

INVASIVE ALLOCHTHONOUS INPUT: THE CHINESE TALLOW TREE AND  
STREAM FOOD WEBS

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Master of Science

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by

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## ABSTRACT

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The invasive Chinese Tallow tree (*Triadica sebifera* or *Sapium sebiferum*) was heavily introduced to the southern United States from Asia at the turn of the 20th Century. A Tallow invasion can reduce richness within the plant community by direct competition and can decrease density of consumer communities by limiting basal food resources. Additionally, tallow leaches rapidly into aquatic systems, where a sharp increase in aerobic microbial decomposition can simultaneously drop dissolved oxygen and pH levels, thus causing mortality in macroorganisms. I predicted an input of solely Tallow leaves into mesocosms (artificial streams) would temporarily increase of N & P concentration, algae concentration, invertebrate density, and fishes because of increased rates of rapid decomposition, but would fail to sustain long-term and overall growth for that same reason. In contrast, sycamore leaves would provide a more sustained, long-term allochthonous subsidy to the mesocosms, thus resulting in increased growth of fishes and other response variables relative to that of tallow leaf treatments. Cellulose paper was used as a no-leaf control to account carbon input. Bullhead minnows (*Pimephales vigilax*) were stocked in half of our experimental stream mesocosms, where benthic algae, invertebrate density, and nutrient content were sampled for 16 weeks. After 16 weeks, 50% of the original Sycamore leaves remained, whereas less than 10% of the cellulose paper (control) and Tallow remained. The concentration of benthic algae was highly dependent on time as values increased significantly after week 6, and tended to be higher in treatments with no-fish and cellulose/tallow. Invertebrate density generally

remained higher in no-fish treatments; densities were highest in tallow treatments before the experimental halfway point, and were highest in sycamore treatments past the halfway point. Nitrogen and phosphorous concentrations fluctuated highly throughout the experimental runtime, and showed no significant interactions among treatment groups. Fish were largest in mesocosms with the Sycamore leaves where either the undecomposed leaves provided additional surface area for food resources, or growth was higher relative to tallow treatments because of possible physiological inhibition. Tallow treatment fish growth was significantly smaller than sycamore, and relatively equal to cellulose. Herein, we discuss the reasons for the decreased fish growth in the presence of tallow leaves such as: (1) rapid decomposition providing a short-term nutrient pulse that moved through the food web quickly, and (2) physiological inhibition from the chemical composition of tallow leaves.

**KEY WORDS:** Tallow, allochthonous input, sycamore, decomposition, bullhead minnow.

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## CHAPTER I

### Introduction

The focus of conservation biology has been on the rapid decline of biodiversity over the past few centuries due to habitat loss, overexploitation, pollution, climate change and invasive species. Each is known to alter ecosystem properties and endanger species globally (Cain et al. 2010). Introduced species, by definition, include both invasive and non-native (non-invasive) introductions because of accidental or intentional release, or due to anthropogenic-related migration resulting from climate change (Dukes and Mooney 1999; Ricciardi et al. 2000).

To qualify as an invasive species, an organism must have a net negative impact on the local flora and/or fauna, whereas a non-native species does not cause any measurable harm to native organisms in its new range (USDA 1999). Economically, U.S. agricultural agencies lose an estimated one fourth of allotted federal funding to the cost of managing invasive species, which requires constant updating of the invasive species databases to allow a timely response to newer threats (Simberloff 1996; Ricciardi et al. 2000). Much discussion surrounds the agricultural use of exotic plants and how they impact native ecosystems. A commonly cited example is the introduction of the ornamental Japanese vine kudzu (*Pueraria montana*). It had served as a way for farmers to sow topsoil and prevent erosion, but it easily outcompetes the surrounding vegetation for resources, earning it a spot on the Federal Obnoxious Weed List. Kudzu has become a major ecosystem threat (Forseth and Innis 2004). From a risk management standpoint, harmful consequences of an intentional species introduction are the most preventable. For that

reason, regulations have been introduced to ensure the harmful effects of foreign species are kept at a minimum.

The exotic Chinese tallow tree, of the family Euphorbiaceae, is native to southeastern Asia (Webster 1994; Bruce et al 1997). A founding father of the United States, Benjamin Franklin, referred to the species as “a most useful” tree (Franklin 1772). The intention for the introduction of this tree in colonial North America was for ornamental purposes, and the extraction of stillingia oil from its seeds (Bolley and McCormack 1950). In the early 1900s, the US Department of Agriculture (then called the Bureau of Plant Industry) began establishing plantations to culture the tree for its popular ornamental use, rapid growth, and seeds (Bruce et al 1997; Rogers and Seimann 2004). Chinese tallow (hereafter tallow) has a well-established range from the Atlantic coast states of North Carolina, South Carolina, and Florida to the Gulf coast states of Georgia, Mississippi, Alabama, Louisiana, and Texas. It now ranks as one of the top 12 most dangerous invaders to native communities in the United States, and one of the most noxious invaders in the world (Nature Conservancy 1996). With its reputation as a harmful invader, monocultural purposes for tallow are no longer ideal, however its seeds have extracting potential as a biodiesel feedstock (Boldor et al. 2010). The abundance has increased drastically over the past 30 years, with its numbers having nearly doubled in East Texas, and tripled in Louisiana and Mississippi (Oswalt 2010). There are accounts of small-scale introductions in other states, including California, Arkansas, Kentucky, Tennessee, and Wisconsin (EDD MapS 2015). Tallow’s success over multiple ecosystems (shady, sunny, dry, and flooded) has caused it to disturb upland and wetland sites, outcompeting and displacing other native vegetation (Jubinsky and Anderson

1996). The same can be said for native prairies that are disturbed by invasions, where ecosystem structure is altered by the high rate of tallow reproduction (Bruce et al. 1997).

Tallow distribution appears to be limited by freezing winters, so anthropogenic climate change may contribute a higher latitudinal distribution (Gan et al. 2009; Saenz et al. 2013). Its success in the United States can be attributed to the fact that it grows exceedingly well on poorly-drained, flooded and saline soils (Cameron and Spencer 1989). Due to its reproductive success, Chinese tallow tends to form monotypic forests (Bruce et al. 1997; Conway et al. 2002). Tallow leaves decompose faster than most leaves. Based on Meentemeyer's (1984) model, tallow's decay and nutrient release was measured to be significantly higher than predicted, and contributed extra P, K, Zn, Mn, NO<sub>3</sub>-N, and Fe to forest soils (Cameron and Spencer 1989). A general conclusion from Cameron and Spencer (1989) was that the rapid decay of leaves and nutrients into forest soils may enhance productivity to ecosystems. This is an intuitive conclusion that can be measured, but further studies show that tallow leaves/leachate can cause significant environmental harm to aquatic organisms. This would counteract any potential benefits from increased and rapid nutrient release. During the late 2000s, a series of experiments focusing on amphibians and aquatic invertebrates displayed the organismal harm tallow can cause. First in 2008, where Leonard's PhD dissertation showed that amphibian tadpole survival and behavior were significantly altered in the presence of tallow-leached ephemeral ponds. Abiotic factors, mainly dissolved oxygen, caused mortality of many tadpole species (Leonard 2008). Amphibian tadpoles depend on water quality for differential survival, and increased concentrations of tallow tannins/leachate are known to decrease dissolved oxygen and pH (Adams and Saenz 2012; Montez 2016). In exposing

Southern Leopard Frog eggs to varying concentrations of tallow leaves in ephemeral ponds, no hatchling survived past a certain dissolved oxygen ( $<1.59$  mg/L) and pH ( $<5.29$ ) threshold (Adams and Saenz 2012). This mortality was not attributed to toxicity. The rapid leaching rate of tallow leaves causes a sharp increase in aerobic microbial activity, thus reducing total dissolved oxygen of the aquatic system (Montez 2016). These observed effects of tallow leaf litter on tadpoles have caused concern over endangered amphibian populations. Additionally, it raises questions about tallow's leaf litter impact among other classes of organisms. Tallow is also suspected to have allelopathic tendencies, and perhaps a chemical composition that is toxic to some organisms. Early studies of the harmful effects of tallow leaves/seeds were shown in ruminants, where it caused sickness, dehydration, diarrhea, and possibly even death when the feeding duration was long enough (Russell et al. 1969). Originally, it was unclear whether the tallow leaves were legitimately toxic. Tallow leaves that do not undergo immediate leaching were found to inhibit feeding in terrestrial isopods; the tannins in leaves could not be readily consumed thus delaying feeding and causing mortality from starvation (Cameron and La Point 1978). Furthermore, the presence of tallow leaves significantly reshaped invertebrate shredder community structure and bacterial/fungal communities are altered in the presence of tallow leaf litter (Leonard 2008; Montez 2016). Additionally, there are studies that indicate tallow has toxic effects on birds and fishes (Muqarrabun et al. 2014). The ecological effects of invasive species are observable, and native organisms can be disrupted or altered. The following response shifts to those disruptions are important to measure. This is the primary goal I hope to accomplish: to assess whether there are any measurable changes of the Chinese tallow tree (*Triadica sebifera*) in my

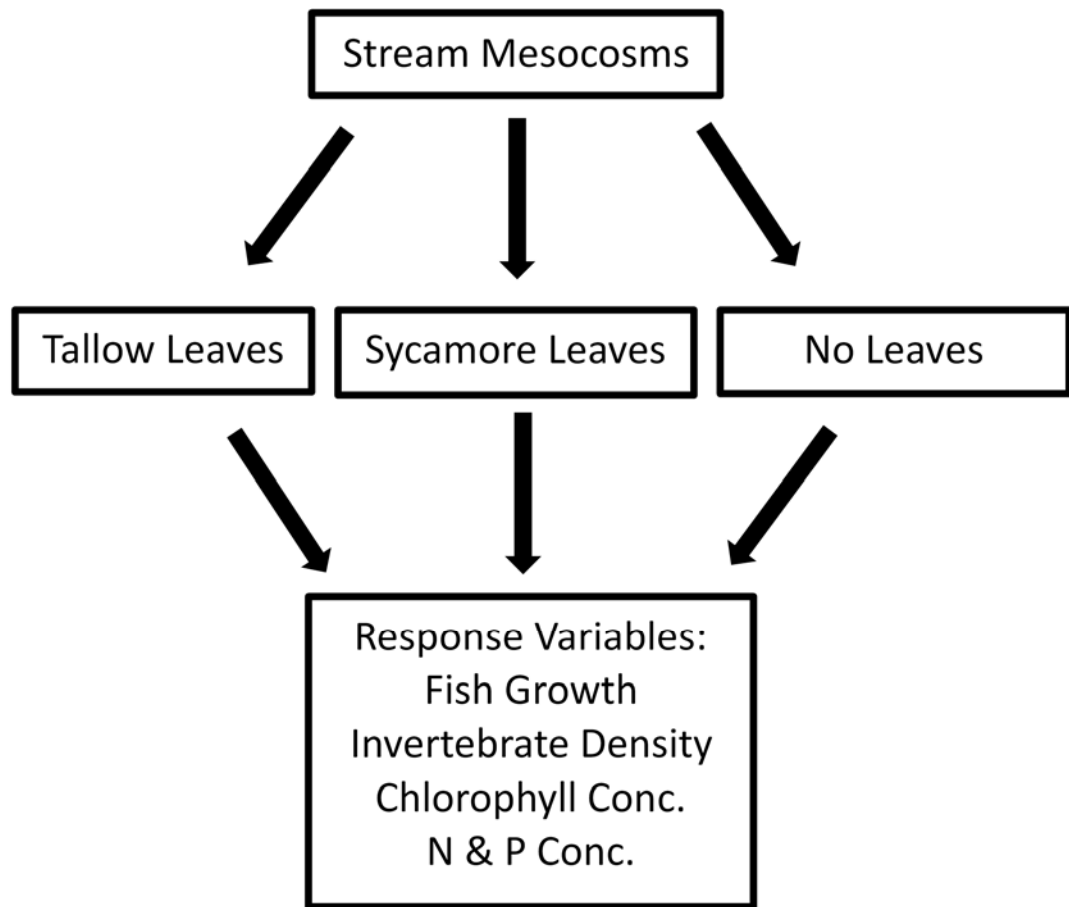
experimental system. My study focuses on the Chinese tallow leaf litter as a food source, rather than the effects of its tannins.

The ecological significance of leaf litter stems from it being a major source of allochthonous input into aquatic ecosystems along with stems, wood and dissolved organic matter. Generally, allochthonous inputs into streams are more significant than in lake and other lentic ecosystems (Cain et al. 2011). A commonly cited example of this is the Bear Brook headwater stream in New Hampshire that receives 99.8% of its total energy from allochthonous inputs (Fisher and Likens 1973). Autochthonous inputs (primary production) are more representative of what regulates energy in lentic ecosystems. Allochthonous input from the riparian zone is typically provides more energy to smaller ordered streams. Global stream area is dominated by moderate/large order rivers (5-9), but global stream length and the total riparian zones are dominated by 1st order streams (Downing et al. 2012). Energy is transferred from lower trophic levels to higher ones, thus the efficiency yield of that energy transfer highly depends on food quality from allochthonous input and net primary production (NPP), while the rest is lost as heat through respiration (Cain et al. 2011). The leachate/organic matter provided from allochthonous leaf litter provides energy and nutrients to many stream organisms, mainly in three categories: autotrophs, invertebrates, and fish (Allan and Castillo 2007). A lack allochthonous input from riparian vegetation can significantly impact macroinvertebrate communities and cause shifts in overall stream production (Delong and Brusven 1994). Chinese tallow trees are successful in riparian habitats, and have higher tolerance to water depth and salinity than most native trees (Connor 1994). As tallow trees continually invade new habitats, it is unknown if monotypic strands of tallow trees can serve as a

similar quality of allochthonous input compared to native trees in the southeastern United States. Generally, dissolved oxygen is not a limiting factor in stream ecosystems. With constant inflow and outflow, any rapid leaching from tallow leaves will quickly move downstream, thus reducing the risk of rapid microbial uptake and lowered dissolved oxygen and pH levels. With that in mind, my research focuses on tallow input as strictly a leaf-based food source for common stream organisms.

Using simplified stream system with a relatively low fish density, the most appropriate application of community ecology would be bottom-up food regulation. This type of system would be dependent on food supply, where the primary consumers (i.e. invertebrate shredders, microbial decomposers) would initially benefit from a large influx of leaves representative of leaf fall (Cain et al. 2011). With the leaves being a major food source to algivorous invertebrates, we would expect algal biomass to be increased initially as well, as it avoids predation. Nitrogen and phosphorous content contained within the leaves would be expected to undergo rapid nutrient release in the aquatic systems as shown in previous studies (Cameron and Spencer 1989; Adams and Saenz 2012).

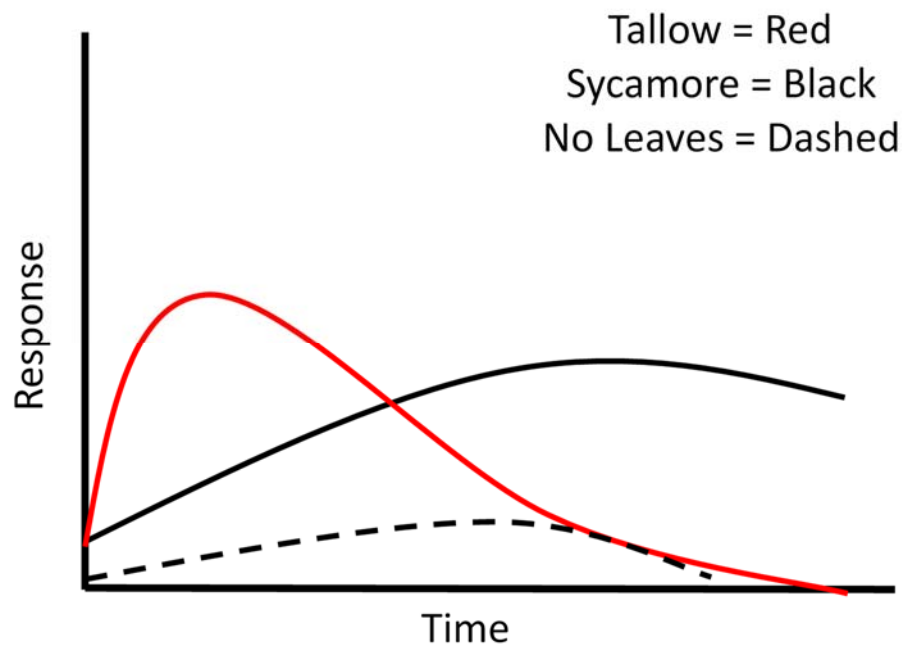




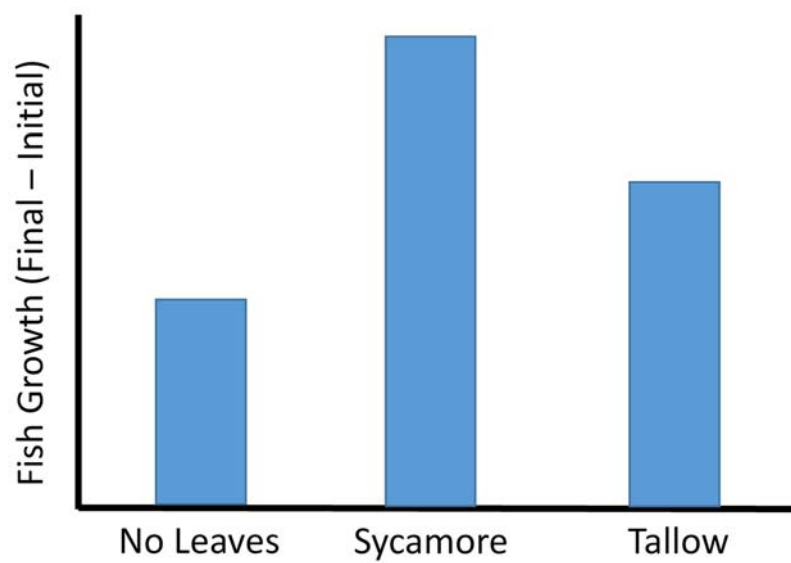
*Figure 1.* Experimental setup of leaf treatments (sycamore, tallow, no leaves) across the 24 mesocosms, including a list of response variables measured. Note: half of the 8 mesocosms per leaf treatment contain fish.

I proposed two specific questions: (1) if I expose an emulated stream system (mesocosm) to an influx of tallow leaves versus native leaves (Fig. 1), would the growth rates and/or densities of stream organisms be altered in some measurable way? And, (2) does the rapid decomposition of tallow leaves have a temporal impact on the total organismal growth of a stream system? We predicted that rapid leaching of tallow leaves will temporally front-load the nutrient subsidy, providing a short-term pulse in nitrogen/phosphorous concentration, algal biomass, invertebrate density (Fig. 2). This would imply there would be rapid growth initially, followed by a sharp decline in growth

rates as the tallow leaves decompose fully, leaving no basal food source for primary consumers. Additionally, I predict the sycamore treatments will display a more gradual response for our variables rather than sharp increases/decreases for tallow treatments (Fig. 2). We expected some fish mortality to occur in tallow treatments as food availability dwindles. Overall, I predict tallow leaves will not provide a large enough allochthonous subsidy to exceed the total fish growth of the native American sycamore tree (*Platanus occidentalis*) leaves. Rather, I predict the sycamore leaf treatment will have larger overall growth of fishes than the tallow leaf treatment (Fig. 3).



*Figure 2.* Magnitude of expected temporal response for dependent variables: invertebrate density, benthic algae biomass, nitrogen concentration and phosphorous concentration. The x-axis is scaled to the expected response over 16 weeks.



*Figure 3.* Expected differences in fish growth (final – initial) of bullhead minnows across the 16-week experimental runtime.

## CHAPTER II

### Materials & Methods

#### Experimental Mesocosms

In April of 2016, 24 mesocosms were assembled at the Center for Biological Field Studies at Sam Houston State University (CBFS, Walker Co., TX, USA). These mesocosms are metallic cattle-feeding tanks with a volume of about 1.846 m<sup>3</sup> (3.683 m X 0.9398 m X .5334 m) and are connected through polyvinyl chloride (PVC) piping. The mesocosms emulate small 1st-2nd order, shallow headwater streams with sand-bottoms that commonly occur throughout the Gulf coastal slope of North America (Hargrave et al. 2010). The tank drainage pipes are set up approximately 13 inches (0.3302 m) above the tank bottom (below the substrate layer) where the water effectively flows out at a slow rate. These dimensions allow approximately 1143.0 L per tank. The flow rate ( $0.12 \pm 0.2$  m s<sup>-1</sup>) is maintained in each tank by a 3500 L h<sup>-1</sup> submersible pump that is connected to the PVC piping. All tanks (henceforth mesocosms) have a constant inflow of well water, and the tanks all drain out through the PVC piping to Harmon Creek, a local stream on the CBFS property. The 24 mesocosms were randomly assigned to one of three treatment groups (tallow leaves, sycamore leaves, and no leaves). They were monitored throughout April to August of 2016 for blockage or any other errors such as algal blooms, tadpole colonization, and electrical outages. They were otherwise left untouched to allow the establishment of a biofilm assemblage and aquatic invertebrate larval colonization from adult ovipositors. The mesocosms were housed under a canopy cover that is represented by vegetation cover in common headwater streams. Once the mesocosms were fully colonized, we began our initial measurements and introduced the leaf treatment groups

and fish on August 21st, 2017. The total runtime of the experiment was from August 21st – December 6th, 2016 (16 total weeks). During the experimental runtime, there was one electrical outage (a circuit trip) just before Week 5 that caused a temporary halt in water pumps and inflow.

## **Leaves**

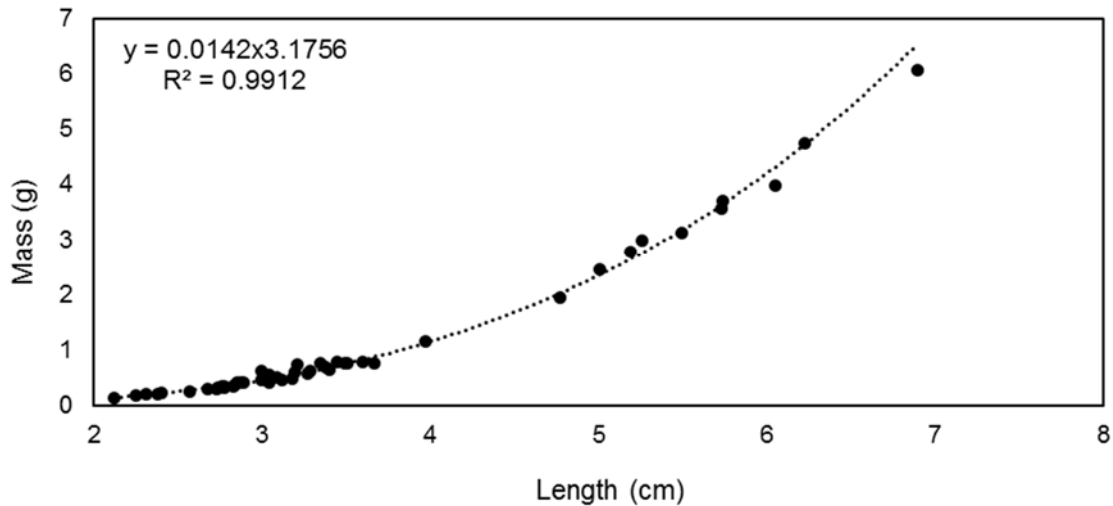
During January and February of 2016, we sampled fallen leaves throughout the Sam Houston National Forest and Huntsville State Park (Walker Co., TX, USA). The leaves that were picked were of a greenish-red color, indicating that they had recently fallen off their respective Chinese tallow or American sycamore tree. While sampling, my colleagues and I placed the leaves in large Hefty© plastic trash bags to store at the Texas Research Institute for Environmental Studies (TRIES, Walker Co., TX, USA). The leaves were air dried and weighed in separate Ziplock© plastic bags, and then were stored to await input into our artificial streams. We used wadding of ULINE© cellulose paper as a control to account for the cellulose input of our leaf treatments and any additional surface area provided by leaves. Of the 24 mesocosms, there were 8 replicates for our 3 leaf treatments. The leaves present blockage problems for the drainage pipes and pumps in the mesocosms. To prevent unnecessary blockage of leaf input, the leaves were initially placed in their respective mesocosms on August 14th, 2016 (one week before the official start of the experiment) contained within the Ziploc© plastic bags that they were weighed in. The bags were then filled with well water to allow the leaves to begin leaching and fully saturate. This was to ensure that the tannins would quickly flow out of the system as it would in a stream, leaving just the nutrients and leaf material in the mesocosms. Also, the saturation would ensure that the leaves sank to the substrate of the

mesocosms as to not cause any potential blockage. The leaf treatments were randomly assigned to the 24 mesocosms using a random number generator. We added ~320.0 g of leaves to each mesocosm, representing a density of 0.3 g L<sup>-1</sup>. Of the 8 replicates for each leaf treatment, half of those had 10 fish present in each mesocosm. This left an equal number of replicates per leaf treatment, and replicates of fish treatments per leaf treatments. On August 21st, 2016, the plastic bags were opened, and the leaves were released into the mesocosms approximately one hour before the fish. On August 23rd, 2016, we began our initial measurements and denoted this as 'Week 0.'

### **Fish**

The highest trophic level for stream organisms is usually represented by fish. In this experiment, the fish group was represented by a generalist benthic omnivore that is common throughout the Mississippi River Basin, the bullhead minnow (*Pimephales vigilax*) (Thomas et al. 2007). It mainly occupies low-current pools and backwaters of streams and is highly tolerant to turbidity; it feeds on a variety of plant and animal sustenance (Miller and Robinson 1973). As a common fish species throughout Texas and a fish that will greatly benefit from quality allochthonous input, the bullhead minnow is an excellent model consumer taxon. On August 21st, 2016, we sampled two areas in east Texas for bullhead minnows: the northern end of Lake Conroe (30°33'47.8"N 95°38'10.0"W), and the Trinity River (30°51'31.2"N 95°23'55.3"W). The locations used at both sites for bullhead minnow capture were boat ramps, thus minnows from each locality were exposed to similar environments before input into our mesocosms. Using the seining method, we captured about 200 bullhead minnows. During this time and throughout the rest of the experiment, all fish were handled with care and all IACUC

protocols (ID # 16-05-26-1010-3-01) were approved and followed. After collection, we transferred the fish via ice coolers back to the Center for Biological Field Studies (CBFS, Walker Co., Huntsville, TX), to await measurement and treatment assignment. At the CBFS, 120 of the ~200 fish were randomly assigned to 12 of the 24 mesocosms. With the randomization of treatment assignment, fish length across treatments was mostly between 3 – 4 cm, about 1 cm less than the natural average (see fish results that show ANOVA statistics of evenness of initial minnow sizes). Using small plastic tubs and a standard metric ruler, each of the 120 fish were measured by taking pictures and uploading them to ImageJ software, which utilizes a computer pixel as a standard distance proportion (Abramoff et al. 2004). Each fish was placed in a tub next to the ruler, and the pictures were taken with an iPhone 6©; this reduced experimental stress on the fish. The remaining fish were utilized for a length-mass regression; they were measured with a calibrated standard metric ruler and scale. In groups of 10, the minnows were added to the treatment and left to acclimate for 2 days. The minnows used in the regression were euthanized and preserved in a 10% formaldehyde solution. Initial measurements of the fish placed in the mesocosms were uploaded to ImageJ and were recorded for future comparison to the Week 15 final measurements. Initial mass was calculated using the regression line (Fig. 4).



*Figure 4.* The length-mass regression for *P. vigilax*, taken from Lake Stubblefield and the boat ramp at Trinity River.

Any mortality with fish acclimation within the day of stocking were replaced with another, and only two had to be replaced on the initial day of stocking. Mortality observed after Week 0 were preserved in the 10% formaldehyde solution. The degree of initial mortality did not differ among treatment conditions, rather it was a result of acclimation stress or experimenter error from poor handling. After Week 15, the fish were recovered from each mesocosm with anywhere between 7-10 out of the original 10 recovered. The recovered fish were measured with a standard metric ruler/balance, and total estimated growth from any one fish was averaged among treatments from Week 0 to Week 15 was calculated. The recovered fish were finally euthanized in 10% formaldehyde solution.

### **Invertebrates**

Every experimental week, invertebrate samples were taken from each mesocosm and preserved in 10% formaldehyde solution. While sampling in each mesocosm, we used the sample plot method to ensure random collection. Of the entire rectangular area



of the mesocosms, we identified 8 equal parts in which 1 of the 8 were selected from a random number generator in each mesocosm. Using a core sampler (.0352 m<sup>2</sup>) and a small mesh net, we took 2 samples from each mesocosm by scooping around 1 inch into the substrate. The samples were drained and placed in labeled Ziploc® plastic bags with 10% formaldehyde solution. The samples were stored at the Texas Research Institute for Environmental (TRIES, Walker Co., Huntsville, TX) studies to later be sorted. Using a microscope, the invertebrate samples were identified to order and placed in glass vials. Densities (no./m<sup>2</sup>) were recorded for each mesocosm throughout weeks 0-16.

### **Benthic Chlorophyll**

Similar to invertebrate sampling, the rectangular mesocosms were divided into 8 equal squares. Using a random number generator, one plot was selected from each mesocosm per week to gather core substrate samples. In each mesocosm, five core samples of the substrate were gathered using HCl acid washed 25mL Eppendorf tubes and then transferred to the Texas Research Institute for Environmental Studies for temporary freezer storage. Following freezing, we added 25 mL of 90% acetone to the Eppendorf tubes, samples were refrigerated overnight, and 3 mL samples were read at 750 nm for turbidity correction, then at 664 nm, acidified with 1N HCl, and read again at 665 nanometers (Clesceri et al. 1996). Benthic chlorophyll ( $\mu\text{g}/\text{cm}^2$ ) was calculated from the absorbances. Of the 5 core samples taken from each mesocosm per week, they were averaged to one value of benthic chlorophyll concentration per mesocosm per week.

### **Nitrogenous and Phosphoric Compounds**

Each week, one sample of stream water was taken from the water column of each mesocosm using an HCl acid-washed 1 L plastic Nalgene® bottle. Each bottle was taken

back to the Texas Research Institute for Environmental Studies for temporary freezer storage. For nitrogen, the Phenate Method was used to determine the amount of ammonia ( $\mu\text{g/L}$ ) in each water sample (Clesceri et al. 1996). For phosphorous, the Ascorbic Acid Method was used to determine the amount of orthophosphates ( $\mu\text{g/L}$ ) in each water sample (Clesceri et al. 1996).

### **Organic/Inorganic Suspended Particulates**

In addition to the HCl acid washed 1 L plastic Nalgene® laboratory bottle for nitrogen and phosphorous water samples, an additional 100 mL HCl acid washed 1 L plastic Nalgene® laboratory bottle was brought for sampling the water column again. The purpose of this bottle was to take a measurement of suspended particulates in the water column. Each mesocosm was sampled throughout every experimental week. The samples were brought back to the Texas Research Institute for Environmental studies for temporary refrigeration storage. The following day, the samples were separated from the particulates using vacuum pump filtration through a 0.45-micron glass fiber filter. For organic particulates, the aftermath of the filtration was massed after drying and subtracted from the post-ash mass. For inorganic particulates, the dried filter paper was placed in a small oven at a temperature for organic dissociation, and then the final post-ash mass was subtracted from the original filter paper mass. The masses were recorded at three decimal places.

### **Stats**

The data were formatted in Microsoft® Excel (Microsoft Inc., Redmond, WA, USA), and then were analyzed in SAS v9.4 Statistical Software (SAS Institute Inc., Cary, NC, USA). A one-way ANOVA was used to analyze the statistical differences for

average fish growth in mass and length among leaf treatments (tallow, sycamore, cellulose), and a Tukey post-hoc comparative analysis was used to compare among each leaf treatment. Also, the same one-way ANOVA analysis was used to determine if there were any significant mass/length differences among initial treatment sizes. Additionally, another one-way ANOVA was used to determine a condition factor for the residuals of our initial length/mass regression.

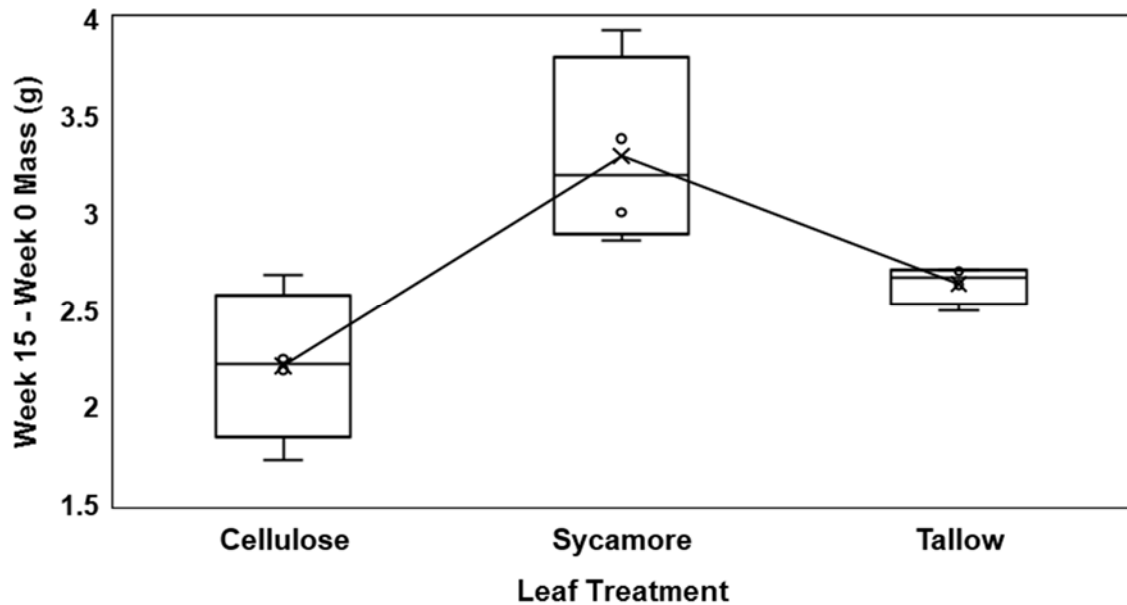
A 3x2 two-way repeated measures ANOVA was used to analyze invertebrate densities, benthic chlorophyll concentration, ammonia concentration, and ortho-phosphate concentration among leaf treatment groups (tallow, sycamore, cellulose), presence of fish versus no fish, and time across all treatments. Univariate statistics were used for a week by week analysis and the Wilks' Lambda Statistic was used for adjustment.

## CHAPTER III

### Results

#### Fish

Of the original 120 fish separated across leaf treatments, 100 fish were recovered with at least 7 fish per mesocosm. The initial lengths of the introduced fish were not significantly different ( $F = 2.11$ ,  $P = 0.1772$ ) as well as the initial masses of the fish ( $F = 2.41$ ,  $P = 0.1456$ ). The mass growth model (Week 15 mass – Week 0 mass) from the one-way ANOVA of *P. vigilax* was highly significant ( $F = 9.07$ ,  $P = 0.007$ ; Fig. 5)..



*Figure 5.* Box-and-whisker plot for growth in mass among leaf treatments. Fish growth is the average masses per treatment at Week 15 minus average masses per treatment at Week 0.

Based on the post-hoc comparisons, the growth of fish (mass) in sycamore treatments was significantly higher than those in tallow treatments ( $F = 6.65$ ,  $P = 0.0298$ ; Tab. 1) and cellulose treatments ( $F = 17.85$ ,  $P = 0.0022$ ; Tab. 1). The growth of fish in

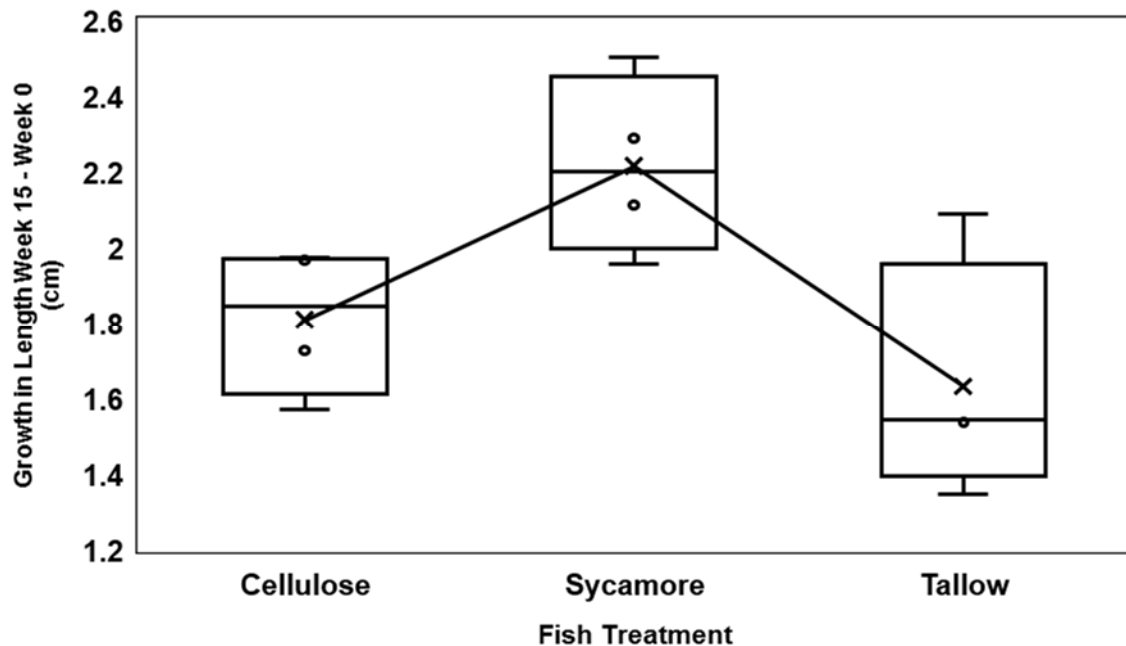
tallow treatments were not significantly different than those in cellulose treatments ( $F = 2.71$ ,  $P = 0.1339$ ; Tab. 1).

Table 1

*Post hoc comparisons of average fish growth (final – initial mass) among leaf treatments.*

Leaf Comparison	N	F	P
Sycamore vs Cellulose	4	17.85	0.0022
Sycamore vs Tallow	4	6.65	0.0298
Tallow vs Cellulose	4	2.71	0.1339

The length growth model (Week 15 length – Week 0 length) from the one-way ANOVA of *P. vigilax* was significant ( $F = 5.51$ ,  $P = 0.0274$ ; Fig. 6).



*Figure 6.* Box-and-whisker plot for growth in length among leaf treatments. Fish growth is the average length per treatment at Week 15 minus average length per treatment at Week 0.

Based on the post-hoc comparisons, the growth of fish (length) in sycamore treatments was significantly higher than those in tallow treatments ( $F = 10.48$ ,  $P = 0.0102$ ; Tab. 2), and but not significantly higher than cellulose treatments ( $F = 5.07$ ,  $P = 0.0509$ ; Tab. 2). The growth of fish in tallow treatments were not significantly different than those in cellulose treatments ( $F = 0.97$ ,  $P = 0.3497$ ; Tab. 2).

Table 2

*Post hoc comparisons of average fish growth (final – initial length) among leaf treatments*

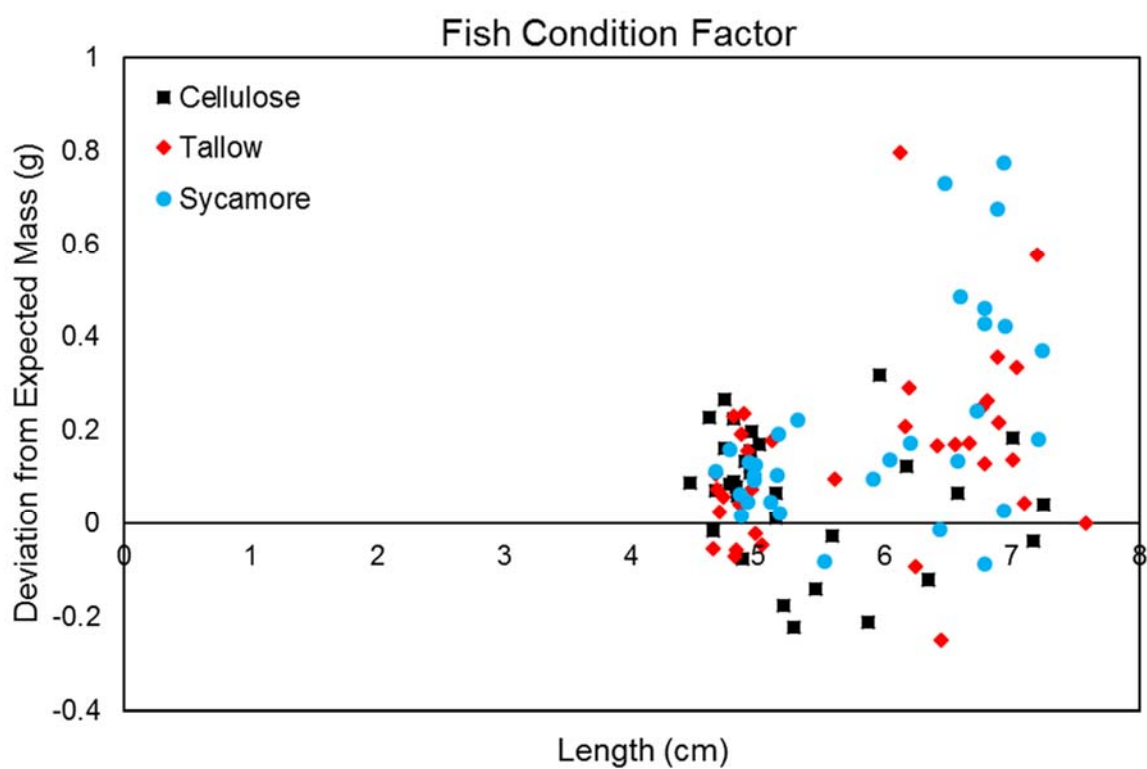
<b>Leaf Comparison</b>	<b>N</b>	<b>F</b>	<b>P</b>
Sycamore vs Cellulose	4	5.07	0.0509
Sycamore vs Tallow	4	10.48	0.0102
Tallow vs Cellulose	4	0.97	0.3497

A one-way ANOVA reported the condition factor (residual: final mass minus expected mass from length-mass regression) for our final masses relative to the initial length/mass regression to be significant ( $F = 7.55$ ,  $P = 0.0119$ ; Fig. 7). Based on the post-hoc comparisons, the mean residuals of fish in sycamore treatments was not significantly higher than those in tallow treatments ( $F = 2.87$ ,  $P = 0.1242$ ; Fig. 7, Tab. 3) and was significantly higher than cellulose treatments ( $F = 15.03$ ,  $P = 0.0038$ ; Fig. 7, Tab. 3). The residual of fish mass in tallow treatments were not significantly higher than those in cellulose treatments ( $F = 4.76$ ,  $P = 0.0571$ ; Fig. 7, Tab. 3).

Table 3

*Post hoc comparisons of the deviations from expected masses from the final masses among each leaf treatment.*

Leaf Comparison	N	F	P
Sycamore vs Cellulose	4	15.03	0.0038
Sycamore vs Tallow	4	4.76	0.0571
Tallow vs Cellulose	4	2.87	0.1242



*Figure 7. Residual plot of the final masses' deviation from expected mass across leaf treatments. Expected mass calculated from length/mass regression for *P. vigilax*.*

## **Invertebrates**

Invertebrate diversity was uniform across weeks and treatments. Estimates of the composition of invertebrate assemblages were made to be about ~90% Dipteran larvae (mostly Chironomidae), 5% Odonate larvae, and 5% containing multiple others such as Ephemeroptera, Trichopteran, and Coleopteran. The 3x2 portion (no time factor included) of the repeated measures ANOVA model reported invertebrate density (no./m<sup>2</sup>) across leaf type (sycamore, tallow, cellulose) was significant ( $F = 4.91$ ,  $P = 0.0217$ , Fig. 8), across fish treatments (presence/absence) was very highly significant ( $F = 32.42$ ,  $P < 0.0001$ , Fig. 8), and was not significant with fish by leaf interaction ( $F = 0.11$ ,  $P = 0.9008$ , Fig. 8). The univariate statistics for the repeated measures (time included) reported: invertebrate density crossed with time factored in was very highly significant ( $F = 9.15$ ,  $P < 0.0001$ , Tab. 4), then the time and leaf interaction was significant ( $F = 1.96$ ,  $P = 0.0443$ , Tab. 4), time by fish interaction was not significant ( $F = 0.0337$ ,  $P = 0.0943$ , Tab. 4), and lastly time by leaf by fish interaction was also not significant ( $F = 0.1809$ ,  $P = 0.2509$ , Tab. 4).



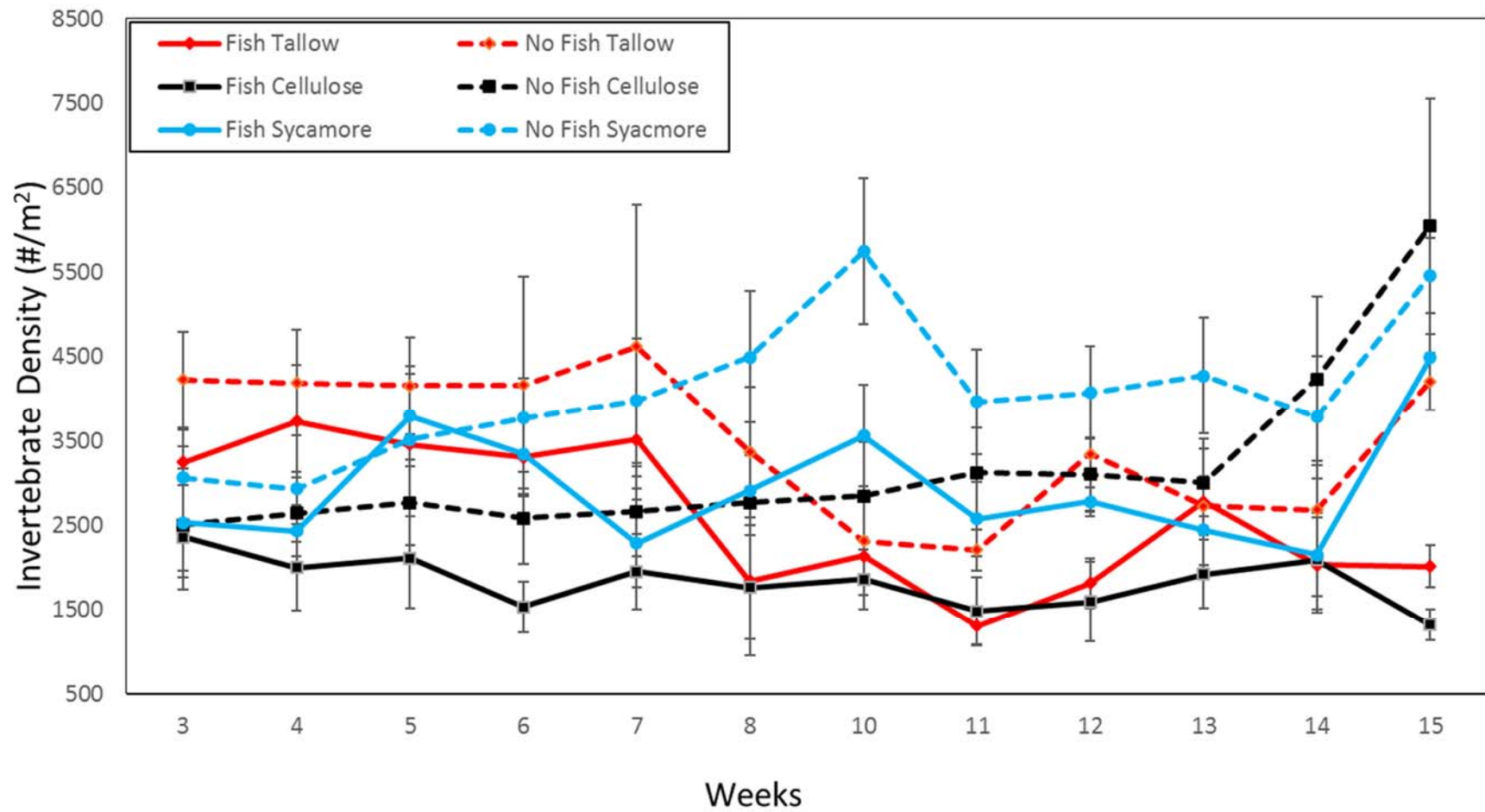


Figure 8. Average invertebrate densities (no./m<sup>2</sup>) for each respective leaf and fish treatment for Weeks 3-15 Note: Weeks 0-2 and week 9 are missing due to misplacement.

Table 4

*Univariate statistics of 3x2 repeated measures ANOVA for invertebrate density; Time factored across all treatments.*

<b>Source of Variation</b>	<b>df</b>	<b>F</b>	<b>P</b>
Time	12	9.15	< 0.0001
Time * Leaf	24	1.96	0.0443
Time * Fish	12	1.92	0.0943
Time * Leaf * Fish	24	1.28	0.2509

### **Benthic Chlorophyll**

The 3x2 portion (no time factor included) of the repeated measures ANOVA model reported benthic chlorophyll concentration ( $\mu\text{g}/\text{cm}^2$ ) across leaf type (sycamore, tallow, cellulose) was very highly significant ( $F = 122.21$ ,  $P < 0.0001$ , Fig. 9), across fish treatments (presence/absence) was very highly significant ( $F = 169.29$ ,  $P < 0.0001$ , Fig. 9), and was significant with fish by leaf interaction ( $F = 3.83$ ,  $P = 0.0424$ , Fig. 9).

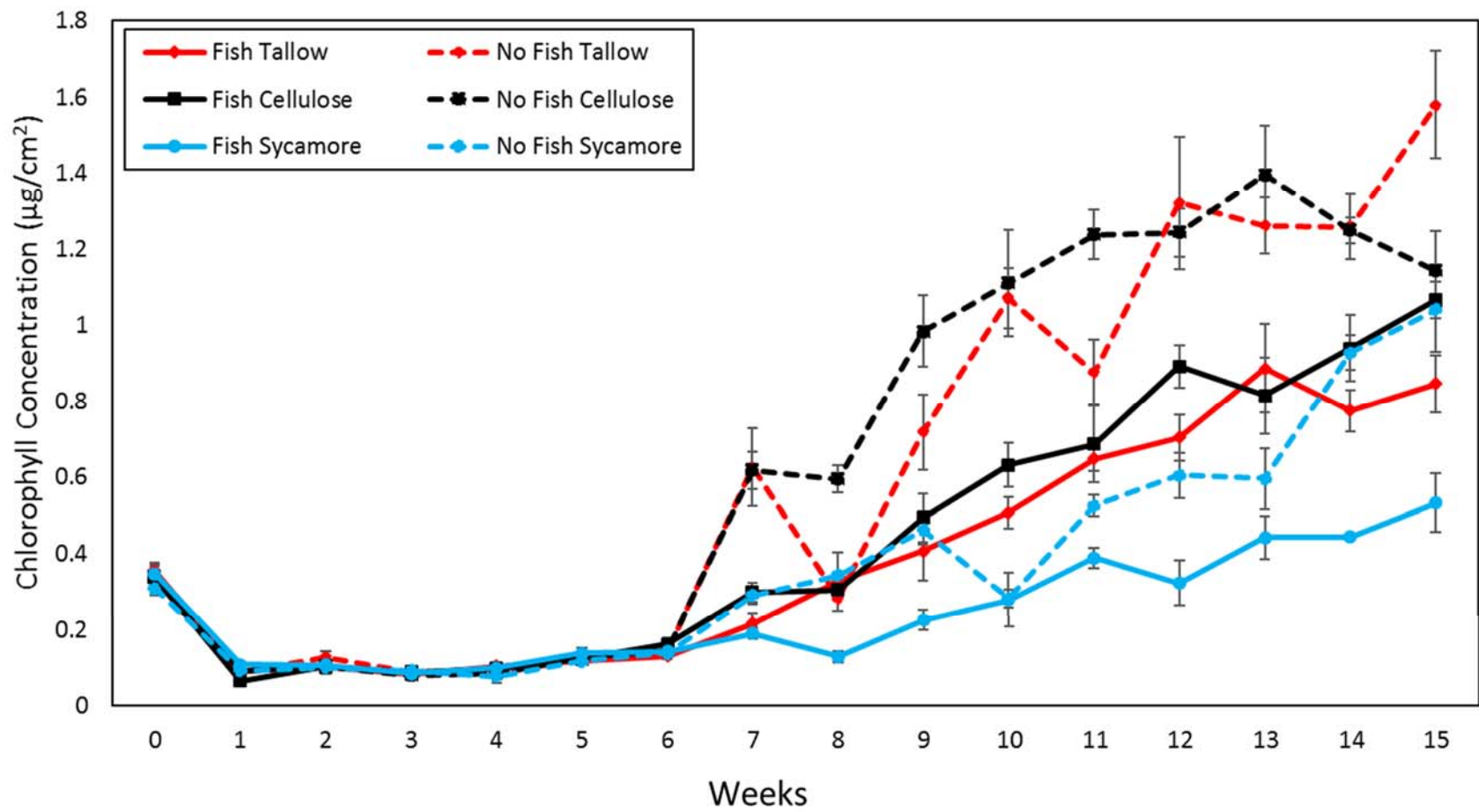


Figure 9. Average benthic algae concentrations (µg/cm<sup>2</sup>) for each respective leaf and fish treatment for Weeks 0-15.

The univariate statistics for the repeated measures reported: benthic algae concentration crossed with time factored in was very highly significant ( $F = 183.62$ ,  $P < 0.0001$ , Tab. 5), then the time and leaf interaction was very highly significant ( $F = 10.29$ ,  $P < 0.0001$ , Tab. 5), time by fish interaction was also very highly significant ( $F = 11.05$ ,  $P < 0.0001$ , Tab. 5), and lastly time by leaf by fish interaction was significant ( $F = 2.66$ ,  $P = 0.0137$ , Tab. 5).

Table 5

*Univariate statistics of 3x2 repeated measures ANOVA for benthic algae concentration; Time factored across all treatments*

Source of Variation	df	F	P
Time	12	183.62	< 0.0001
Time * Leaf	24	10.29	< 0.0001
Time * Fish	12	11.05	< 0.0001
Time * Leaf * Fish	24	2.66	0.0137

## Nitrogen

The 3x2 portion (no time factor included) of the repeated measures ANOVA model reported ammonia concentration (mg/cm<sup>2</sup>) across leaf type (sycamore, tallow, cellulose) was not significant ( $F = 0.44$ ,  $P = 0.6495$ , Fig. 10), across fish treatments (presence/absence) was not significant ( $F = 2.61$ ,  $P = 0.1237$ , Fig. 10), and was not significant with fish by leaf interaction ( $F = 0.24$ ,  $P = 0.7873$ , Fig. 10).

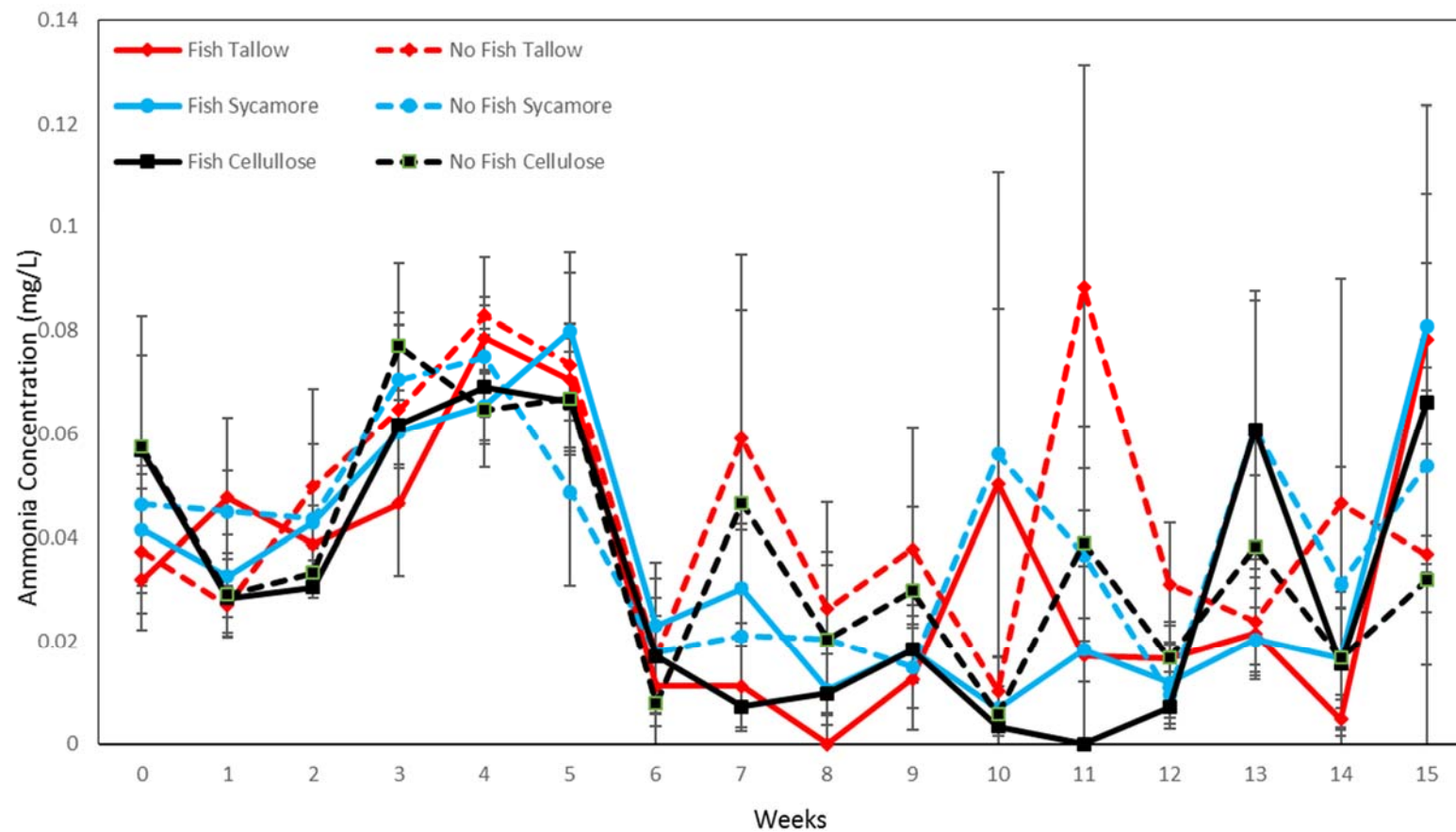


Figure 10. Average ammonia concentrations (mg/cm<sup>2</sup>) for each respective leaf and fish treatment for Weeks 0-15.

The univariate statistics for the repeated measures reported: ammonia concentration crossed with time factored in was very highly significant ( $F = 7.99$ ,  $P < 0.0001$ , Tab. 6), then the time and leaf interaction was not significant ( $F = 0.56$ ,  $P = 0.8763$ , Tab. 6), time by fish interaction was not significant ( $F = 1.47$ ,  $P = 0.1915$ , Tab. 6), and lastly time by leaf by fish interaction was also not significant ( $F = 0.73$ ,  $P = 0.7285$ , Tab. 6).

Table 6

*Univariate statistics of 3x2 repeated measures ANOVA for ammonia concentration; Time factored across all treatments.*

Source of Variation	df	F	P
Time	12	7.99	< 0.0001
Time * Leaf	24	0.56	0.8763
Time * Fish	12	1.47	0.1915
Time * Leaf * Fish	24	0.73	0.7946

### Phosphorous

The 3x2 portion (no time factor included) of the repeated measures ANOVA model reported orthophosphate concentration ( $\mu\text{g}/\text{cm}^2$ ) across leaf type (sycamore, tallow, cellulose) was not significant ( $F = 2.57$ ,  $P = 0.1039$ , Fig. 11), across fish treatments (presence/absence) was very highly significant ( $F = 0.03$ ,  $P = 0.8627$ , Fig. 11), and was not significant with fish by leaf interaction ( $F = 0.10$ ,  $P = 0.9016$ , Fig. 11).

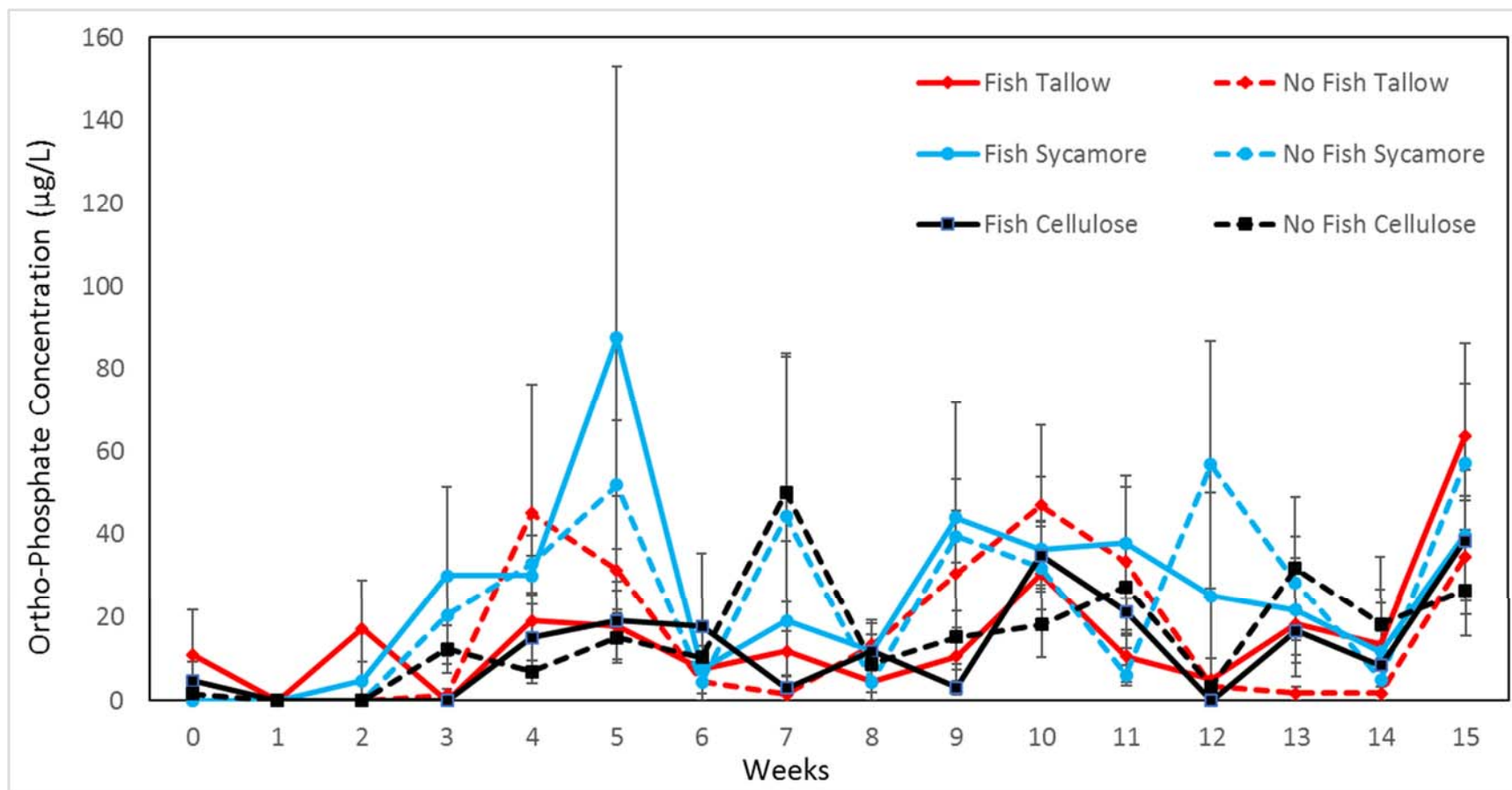


Figure 11. Average benthic orthophosphate concentrations ( $\mu\text{g}/\text{cm}^2$ ) for each respective leaf and fish treatment for Weeks 0-15.

The univariate statistics for the repeated measures reported: orthophosphate concentration crossed with time factored in was highly significant ( $F = 5.33$ ,  $P = 0.0007$ , Tab. 7), then the time and leaf interaction was not significant ( $F = 1.29$ ,  $P = 0.2594$ , Tab. 7), time by fish interaction was not significant ( $F = 0.51$ ,  $P = 0.7348$ , Tab. 7), and lastly time by leaf by fish interaction was also not significant ( $F = 0.83$ ,  $P = 0.5849$ , Tab. 7).

Table 7

*Univariate statistics of 3x2 repeated measures ANOVA for ammonia concentration; Time factored across all treatments*

Source of Variation	df	F	P
Time	12	5.33	0.0007
Time * Leaf	24	1.29	0.2594
Time * Fish	12	0.51	0.7348
Time * Leaf * Fish	24	0.83	0.5849

### Leaves and Suspended Particulates

The leaves decomposed as expected with anywhere from 64-112 g remaining of the original 320 g of sycamore leaves. As shown before, the tallow leaves displayed rapid decomposition and were observed to be gone by Week 7 of this experimental runtime (Cameron and Spencer 1989) (Tab. 8). Similarly, the cellulose paper fully decomposed around the same time except for one mesocosm where a small moss bloom prevented the last ~30 g of cellulose paper from decomposing. The stream water had trace amounts of suspended particulates. They were not measured in any significant manner, where week



by week we observed near zero (and in some cases, actual zeroes) grams of matter left on the filter paper, and thus are not included.

Table 8

*Average starting leaf mass (Week 0) and average final leaf mass (Week 15) for all leaf treatments.*

	<b>Average Initial</b>	<b>Average Final</b>
Cellulose	325.61875	3.29
Sycamore	328.34625	88.05125
Tallow	321.18375	0

Table 9

Statistics for the 3x2 repeated measures ANOVA for response variables for Weeks 0-15. Note: N/A = not available.

	Week																
Source of Variation	df	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Invertebrate Density																	
Model	5	ns	N/A	N/A	ns	ns	ns	ns	ns	ns	N/A	*	*	*	ns	ns	*
Leaf	2	ns	N/A	N/A	ns	*	ns	ns	ns	*	N/A	*	*	ns	ns	*	*
Fish	1	ns	N/A	N/A	ns	ns	ns	ns	ns	ns	N/A	*	*	**	ns	ns	**
Leaf * Fish	2	ns	N/A	N/A	ns	ns	ns	ns	ns	ns	N/A	ns	ns	ns	ns	ns	*
Benthic Algae Concentration																	
Model	5	ns	ns	ns	ns	ns	ns	ns	***	***	***	***	***	***	***	***	*
Leaf	2	ns	ns	ns	ns	*	ns	ns	***	***	***	***	***	***	***	***	*
Fish	1	ns	ns	ns	ns	ns	ns	*	***	***	***	***	***	***	**	***	*
Leaf * Fish	2	ns	ns	ns	ns	ns	ns	ns	**	**	ns	*	*	ns	ns	ns	ns
Nitrogen (Ammonia) Concentration																	
Model	5	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Leaf	2	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Fish	1	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	*	ns	ns	ns	ns
Leaf * Fish	2	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Phosphorous (ortho-) Concentration																	
Model	5	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Leaf	2	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	*	ns	ns	ns
Fish	1	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Leaf * Fish	2	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns

Key: ns = not significant, \* = significant ( $P < 0.05$ ), \*\* = highly significant ( $P < 0.001$ ), \*\*\* = very highly significant ( $P < 0.0001$ )

## CHAPTER IV

### Discussion

Most of the research regarding Chinese tallow have been focused on its effects on native vegetation, ephemeral pond organisms, and its potential as biofuel. The novelty of this study attempts to incorporate the principles of stream ecology, such as stream dependence on allochthonous input, with the invasive characteristics of tallow leaves. Despite the negative effects tallow can have on other native organisms, its functional role as a tree in an ecosystem is still similar to native trees. Most importantly, the leaf litter can provide nutritional input into soil, pond, and stream ecosystems (Cameron and Spencer 1989). The question remains: does tallow leaf litter provide any more/less energy input into stream ecosystems compared to native leaves? The prediction of temporal front loading of a nutrient subsidy was not supported for any response variable. The prediction of decreased long-term growth was supported for fish growth and invertebrate density.

The fish growth in the sycamore treatments was significantly higher than both the tallow and cellulose treatments. The average growth in tallow treatments were higher than that of cellulose treatments but not significantly so. Perhaps the significance between fish growth in tallow and cellulose treatments would have been higher if measured at the midpoint of the experiment. The residual plot of our final masses showed the residuals of sycamore being significantly larger than cellulose treatments and nearly significantly larger than tallow treatments (Tab. 2). A general conclusion to draw from this is that sycamore fish gained more mass per unit length than the fish from the other two treatments. In other words, the sycamore fish were “fatter” than expected. Additionally, the growth in length showed slightly comparable results. The sycamore

treatments were significantly higher for growth in length than tallow but not cellulose (it was nearly, where  $P = 0.0509$ ). Tallow and cellulose were not significantly different in growth of length. This further supports the claim that sycamore fishes were “fattier” than the other two treatments, given that they had less overall growth in length than mass. The rapid leaching of tallow tannins did not cause any mortality in our stream systems as it quickly flowed out; the opposite is shown in small ephemeral ponds where the tannins remain for some time (Adams and Saenz 2012). Based on prior research and the results from this study, the differences among leaf treatments for fish growth could be attributed to either or both of the following: (1) rapid decomposition providing a short-term nutrient pulse that moved through the food web quickly, and (2) physiological inhibition from the chemical composition of tallow leaves (i.e. poison). Tallow’s fast leaching and decomposition did not appear to flow through the food web significantly over the long-term. Sycamore treatments displayed the highest fish growth, and this could be attributed to many variables. The trophic energy transfer of detritus is widely understood and is also dependent on time; as observed before, a percentage of the breakdown of allochthonous material is transferred up trophic levels to the primary consumers (Moore and Hunt 1988, Moore et al. 2004). In our system, the stream consumer *P. vigilax* benefited from additional energy transfer as the sycamore leaves remained in the stream systems until the end. Additionally, the undecomposed Sycamore leaves provided an additional surface area for microbes, algae, and aquatic invertebrates biomass. It is plausible that this increased surface area and additional food resources drove the increase in fish growth in the Sycamore leaf treatments over the entire 16-week experimental runtime. Thus, the rapid decomposition of Tallow likely provided a short-term nutrient pulse that moved

through the food web quickly and did not result in significant increases in fish growth relative to that in sycamore treatments. The, slower-decomposing Sycamore leaf provided a longer-term subsidy for colonization sites for aquatic life that promoted growth of fishes, which has been hypothesized to occur at smaller fish densities (Gary and Hargrave 2017). These data suggest invasion of Tallow into riparian zones of small streams systems may the growth of secondary consumption. Additionally, Chinese tallow has long been suspected of having allelopathic tendencies. Although, this has not been fully substantiated. Plants from the genus *Sapium*, including tallow, have been used reported to be used as bird/fish poisons at different concentrations of their chemical extracts; tallow leaves were found to have tumor-promoting agents in fish such as phorbol esters (Al Muqarrabun et al. 2014). The reduced growth in tallow treatments (which were similar to the no-leaf treatments), could be attributed to physiological inhibition. If this were the case, the tallow leaves full decomposition at around Week 7 would then allow fish growth to return to its normal state. In other words, during the first 7 weeks of the experiment, tallow treatment fish were growing at a rate less than normal due to the chemical inhibition from the tallow leaves. After decomposition, the tallow treatment fish could then “catch up” in growing, thus resulting in similar growth to the fish in the cellulose treatment. Sycamore treatment fish grew under normal conditions, resulting in the highest overall growth. It is quite possible that inhibition, or a combination of inhibition and a lack of basal food source on the back end of the experimental runtime caused the differences in tallow fish growth. For future studies, it would be interesting to observe the masses of specific fish organs and fatty tissues to see what is accounting for the differences among growth and fattiness in fishes.

Across all dependent variables, tallow leaves exhibited some of the same responses to that of cellulose leaves. This suggests that rapid decomposition may prove to be much less useful to stream organisms and is nearly comparable to not having any basal food source long-term. Benthic chlorophyll (algae) did appear to be highest in cellulose and tallow treatments over time. This is likely due to the lack of leaf cover on the stream substrate bed after decomposition, where undecomposed sycamore leaves inhibited chlorophyll from being on the substrate. Algal blooms are known to happen in systems that are phosphorous-limited and cannot be mediated by any algivorous organisms (Sundareshwar et al. 2011). Fish did not grow as much in the tallow and cellulose treatments, so the increased benthic algae did not appear to facilitate the growth of fishes. This is interesting because bullhead minnows are mainly benthic feeding species (Thomas et al. 2007). Invertebrate density did appear to be slightly higher in sycamore treatments compared to tallow and cellulose. Additionally, invertebrate densities were higher in no fish treatments, suggesting that fish preferred to feed on invertebrates. The nutritional content of invertebrates is likely higher than benthic algae (both in bullhead minnow diet), and invertebrate density was not dependent on time. Therefore, it is reasonable to suggest that invertebrates were not a limiting food source and fish could afford to be choosy in their diets, feeding on the higher nutritional food item. Fish are known to exhibit choosy behavior in their diets should the circumstances for prey not be limiting (Gibson 1983). This supports the idea that invertebrate and microbial colonization on additional surface area provided long-term (longer-term than tallow leaves and cellulose) additional food resources that facilitated growth.

Nitrogen and phosphorous compounds were highly variable and non-significant across all treatments. Nitrogen and phosphorous compounds in streams tend to be limited, and appeared so in the mesocosms despite the fact that we added a significant source of those compounds in leaves. In naturally occurring 2nd order streams, nutrient limitation (especially phosphorous) can limit invertebrate and algal survival/growth, thus effecting higher trophic levels (Elwood et al. 1981). Both nitrogen and phosphorous were highly significant with time, but not among treatments. The nitrogen and phosphorous content had many fluctuations over the 16 weeks, that cannot be attributed to any treatment affect, as none were significant. The large drop off in weeks 5-6 cannot be explained by any weather event that would cause dilution, as it did not rain any significant amount during that time. Another possibility may be the electrical/circuit error of the well water flowing into the mesocosms that occurred just before week 5, where the water inflow is abruptly stopped and could cause a sharp increase in nitrogen and phosphorous concentration, but would then return to normal as the problem was fixed and the outflow diluted the concentrations. Nitrogen-fixing bacteria may account for the higher nitrogen amounts in the later weeks of the experiment, where we would expect it to be the least with all the leaves decomposed. The tannins of the leaves were left to saturate at the beginning of the experiment before release, this rapid release of nutrients that quickly flowed out, likely accounted for most of the nutritional content contained within the leaves. Meaning, the nutrients released too quickly to get a significant signal in any results, where other studies measured the nutrient release on a much shorter time scale to observe the effects of decomposition (Cameron and Spencer 1989). The variation in our other response variables could be explained by the inconsistency of nitrogenous or

phosphoric compounds over time. Even though sycamore treatments did not contain significant amounts of nitrogen and phosphorous in the water column (likely due to inflow/outflow), it is reasonable to suggest that higher nutrient levels were present in the trophic predator/prey interactions for fish, thus promoting growth. The same cannot be said for tallow treatments where the rapid decomposition likely stunted growth as the nutrients did not travel through the food web past week 7 (full decomposition).

My prediction about tallow providing a short-term pulse subsidy was not supported. Nitrogen, phosphorous, and algae concentration were all variable across time. Algal concentration over time, responded oppositely of a pulse and was higher during the 2<sup>nd</sup> half of the experimental runtime (past week 6). This may be because food-webs and trophic energy transfer is time delayed from initial input (May 1973). However, fish growth can be attributed to the nutritional quality and energy transfer as they represent the highest trophic level in these artificial streams. There is support for the conclusion that sycamore leaves provided a higher-quality leaf material subsidy for growth as opposed to tallow leaves. Rapid decomposition of tallow leaves appears to result in significantly reduced nutritional and energy transfer. Future studies about tallow leaf litter should be focused on exactly how much energy is transferred to higher trophic levels, mainly through stable isotope experimentation. Additionally, we must rule out the possibility of physiological inhibition from the chemical content of tallow leaves at smaller densities in open systems like streams.

Tallow trees already have the reputation for being a noxious invader, and attempt at controlling their spread has been practiced through incineration of trees and other tactics. The inevitable and continual increase of tallow tree density across the United



States and other countries will have ecosystem effects that are mostly negative. It is imperative that we learn as much as there is to know about tallow trees in order to mitigate the potential effects of a runaway invasion. The capability of this tree to form monotypic strands and displace native trees through high reproductive output is reason for concern. Assuming this same phenomenon can happen in riparian zones, the research presented may provide insight as to how stream production and energy transfer may be significantly reduced during months of leaf fall. Unlike tallow studies with ponds, the tannin leaching is not relevant with streams, but rather the nutritional content of the leaves as microbial decomposers, invertebrate grazers/shredders, and secondary fish feeding will all be affected by this foreign leaf. Conservation strategies may need to be put in place as this tree continues to expand its range, mainly because of climate change. Its distribution is limited by cold winters, and warmer climates may increase the invasion potential of the tree. Environmental policy-makers have much to consider about this tree's future, as it has permanently established an irreversible distribution in the United States.

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## VITA

### **Education**

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#### **MS in Biology**

**in progress**

Sam Houston State University

Department of Biological Sciences

Thesis: Invasive Allochthonous Input: The Chinese Tallow Tree and Stream Food Webs

Committee: Dr. Chad Hargrave, Dr. Jeffery Wozniak, Dr. James Harper

- Concentration in Aquatic Ecology: 32 Credit Hours (6 research based)
- October 2017 is expected date of thesis defense, with December Graduation

#### **BS in Biological Sciences**

**Aug 2011 – May 2015**

University of Maryland, College Park

College of Computer, Mathematical, and Natural Sciences

- Concentration in Ecology and Evolution: 120 credit hours
- 12 credit hours in statistics

### **Teaching and Employment**

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#### **Adjunct Faculty**

**August 2017 - Current**

Community College of Baltimore County

Department of Biology

- Seven sections of BIOL110 Recitation
- BIOL108: Investigating the Living World Laboratory
- Total of 7.5 credit workload

#### **Teaching Assistant**

**Jan 2016 – May 2017**

Sam Houston State University

Department of Biological Sciences

- Taught four lab sections of Contemporary Biology
- Taught eight lab sections of Ecology in Fall 2016 and Spring 2017
  - Showed junior level science majors basic freshwater ecology sampling

#### **Martial Arts and Fitness Instructor**

**2008-2014**

Vuong's Martial Arts

Gambrills, Maryland

- Primarily a Tae Kwon Do instructor for all ages after receiving 1<sup>st</sup> degree black belt. Received 2<sup>nd</sup> degree black belt in 2014.
- Taught group fitness (cardio kickboxing, yoga, circuit training) in 2014.
- Coached the school's 2013 National Junior Olympic Team
- Participated in various demonstrations and seminars on self-defense training.
- Attended seminars focused on pedagogical development



**Experience Leader****2013-2014**

University of Maryland Alternative Breaks  
College Park, Maryland

- Responsible for coordinating an emersion experience for University of Maryland students in South Carolina.
- Focused on the societal causes and implications of poor healthcare and childhood obesity.
- Worked with various organizations in the Charleston and Columbia areas such as the Palmetto Place Shelter.
- Participated as a volunteer in the program in 2012 and 2015

**Research Interests and Experience**

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**Interests**

- To explore changing ecological dynamics in aquatic ecosystems as they pertain to shifting biotic and abiotic factors such as: invasive species, climate change, and habitat loss.
- To assess changes in biodiversity of aquatic organisms ranging from macroinvertebrates to fishes.

**Future Publications**

Schalk, C.M., S. Silva, D. Hagyari, J. Wagner, L. Tiegs, C. Sadeghian, T. Schriever, C.G. Montaña. *In preparation*. Revisiting ‘What do tadpoles really eat?’: A ten-year report card. Target Journal: *Freshwater Biology*.

**MS Program Experience**

Organismal Sampling Techniques:

- Seining
- Netting
- Basic fishing
- Electroshock sampling
- Dichotomous key and Taxonomic identification
  - Invertebrates (through a freshwater entomology class)
  - Freshwater fish (graduate level ichthyology)
- Algae sampling with spectrophotometer readings

Water Sampling:

- Experience with nitrogenous (nitrates and ammonia) and phosphorus compound analysis on a microplate.
- Have sampled for total organic and inorganic matter (vacuum filtration, ash, etc.)

### **Conferences Attended and Societal Membership**

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Texas Academy of Science (member)

- Junction, Texas, 2016
- Attended to spectate and network

Joint Meeting for the Society of Ichthyologists and Herpetologists (member)

- New Orleans, Louisiana, 2016
- Presented poster

Texas Chapter of the American Fisheries Society (Poster)

- Corpus Christi, Texas, 2017
- Presented thesis poster

### **Skills**

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Languages:

- Native: English
- Spanish: speaking (intermediate), writing (basic)

Computer Software:

- Microsoft Office Applications
  - MiniTab
  - SAS
  - PAST
  - ImageJ
- SigmaPlot