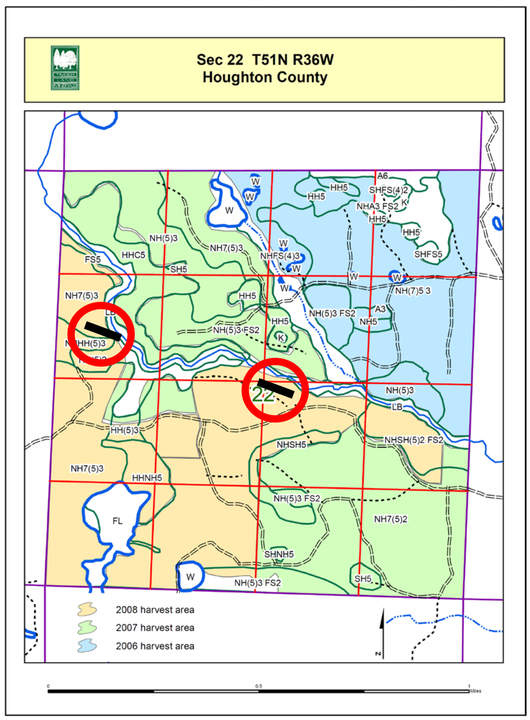
Compartment 45
T51N, R36W, Sec. 11, 13, 14
T51N, R35W, Sec. 7
County: Houghton
Unit: Baraga
YOE: 2010
Acres: 1,898 GIS Calculated
Stand Examiner: Brad Carlson
Map Revised: 8/04/2008
Map Phase: Pre-review



d

Unpublished DNR inventory data (Price 2011).

Lake Fifteen Creek (LKF)
YOE: 2006 – 2008
Acreage: 433
Owner: Keweenaw Land Association



e

Figure 9.9: PLAT maps of areas designated for selection logging within the Otter River Watershed including year of entry (YOE), acreage, and land owner information for a) PLC, b) OSR, c)DEC, d) OGR, and e) LKF. Relative placement of Malaise traps are designated by a black dash encircled with a red line (Flynn 2011). See appendix B for documentation of permission to republish figure 9.9e.

Table 9.1

Tukey multiple comparison test (Zar 1999) of sand depth in seven headwater streams in Michigan's Upper Peninsula.

Order Number	1	2	3	4	5	6	7
Stream	DEC	WBS	THM	OGR	LKF	PLC	OSR
Mean Sand Depth (m)	0.052	0.028	0.041	0.287	0.561	0.284	0.151

Comparison (B v. A)	**Difference (Mean B - Mean A)**	**SE**	**q**	**$q_{0.05, 70, 7}$**	**Conclusion**
5 v. 2	0.534	0.04599	11.61	4.314	Reject
5 v. 3	0.520	0.04599	11.32	4.314	Reject
5 v. 1	0.510	0.04599	11.09	4.314	Reject
5 v. 7	0.411	0.04599	8.931	4.314	Reject
5 v. 6	0.277	0.04599	6.025	4.314	Reject
5 v. 4	0.274	0.04599	5.962	4.314	Reject
4 v. 2	0.260	0.04599	5.644	4.314	Reject
4 v. 3	0.246	0.04599	5.354	4.314	Reject
4 v. 1	0.236	0.04599	5.124	4.314	Reject
4 v. 7	0.137	0.04599	2.969	4.314	Not Rejected
4 v. 6	Do not test				
6 v. 2	0.257	0.04599	5.580	4.314	Reject
6 v. 3	0.243	0.04599	5.290	4.314	Reject
6 v. 1	0.233	0.04599	5.060	4.314	Reject
6 v. 7	Do not test				
7 v. 2	0.123	0.04599	2.674	4.314	Not Rejected
7 v. 3	Do not test				
7 v. 1	Do not test				
1 v. 2	Do not test				
1 v. 3	Do not test				
3 v. 2	Do not test				

Table 9.2

Instream habitat characteristics from longitudinal surveys of a 500m reach in seven headwater streams in Michigan's Upper Peninsula during the summer of 2011.

Habitat Variable	Mean	SE	Std. Dev.	Range	Min.	Max.
Sand Depth (cm)						
DEC	5.2	1.1	8.4	36	0	36
WBS	2.8	0.34	2.5	12	0	12
THM	4.1	0.51	3.8	24	0	24
OGR	29	2.1	16	73	0	73
LKF	56	4.8	35	100	0	100
PLC	28	3.2	24	85	5	90
OSR	15	3.2	24	95	0	95
Wetted Width (m)						
DEC	3.67	0.136	1.01	3.1	2.1	5.2
WBS	3.86	0.141	1.03	3.3	2.6	5.9
THM	3.1	0.084	0.616	2.1	2	4.1
OGR	2.07	0.065	0.475	1.5	1.3	2.8
LKF	2.18	0.047	0.341	1	1.6	2.6
PLC	3.58	0.218	1.6	5.4	1.9	7.3
OSR	6.4	0.144	1.01	3	5.1	8.1
Water Depth (cm)						
DEC	12	0.96	7.1	32	0	32
WBS	10	0.92	6.7	25	0	25
THM	9.1	0.83	6.1	26	0	26
OGR	9.9	1.3	9.8	70	0	70
LKF	12	1.2	9.1	45	0	45
PLC	17	2.0	14	68	0	68
OSR	37	4.4	31	144	4	148
Discharge (cm^3/s)						
DEC	6.06	0.957	7.09	27.7	0	27.7
WBS	3.72	0.56	4.11	16.5	0	16.5
THM	3.42	0.484	3.56	13.2	0	13.2
OGR	1.86	0.433	3.18	22.4	0	22.4
LKF	1.72	0.253	1.86	7.18	0	7.18
PLC	3.98	0.668	4.91	19.9	0	19.9
OSR	13.3	1.94	13.6	61.4	0	61.4
Riparian Vegetation Density (%)						
DEC	45	9.3	19	39	32	71

Table 9.2, continued

Habitat Variable	Mean	SE	Std. Dev.	Range	Min.	Max.
WBS	26	12	23	47	2.6	50
THM	42	4	8	17	31	48
OGR	31	4.9	9.8	22	17	40
LKF	38	6.4	13	30	26	56
PLC	44	15	31	60	15	75
OSR	43	8.8	18	39	24	63
Riparian Canopy Cover (%)						
DEC	79	0.041	0.14	0.48	0.5	0.98
WBS	71	0.039	0.13	0.48	0.45	0.93
THM	77	0.040	0.13	0.45	0.45	0.9
OGR	81	0.020	0.065	0.25	0.68	0.93
LKF	75	0.027	0.089	0.28	0.58	0.85
PLC	69	0.025	0.084	0.23	0.58	0.8
OSR	54	0.038	0.13	0.43	0.33	0.75

Table 9.3a

Abundance (number) of the flying insects (identified to order) captured in the riparian areas along seven headwater streams in the Otter River Watershed of Michigan's Upper Peninsula during 12 trap nights in 2011. West Sante River (WBS), Thirteen Mile (THM), Deer Camp (DEC), Otter Siding Creek (OSR), Pike Lake Curve (PLC), Ogre (OGR), and Lake Fifteen Creek (LKF).

Number of Insects (%)								
	Stream							
	WBS	**THM**	**DEC**	**OSR**	**PLC**	**OGR**	**LKF**	**Total**
Terrestrial	21(33)	16(44)	9(32)	13(24)	52(73)	5(26)	5(39)	121(42)
Phalangida	0(0)	0(0)	0(0)	1(8)	0(0)	0(0)	0(0)	1(0.8)
Lepidoptera	3(14)	3(19)	0(0)	1(8)	4(8)	0(0)	0(0)	11(9)
Araneida	0(0)	0(0)	1(11)	1(8)	0(0)	1(20)	0(0)	3(2)
Hymenoptera	1(5)	2(13)	1(11)	1(8)	1(2)	0(0)	0(0)	6(5)
Coleoptera	17(81)	11(69)	7(78)	9(69)	47(90)	4(80)	5(100)	100(83)
Aquatic	43(67)	20(56)	19(68)	41(76)	19(27)	14(74)	8(61)	164(58)
Ephemeroptera	0(0)	0(0)	0(0)	0(0)	1(5)	0(0)	0(0)	1(0.6)
Plecoptera	3(7)	0(0)	0(0)	1(2)	1(5)	0(0)	0(0)	5(3)
Trichoptera	1(2)	6(30)	1(5)	0(0)	1(5)	0(0)	3(38)	12(7.3)
Diptera	39(91)	14(70)	18(95)	40(98)	16(84)	14(100)	5(62)	146(89)

Table 9.3a, continued

	WBS	THM	DEC	OSR	PLC	OGR	LKF	Total
Total (%)	64(22)	36(13)	28(10)	54(19)	71(25)	19(7)	13(5)	285

Table 9.3b

Dry mass of the flying insects (identified to order) captured in the riparian areas along seven headwater streams in the Otter River Watershed of Michigan's Upper Peninsula in the summer of 2011. West Sante River (WBS), Thirteen Mile (THM), Deer Camp (DEC), Otter Siding Creek (OSR), Pike Lake Curve (PLC), Ogre (OGR), and Lake Fifteen Creek (LKF).

Dry Mass (mg) of Insects (%)

	Stream							
	WBS	**THM**	**DEC**	**OSR**	**PLC**	**OGR**	**LKF**	**Total**
Terrestrial	81(47)	84(93)	51.2(72)	24(19)	162(72)	11(19)	18(69)	431.2(56)
Phalangida	0 (0)	8.7 (10)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	8.7(2)
Lepidoptera	21.7(27)	41.8 (50)	0 (0)	5.8 (24)	21.6(13)	0 (0)	0 (0)	90.9 (21)
Araneida	0 (0)	0 (0)	11.9 (23)	2.1(9)	0 (0)	0 (0)	0 (0)	14(3)
Hymenoptera	4.9 (6)	5 (6)	0 (0)	2.9 (12)	1.2(1)	0 (0)	0 (0)	14(3)
Coleoptera	54.6(67)	28.8 (34)	39.3 (77)	13.2 (55)	140(86)	10.7 (100)	18.3(100)	304.9 (71)
Aquatic	91(53)	6.7	20.4(28)	100(81)	64.3(28)	48(81)	7.9(31)	338.3 (44)
Ephemeroptera	0 (0)	0 (0)	0 (0)	0 (0)	28.6(44)	0 (0)	0 (0)	28.6 (8)
Plecoptera	17.4(19)	0 (0)	0 (0)	19.2 (19)	0.4(1)	0 (0)	0 (0)	37 (11)
Trichoptera	1.8(2)	2.7 (40)	7.7 (38)	0 (0)	0.2(0.3)	0 (0)	4 (51)	16.4 (5)
Diptera	71.9(79)	4 (60)	12.7 (62)	81.4 (81)	35.1(55)	48.3 (100)	3.9(49)	257.3 (76)
Total (%)	172(22)	90.7 (12)	71.6 (9)	124 (16)	226.3 (29)	59(8)	25.9(3)	769.5

Table 9.4

Riparian bird community surveyed in 2011 along seven headwater streams in Michigan's Upper Peninsula. WIWR: Winter wren (*Troglodytes troglodytes*), AMRE: American redstart (*Setophaga ruticilla*).

	Stream							
	DEC	**WBS**	**THM**	**OGR**	**LKF**	**PLC**	**OSR**	**Total**
Abundance (Number of Birds)	22	22	41	25	34	46	56	246
Species Richness (Number of Species)	8	13	19	11	16	18	24	109
Emergent Insect-Preferred Bird Abundance (Number of Birds)								
WIWR	0	2	3	1	3	0	5	14
AMRE	0	0	0	6	2	5	6	19
Total	0	2	3	7	5	5	11	33

Table 9.5

Pearson Correlation Coefficients between instream habitat characteristics and riparian bird community along seven headwater streams of Michigan's Upper Peninsula. Values between ±0.6 to ±1.0 is considered sufficient for consideration of relationship (in bold).

Variables	Correlation Coefficient
Bird Species Richness v. %BO	-0.28
Bird Species Richness v. %CO	-0.14
Bird Species Richness v. %P	0.24
Bird Species Richness v. %G	-0.33
Bird Species Richness v. %S	-0.26
Total Bird Abundance v. %BO	-0.51
Total Bird Abundance v. %CO	-0.25
Total Bird Abundance v. %P	-0.15
Total Bird Abundance v. %G	-0.12
Total Bird Abundance v. % S	-0.051
Winter wren Abundance v. %BO	-0.22
Winter wren Abundance v. %CO	-0.31
Winter wren Abundance v. %P	-0.17

Table 9.5, continued

Variables	Correlation Coefficient
Winter wren Abundance v. %G	-0.44
Winter wren Abundance v. %S	0.13
American redstart Abundance v. %BO	-0.29
American redstart Abundance v. %CO	0.17
American redstart Abundance v. %P	0.57
American redstart Abundance v. %G	-0.058
American redstart Abundance v. %S	-0.41
Bird Species Richness v. % Canopy Cover	**-0.72**
Bird Species Richness v. % O coverage	**0.66**
Bird Species Richness v. % C coverage	**0.69**
Bird Abundance v. % C coverage	**0.66**
WIWR Abundance v. % C coverage	**0.6**

10. APPENDIX B

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January 3, 2011

Keweenaw Land Association, Limited
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