The Effects of Artificial Floating Wetland Island Construction Materials on Plant Biomass

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DEDICATION

I dedicate this thesis to my parents who have always reminded me I am 'the first kid on the bus' and can achieve anything I set my mind to. Thanks Mom and Dad!

I would also like to thank Alexandra Jangrell-Bratli for being such a great research partner and friend through the last few years.

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ABSTRACT

Two artificial floating wetland island types were constructed to determine if floating wetland islands made from 'natural' environmentally sensitive materials would perform similarly to those islands made of 'artificial' plastic derived materials with regard to vegetation dynamics, biomass, plant percent cover, carbon, nitrogen, and phosphorus content, material durability, and buoyancy. The islands were placed in an urban lake in St. Petersburg, FL and initially transplanted with *Pontederia cordata* (pickerelweed), *Schoenoplectus tabernaemontani* (bulrush), *Canna flaccida* (golden canna), and *Sagittaria lancifolia* (duck potato). Islands were measured through the growing season for percent cover, weight, and plant category composition. At the end of the study, biomass was harvested and oven dried. Nitrogen, carbon, and phosphorus content were analyzed for each species.

All floating wetland islands remained buoyant throughout the study. The substrate on the 'natural' bamboo islands disintegrated within one month in the aquatic environment, which was not sufficient for most bamboo island vegetation to establish and create a self-sustaining buoyant root mat. Biomass from three of eight bamboo islands was harvested.

Vegetation dynamics depended on raft type. Emergent macrophytic vegetation decreased 13% on average across all islands. Conversely, floating aquatic vegetation (FAV) increased on average 39%. Mean algae cover was greatest on the open PVC islands (58%) and less than half that for all other islands. *Ludwigia grandiflora* (primrose

willow) was not initially transplanted to any of the floating wetland islands, but averaged 40% on all harvested islands by the end of the study, greater than any other emergent macrophyte on average.

Mean island weights varied for island groups (PVC open: 15 kg; Bamboo unharvested: 18 kg; Bamboo harvested: 22 kg; PVC enclosed: 23 kg). Weight increases resulted from biomass growth (PVC open: 131 g/m^2; Bamboo harvested: 1,461 g/m^2; PVC enclosed: 1,511 g/m^2), mainly from *Ludwigia grandiflora* (2,123 g/m^2).

Islands with greater biomass had a greater mass of nitrogen, phosphorus and carbon content. Percent nitrogen, phosphorus and carbon were dependent on species rather than raft type. *Ludwigia grandiflora* and *Pistia stratiotes* (water lettuce) had the greatest percent of N (3.7% and 3.9%) and P (0.2% and 0.4%) over other island species.

Island location and enclosure led to differences in percent cover within the island groups. The parameter of lakeward or landward accounted for 44% of variation in the total mean percent cover ($p<0.001$). The parameter or north or south accounted for 32% of variation ($p=0.002$). Enclosure accounted for 24% of variation ($p=0.014$).

1. Introduction

Wetlands can generally be defined to require shallow water or flooded soils for part of the growing season, have organisms adapted to this wet environment, and have soil indicators of this flooding such as hydric soils (Mitsch and Gosselink, 2000). Different types of wetlands are identified by different names, such as: fens, bogs, swamps, marshes, wet prairies, and wet savannas (Kushlan, 1990). Wetland habitats are sometimes found in aquatic environments in the form of floating vegetated islands (Mitsch and Gosselink, 2000). These islands are very common in Florida and throughout the world (Sasser et al., 1996; Mallison et al., 2001; Somodi and Botta-Dukat, 2004; Van Duzer, 2004; Headley and Tanner, 2006).

1.1. Natural Floating Island Formation

Floating vegetated islands, also known as floating wetland islands in this study, can be broadly defined as emergent vascular plants growing on a buoyant mat of live and dead plant roots and organic matter including decomposing peat (Sasser et al., 1991; Mallison et al., 2001). Furthermore, these islands float over a layer of free water over a layer of decomposed organic sludge (Sasser et al., 1991). Floating wetland islands are sometimes referred to as tussock islands (Alam et al., 1996), floating islands (Trivedy et al., 1978), floating marsh (Sasser et al., 1996), sudds (Ellery et al., 1990), flotants (Russell, 1942), floatons (Mallison et al., 2001), or plav, *embalsados*, floating peat, (Headly and Tanner, 2006). These rafts can form a number of ways. Peaty organic sediments can float up to the surface from the deeper sediments whereby seeds can germinate on the now floating organic substrate. This usually occurs after storm events

when emergent vegetation and sediment become dislodged from the shallow lake shore or lake bottom and drift into deeper sections of a water body due to wind, wave, and water fluctuations (Azza et al., 2006; Cherry and Gough, 2006).

A common cause that leads to the separation of organic substrate and vegetation making floating islands is fluctuating water level (Cherry and Gough, 2006). However, floating islands occurred at Lake Pondrosa, AL without water level fluctuation (Cherry and Gough, 2006). The islands probably formed as a result of a temperature increase, which caused increased gas formation, which then dislodged the organic sediments forming an island that vegetation was able to colonize (Cherry and Gough, 2006). Floating root mats typically occur after wind and wave action disturb low-energy areas and vegetation or sediment is able to dislodge and form a mat. Also, these mats are often anchored at the shallow lakeshore but are floating at the end where the water is deeper (Azza et al., 2006). Occasionally, the lakeward end of the floating mat vegetation might break away during periods of large rapid rises in water level and establish somewhere else, or might not survive and just disintegrate back into the lake (Thompson and Hamilton, 1983; Thompson 1985; as cited by Azza et al., 2006). Furthermore, floating wetland islands could form after a build-up of microbial gases in the lake sediments after the breakdown of organic matter. When the gases are released, sediments and other debris are released into the water column (Ellery, 1990). This creates a new open substrate area in deeper water where emergent vegetation is able to colonize. These methods can all be termed the peat float-up processes (Kadlec and Wallace, 2009).

Floating wetland islands can also form when aquatic plants clump together forming a raft. This raft might or might not be attached to the shore. The floating aquatic

vegetation itself is not considered a floating wetland island, but marks the initial stages of one (Russell, 1942; Kadlec and Wallace, 2009). For the clumped aquatic vegetation to form a wetland island, sediments and debris need to get trapped in the roots to start to form a dense consolidation of sediments being the beginning stages of a floating mat (Russell, 1942; Azza et al., 2006). Without the dense mat, the floating aquatic plants can break apart easily. Floating mat communities basically consist of two parts (Hill and Webb, 1982). The first part is the grouping of floating aquatic vegetation such as *Pistia stratiotes* (water lettuce) and *Eichhornia crassipes* (water hyacinth). Floating aquatic plants are considered the primary organisms for a floating wetland island. The second part occurs after sediments accumulate and a mat begins to form. This allows secondary species to colonize the newly formed floating wetland island mats. Both primary and secondary species composition will vary based on geographical location (Hill and Webb, 1982). Kadlec and Wallace (2009) refer to this method as the grow-over process.

The third cause of natural floating island formation is when rooted benthic vegetation breaks away from the bottom bringing vegetation and substrate to float on the waters surface (Azza et al., 2006; LePage, 2011). This phenomenon was observed in Hungary when reed-beds were damaged and some of the vegetation became buoyant, along with sediments and in some cases mature *Salix cinerea* (willow) (Somodi and Botta-Dukat, 2004). Once the vegetation breaks away from the substrate bottom, some of the plant biomass will fall and float in the water column. If there is enough buoyancy, the island can sustain itself. These islands are usually temporary in nature (Hoeger, 1988). This is a mat floating process (Kadlec and Wallace, 2009).

In order to be self-sustaining, the floating wetland island must be buoyant and sturdy. Floating rafts facilitate further vegetative growth on top of a mat consisting of dead biomass and sediments, and are held together by interconnected root stems and rhizomes (Hoeger, 1988; Mallison et al., 2001; Azza et al., 2006; Headley and Tanner, 2006). Buoyancy results from air sacs in vegetation, or when dead rhizomes fill with gases and become suspended (Somodi and Botta-Dukat, 2004). Floating wetland islands typically consist of a 40-60cm deep floating organic mat supporting plant growth (Headley and Tanner, 2006), but might exist in many other forms (Sasser et al., 1996; Mallison et al., 2001). Various forms of floating wetland islands occur in the Mississippi River delta, and these floating wetland islands are diverse and vary depending on hydrology, substrate, and vegetation (Sasser et al., 1996). The floating mat is divided up into the root and peat zones (Gaudet, 1977). The *Panicum* floating mats, observed by Sasser et al. (1996) were firm and consisted of different zones. The top 20-30 cm consisted of living and dead root matter. Most of the decomposing roots and less active living roots occurred between 30-50 cm, which is considered the peat zone. These mats remained floating and buoyant unless the water level in the lake dropped dramatically, then the mat sat atop the lake surface (Sasser et al., 1996). Another kind of floating mat observed was the *Sagittaria* thick mat in which the fibrous root mat was less distinctive than the *Panicum* floating mats but the peat layer was thicker. The *Eleocharis* thin mats were dominated by *Eleocharis* first, but were out competed by *Ludwigia leptocarpa* (primrose willow), *Phyla nodiflora* (frog fruit), and *Bidens laevis* (bur-marigold). These mats were not more than 30 cm thick (Sasser et al., 1996).

After a healthy root mat is established, other plant species might colonize the floating raft. Vegetation grown on the island initially forms from regrowth of older vegetation pieces and germination from the imbedded seed bank (Cherry and Gough, 2006). After mat formation, emergent plants are able to grow in areas with increasing lake depth, where they would otherwise not be able to survive (Azza et al., 2006).

1.2. Natural Floating Island Vegetation

The vegetation of floating wetland islands can be diverse, but is usually dependent on the plants living in the area because most natural floating islands form from existing vegetation found on site. The vegetation of a floating wetland island will change based on its formation and succession. The first plants that colonize the islands are floating and submerged aquatics like *Eichhornia crassipies* (water hyacinth) and *Achyranthes philoxeroides* (alligator weed) (Russell, 1942). After the initial colonization of floating aquatic vascular plants, secondary colonizers include grasses like *Phragmites communis* (common reed), and *Leersia hexandra* (southern cutgrass) in the Amazon, *Hymenachne amplexicaulis* (West Indian marsh grass) and *Paspalum paspaloides* (knotgrass) in Australia and other emergent plants like, *Ludwigia* spp. (primrose willow), *Scirpus* spp. (bulrush), and *Typha* spp. (cattail) worldwide (Hill and Webb, 1982). Other emergent vegetation with the ability to form vegetated mats includes, *Carex* spp. (sedge), *Cladium* spp. (sawgrass), *Cyperus* spp. (flatsedge), and *Vossia* spp. (hippograss) (Azza et al., 2006). John et al. (2009) observed a total of 24 macrophyte taxa on three types of floating islands off the coast of Kerala, India demonstrating that floating islands come in many shapes, sizes, and types.

In the Shark Valley Slough of the Florida Everglades, natural floating island mats were usually envelop and combine with *Ultricularia foliosa* and *U. purpurea* (bladderwort) (Olmsted and Armentano, 1997). Alam et. al (1996) observed floating rafts formed from *Eichhornia crassipies* (water hyacinth) in Lake Istokpoga, FL. In Orange Lake, FL floating island varieties were grouped according to the dominant vegetation. The five types of floating islands consisted of *Scirpus cubensis* (Cuban bulrush), *Hydrocotyle* spp. (pennywort), *Typha latifolia* (cattail), *Polygonum* spp. (smartweed), and *Pontederia cordata* (pickerelweed) among others (Mallison et al., 2001) (Table 1.1.1).

Table 1.1.1: Number of floating islands per type containing ≥10% coverage of each plant taxa, Orange Lake, FL. October 1997. Percent of totals in parentheses (Modified from: Mallison et al., 1997).

	Floating Island Type					
Individual Plant taxa	Bur marigold, cattail, and smartweed	Cuban bulrush and water pennywort	Facultative	Grasses	Pickerelweed	Total
Water pennywort	17 (100)	30 (97)	11 (79)	8 (100)	34 (97)	111 (96)
Pickerelweed	8 (47)	16 (52)	3 (21)	2 (25)	35 (100)	69 (59)
Cuban bulrush	9 (53)	22 (71)	6 (43)	3 (38)	14 (40)	58 (50)
Water primrose	4 (24)	6 (19)	10 (71)	1 (13)	6 (17)	29 (25)
Frog's bit	3 (18)	13 (42)	2 (14)	2 (25)	3 (9)	27 (23)
Total number of islands	**17**	**31**	**14**	**8**	**35**	**116**

1.3. Benefits of Natural Floating Islands

Natural floating islands have been shown to provide bird-nesting areas (Russell, 1942), wildlife sanctuaries (LePage, 2011), and have demonstrated the ability to remove excess nutrients from water (Kadlec and Wallace, 2009). Natural floating islands might also help maintain species richness of emergent wetland plants (Cherry and Gough, 2006). Cherry and Gough (2006) studied the species percent cover of naturally occurring

floating islands and compared the species richness of the islands to the species richness of the surrounding deep-water marsh. They found that the islands had higher species richness than the deep-water marsh because emergent vegetation was able to colonize and persist on the floating islands, where it otherwise could not exist. Without the floating substrate, floating-leaved perennials would mainly dominate the deep-water areas. They inferred that the floating islands could help maintain and replenish the seed bank of species, which would otherwise be uncommon. Floating islands help bald cypress seedlings to establish in an otherwise constantly inundated area with no other opportunity for seed germination by providing substrate (Huffman and Lonard, 1983).

It has been demonstrated that certain fish species, such as the African cichlid, use natural floating islands for transport (Oliver and McKaye, 1982). The floating islands act like a disperser for genes and can lead to founder generations in other locations. Many other animals like the dragonfly and damselfly larvae, water scorpions (Hemiptera: Nepidae), *Caridina nilotica* (freshwater prawns), and post-larval fish were observed beneath the floating islands (Oliver and McKaye, 1982). Russell (1942) mentioned that flotants in Louisiana were home to alligators, teeming insect life, wild geese, and other birds.

Floating mats enable emergent plants to colonize deep-water areas where they would not otherwise be able to live. These mats allow the potential for the emergent vegetation to cover an entire lake. However, the gain in vertical emergent growth that the mat facilitates outweighs the loss in biomass from not being able to grow horizontally along the lakeshore (Azza et al., 2006).

The ecological significance of emergent floating mats is not well understood. The mats might represent a successional stage from the aquatic floating habitat to eventually becoming part of dry land (Sculthorpe, 1967 as cited by Azza et al. 2006). Or, the mats might represent a stable community structure (Sasser et al., 1995). In the Florida Everglades peaty floating islands dominated by sawgrass succeeded into islands dominated by wax myrtle and then bay trees. Once this kind of succession occurs, the floating island can be termed a 'tree island' (Loveless, 1959). The transition from marshland to forested land can take up to 1,000 years and floating peat islands can speed up this successional process (Glasser, 1985). Huffman and Lonard (1983) describe the successional patterns of floating islands in a Southwestern Arkansas Bald Cypress Swamp. They say the first stage is the formation of the floating mat. The mat usually starts on partially submerged tree limbs or roots. It is assumed this is by way of a build up of organic matter clinging to a stationary object like a tree limb. After the mat is formed, pioneer species, like water-willow, colonize the organic debris. The water-willows lead to colonization by herbaceous vegetation like *Cyprus odoratus* (flat sedge) and *Hydrocotyle verticillata* (water pennywort) among others. Next is the herb and shrub stage. These plants colonize the floating island and once this stage is reached, the mat is very heavy and often sinks. Once the island is submerged, only bald cypress is able to survive. This last stage is referred to as the Tree Stage (Huffman and Lonard, 1983).

1.4. Problems Associated with Natural Floating Islands

Invasive, sometimes exotic, mat-forming plants are prevalent in aquatic environments and can cause economic and environmental damage like, *Pistia stratiotes* (water lettuce), and *Lemna spp.* (giant duckweed) (Charudattan, 2001). Recreational

problems might also occur if tussock islands block boater or fishing access (Alam et. al, 1996).) If this happened, island biomass could be harvested by chopping the island into smaller pieces and depositing it along the lake shoreline to desiccate the plants and remove the unwanted floating mats (Alam et al., 1996).

1.5. Artificial Floating Islands

In an attempt to recreate some of the benefits of naturally occurring floating wetland islands, the formation of constructing floating wetland islands (CFWI) has recently been explored (Nakamura and Shimatani, 1993; Headley and Tanner, 2006; Kelly and Southwood, 2006; Li et al., 2007; Li et. al, 2010; Medcalf and Rothenburg, 2010). Artificially constructed floating wetland islands are also know as floating vegetation mat (FVM), artificial floating islands (AFI), floating reedbed rafts, floating meadows, Vetiver grass pontoons, Floating Pond Restorer™, floating islands: BioHaven™, Beemats^LLC, and floating wetland islands or blankets: Aquagreen™ (Headley and Tanner, 2006). In 1980, the first constructed floating island was built for waterfowl nesting habitat, and was called 'schwimmkampen' which translates to 'floating city' (Hoeger, 1988). Recently, it has been shown that constructed floating wetland islands can optimize wetland vegetation by allowing plant growth in otherwise devoid areas where the water level might be too deep for vegetation to grow (Kerr-Upal et. al, 2000; Visser et al., 2006) This could increase wildlife habitat and facilitate such environmental benefits as nutrient removal and increased water quality (Tanner, 1996; Stewart et al., 2008). Artificial floating islands have four main functions: 1. water purification, 2. habitat improvement, 3. erosion protection, and 4. enhanced landscapes (Nakamura and Mueller, 2008).

1.6. Artificial Floating Island Materials

Constructed floating wetland islands differ from their natural counterparts through their initial substrate formation. Constructed floating wetland islands include an initial man-made raft. The raft can be made from various materials such as Styrofoam, metal, plastic, vegetation, or dredged lake sludge (Headley and Tanner, 2006; Kelly and Southwood, 2006; Nahlik and Mitsch, 2006; Visser et al., 2006; Li et al., 2007; Nakamura and Mueller, 2008; Stewart et al., 2008; Hu et al., 2010; Li et al., 2010; Medcalf and Rothenburg, 2010). The materials for the constructed floating island raft might be wide ranging, but should be durable, functional, environmentally sensitive, buoyant, easily anchored, and not be too heavy (Kerr-Upal et al., 2000). If materials are anything but durable, functional, environmentally friendly, etc., the constructed floating island might not reach the intended goals of the project and might fail. More research is needed to study varying raft materials for floating mats (Hubbard, 2010).

Artificial floating islands can be classified into two groups, those that are ‘wet’ and have vegetation permeating into the water column, and those that are ‘dry’ with vegetation enclosed within the artificial island mass (Nakamura and Mueller, 2008). The ‘wet’ design for artificial floating islands is used most often. Common materials used include coconut fiber (Nakamura and Mueller, 2008).

The Schwimmkampen islands produced by Bestmann Green Systems™ are constructed from a polyethylene, polyurethane, and neoprene bottom topped with a planting substrate made from natural fibers and cork (Hoeger, 1988). The cork adds buoyancy to the island. The artificial materials are resistant to degradation from microorganisms and other ‘pests’ (Hoeger, 1988).

A steel frame with styrene foam was constructed as a base for the artificial floating islands created by Nakamura and Shimatani (1996). The frames were covered with a polyurethane foam substrate and planted with *Zizania latifolia T*. (wild rice), *Typha latifolia L*., *Scirpus triangulatus Roxb*. (roughseed bulrush), *Sparganium erectum L*. (bur-reed), *Iris pseudacorus L*. (yellow irises), and *Phragmites australis* (common reed) before being placed in Lake Kasumigaura, Japan. These materials persisted through the entire study of three years.

Sixty three artificial floating islands were constructed from polystyrene blocks situated between wooden frames for a total size of 3.6 m x 2.4 m in Scotland for the purpose of increasing breeding success of the *Gavia stellata* (Black- and Red-throated divers). Once complete, the artificial island frame was covered by a mesh fishing net and planted with *Trichophorum* spp. (bulrush), *Eriophrum* spp. (cotton sedge) and/or *Calluna* spp. (heather) and sometimes *Juncus* spp. (rush). Rafts were anchored to the lake bottom to prevent unwanted drifting (Hancock, 2000).

Visser and Sasser (2006) initiated an experiment in which they tested various types of artificial floating island materials for structural integrity, buoyancy, and growth response at the Louisiana State University (LSU) Agricultural Center where the artificial islands were tested in outdoor research ponds. Many materials were used for artificial island frames and island substrate including wood, PVC, Bamboo, Styrofoam, burlap, coconut fibers, chicken-wire, and jute (Table 1.6.1). All islands were initially planted with *Panicum hemitomon* (maidencane). They found that the PVC and Bamboo frames were the most buoyant and as a result led to greater species diversity than islands with less buoyant frames. If the island frame did not retain buoyancy, most of the substrate

disintegrated. Similarly, Kelly and Southwood (2006) engineered 174 artificial floating islands constructed from 20 cm diameter PVC frames that were protected from ultraviolet rays and arranged in a 2 m square with galvanized mesh base and coir pallets as the plant substrate medium.

Biohaven® floating islands were tested for the removal of ammonium, nitrate, and phosphate under aerobic and anoxic conditions in the laboratory (Stewart et al., 2008). Artificial floating wetland islands made from polyurethane foam and polyester fiber frames (Biohaven® Floating Islands International) with a substrate of 1 parts sand, 2 parts sphagnum peat, and 1 part compost were used also to test removal of stormwater pollutants like copper and zinc (Tanner and Headley, 2011).

Three floating islands comprised of closed-cell foam mats (Beemats^{LLC}) were installed in Mulloch Creek (Lee County, FL) to document the success of these islands on the removal of nitrogen and phosphorous. This material persisted through the course of the study, seven months, with no apparent problems (Medcalf and Rothenburg, 2010).

One hundred and forty artificial floating islands were constructed from a polyvinyl chloride (PVC) 2 m x 1 m frame with a series of 34-knotted ropes to act as the floating island substrate for the plants. These islands were placed in a rural river in Honghu, China and planted with *Oenanthe javanica* (Chinese celery), *Gypsophila* spp. (baby's-breath), *Rohdea japonica* (sacred lily), *Dracaena sanderiana* (lucky Bamboo) and shrubs; *Gardenia jasminoides* Var. *grandiflora* (August beauty) and *Gardenia jasminoides* Var. *prostrata andtrees*, *Salix babylonica* (weeping willow) (Zhu et al., 2011).

Another creative material used in the construction of artificial floating islands is the waste from dredging. Ecological sludge floating-bed (ESFB) technology was used by Hu et al. (2010) to reconstitute the waste product into a beneficial artificial island. Dredged sludge and basic oxygen steel making furnace (BOF) slag were used as binding agents in the artificial floating island. Lightweight closed pore expanded prelate was used as the floatation agent for the island. The ESFB dimensions were 80 cm x 80 cm x 5 cm.

Interestingly, Li et al. (2010) enhanced the performance of artificial vegetated floating islands by incorporating bivalves and filter feeders to the artificial island. They call this approach an 'integrated ecological floating-bed' (IEFB). They determined that the IEFB islands outperformed islands consisting of either just vegetation or just bivalves with regard to removal of nitrogen and phosphorus. The materials used for this study consisted of a 1.0 m wide x 1.0 m long x 1.1 m high polypropylene random copolymer (PPR) perforated substrate plate with sealed empty drinking bottles attached to the substrate to give it buoyancy. There were three zones to the artificial floating island. The top zone was the plant zone, followed by the middle zone consisting of a 30 cm cage for *Corbicula fluminea* (freshwater clam) and lastly a biofilm carrier in the lowest zone.

Table 1.6.1: Island Materials Used. Overview of the 27 artificial floating islands including the island size, frame material, substrate material, additional substrate added if any, and how the vegetation was planted on the artificial island (Modified from: Visser and Sasser, 2006).

Island Number	Island dimension (m)	Frame material	Initial substrate material	Additional substrate material	Form of vegetation initially planted on island (all maidencane)	Existed throughout study? (Y/N)
1	3 x 3	Pine	Rope		plugs	N
2	3 x 3	Pine	Jute	Hardwood mulch	plugs	N
3	1.2 x 3	PVC, pine	Straw, coconut fiber	Hardwood mulch	plugs	Y
4	3 x 3	Styrofoam, pine	Burlap	Hardwood mulch	plugs	N
5	3 x 3	PVC	Coconut fiber	Hardwood mulch	Plugs, fragments	Y
6	1.2 x 1.2	Pine	Birch	Hardwood mulch	plugs	Y
7	1.2 x 1.2	PVC	Coconut fiber	Hardwood mulch	plugs	Y
8	1.2 x 1.2	No frame	Burlap	Water-hyacinth	plugs	N
9	1.2 x 1.2	Styrofoam, pine	Coconut fiber	Hardwood mulch	plugs	N
10	1.2 x 1.2	Pine	Coconut fiber	Hardwood mulch	plugs	N
11	1.2 x 1.2	Pine	rope		plugs	N
12	1.2 x 1.2	Pine	Chicken wire		plugs	Y
13	1.2 x 1.2	PVC	Chicken-wire		plugs	Y
14	1.2 x 1.2	PVC	Chicken-wire	Peat, bagasse	fragments	Y
15	1.2 x 1.2	Cedar lattice	Coconut fiber		plugs	Y
16	1.2 x 1.2	Cedar lattice	Coconut fiber		plugs	Y
17	1.2 x 1.2	Cedar lattice	No substrate		plugs	Y
18	1.2 x 1.2	Cedar lattice	Coconut fiber		plugs	Y
19	1.2 x 1.2	Pine	Chicken-wire		Plugs, fragments	N
20	1.2 x 1.2	Pine	Birch	Peat, bagasse	Plugs, fragments	Y
21	1.2 x 1.2	Pine	Coconut fiber	Peat, bagasse	Plugs, fragments	Y
22	1.2 x 1.2	Bamboo	Chicken-wire		Plugs, fragments, rhizomes, stems	Y
23	1.2 x 1.2	Bamboo	Birch	Peat, bagasse	Plugs, fragments	Y
24	1.2 x 1.2	Bamboo	Coconut fiber	Peat, bagasse	Plugs, fragments, rhizomes, stems	Y
25	1.2 x 1.2	PVC	No substrate	Styrofoam	Peat pots	Y
26	1.2 x 3	PVC	Chicken-wire	peat	Peat pots	Y
27	1.2 x 3	PVC	Chicken-wire		fragments	Y

1.7. Artificial Floating Island Vegetation

Artificial floating islands differ from naturally occurring floating islands because larger emergent wetland plants can be utilized initially (Headley and Tanner, 2006; Hubbard, 2010). Larger emergent vegetation is not usually found initially on naturally occurring floating wetland islands because this type of vegetation lacks the necessary rhizomes and air sacs needed for sustained buoyancy. Without an established floating mat, the island could break apart. With the addition of an artificial substrate and buoyant frame, constructed floating wetland islands are able to utilize a greater variety of wetland vegetation from the beginning, which helps to gain more environmental benefits like attracting a broader range of wildlife. Plants chosen for the constructed floating island, similarly to constructed wetland plants, should be native, ecologically acceptable, tolerant of local climate conditions, and exhibit rapid establishment (Tanner, 1996; Kerr-Upal et al., 2000). To avoid potential problems such as blocking boater access, the introduction of non-native species into an environment should be avoided as this can facilitate unwanted expansion into the greater water body.

1.8. Artificial Floating Island Benefits

A few benefits that artificial floating islands provide include water purification, a decrease in plankton proliferation, habitat for fish and prawns, extra area for vegetation cover (Nakamura and Shimatani, 1993). Artificial floating islands were beneficial in water quality and habitat improvement (Headley and Tanner 2006). The many different applications of artificial floating islands include the treatment of stormwater runoff to remove glycol (Revitt et al., 1997). Islands minimize the effects from sewage overflow areas and sewage wastewater (Van Acker et al., 2005; Ash and Truong, 2003). They aid

in nutrient removal from swine wastewater lagoons (Hubbard et al., 2004). Islands can help the biomineralization of metals from acid mines (Smith and Kalin, 2000). Also, islands increase pollutant removal and resource recovery and improved pond treatment performance (Todd et al., 2003). Furthermore, Hoeger (1988) list many benefits provided by the Bestmann Green Systems™ Schwimmkampen artificial floating islands. The artificial islands can be used for shoreline protection, wildlife habitat, landscape aesthetics, water purification and filtration, biological disinfection, and added natural habitat in urban areas. Artificial floating islands are part of the ecological engineering trend since they are affordable, low maintenance, and can assist in pollution control and nutrient removal (Zhou and Wang, 2010).

One of the many demonstrated benefits of artificial floating islands is that the rafts have been used as bird nesting habitats and sanctuary in otherwise urban-encroached areas (Burgess and Hirons, 1992; Piper et al., 2002). Burgess and Hirons (1992) found that floating raft location and vegetated cover are important factors in the success of the nest. Piper et al. (2002) found that floating platforms without added vegetation suffice as nesting sites for *Gavia immer* (common loon), but these birds were first noticed nesting on floating mats of *Carex* spp. (sedge) and *Sphagnum* spp. by Mathisen (1969). Hancock (2000) found that the addition of artificial floating rafts increased the rate of chick production of the *Gavia stellata* by an estimated 44% in Scotland.

Zhu et al. (2011) found that floating island vegetation could be harvested to take excess N and P out of wastewater. Stewart et al. (2008) determined Biohaven® artificial floating islands could be used to reduce excess concentrations of ammonium, nitrate, and phosphate and would be an alternative to conventional treatment wetlands. Tanner and

Headley (2011) found that Biohaven® artificial floating islands were capable of the removal of Cu and Zn and speculated that that they islands were capable of removing particulate-bound metals although they did not specifically study this.

1.9. Purpose of Study and Research Questions

The purpose of this study was to determine if constructed floating wetland islands made from ‘natural’ materials would perform similarly to those islands made of ‘artificial’ materials. The benefit of constructing floating wetland islands out of ‘all natural’ materials is that it meets the ‘environmentally sensitive’ material requirement for floating wetland islands (Kerr-Upal et al., 2000) that other materials like plastic or Styrofoam may not meet.

To examine how the use of different materials in the construction of floating wetland islands affect island success, I conducted an experiment in a shallow, urban, eutrophic lake to compare the durability of constructed floating islands built of natural Bamboo with those built of Polyvinyl chloride (PVC). Both island types were planted with Florida native wetland species. For each substrate type, I examined changes in percent cover of plant species, plant growth patterns, root mass accumulation, and substrate durability over an eight-month period. Plants were harvested at the end of the study to determine plant biomass, and plant roots and shoots were analyzed for phosphorus, nitrogen, and carbon content.

The first goal of the research study was to analyze plant growth characteristics after being transplanted to the CFWIs to determine which constructed floating wetland island raft (Bamboo or PVC) would support the most plant growth. Bamboo and PVC are

both buoyant materials and should be functional as CFWI frames (Visser et al., 2006). I did not think substrate material would make a difference in plant growth characteristics. I assumed as long as the CFWI remained buoyant and the frame held together, the plants would grow and establish a root mat regardless of the island materials. A second research question was which species will have the highest increase in percent cover through the study. No studies have documented percent cover increase on a CFWI for the specific species examined in this experiment. The species chosen for this study were *Pontederia cordata* (pickerelweed), *Schoenoplectus tabernaemontani* (bulrush), *Canna flaccida* (golden canna), and *Sagittaria lancifolia* (duck potato). I thought that *Pontederia cordata* would outcompete the other species due to the personal observation of the vigor the plant demonstrates on the lakeshore. A third research question was whether the same plant categories were found in the same distributions on each CFWI substrate. Since species tend to exist in similar quantities on established natural tussock islands as they do on shore (Alam, et al., 1996), I did not think that island substrate would make a difference in plant composition for each CFWI type. I did think plant morphology and growth characteristics would, however, influence CFWI species composition.

A second goal of the research study was to determine if weight differences in island type would influence other island characteristics such as plant percent cover and island durability. The main focus in the literature is that the island must remain buoyant, and weight seems arbitrary as long as buoyancy is achieved (Kerr-Upal et al., 2000). The research question was whether island weight makes a difference in plant percent cover and island durability. I did not think island weight would cause a difference in plant growth or island durability over the course of the study.

A third goal of the research study was to determine if island type would influence plant nutrient accumulation. Since many experiments have been conducted to determine if artificial floating islands were conducive to nutrient remediation techniques (Hubbard et al., 2004; Stewart et al. 2008; Zhu et al., 2011), I felt it important to determine if raft materials influence plant nutrient content. The research question was whether plant nutrients vary based on island type or by plant category such as emergent or floating aquatic vegetation. I did not think plant nutrients would be different on the two island types, but would rather be different from each other based on biological plant characteristics.

The last goal of the research study was to compare islands constructed from synthetic-based materials with those made from natural materials. The purpose was to determine which constructed floating wetland island (CFWI) raft would prove more durable over the eight-month time frame. There have not been many published studies comparing CFWI 'all natural' vs. 'all artificial' materials against one another, but Visser et al. (2006) did compare similar materials and demonstrate that both PVC and Bamboo frames do not degrade after eight-months in an aquatic environment. I thought the PVC islands would be more durable over the course of the study than the Bamboo islands. The PVC islands were constructed completely from plastic materials, which do not readily disintegrate in an aqueous environment. Although I thought the Bamboo frame would remain buoyant throughout the study, I assumed the substrate material would decompose after the plants had established a self-sustaining root mat. The Bamboo islands were meant to eventually degrade over time after the vegetation had established a self-sustaining root mat.

2. Methods

2.1. Study Site

PVC and Bamboo floating wetland islands were placed in an urban eutrophic lake in southwest Florida. Although these islands could have been placed in any number of urban eutrophic lake environments, the specific study site was chosen based on location and familiarity. Crescent Lake, is a 7.85 ha urban lake located in St. Petersburg, Florida (N27° 47.23’, W82° 38.28'). Crescent Lake waters flow into Coffee Pot Bayou before draining into Tampa Bay. The lake is surrounded by Crescent Lake Park, which includes a playground, dog park, and running track. Crescent Lake receives storm-water runoff from a large urban watershed area approximately 10 times the size of the lake (Dunathan, 2009; Figure 2.1.1a). Since there was little shoreline vegetation to remediate the runoff of nutrients from the surrounding watershed, a lake restoration project was initiated in April 2007 to create wetland habitats to help restore the lake to ecological and environmental health (Farlow, 2007). This project was funded through a grant from the Tampa Bay Estuary Program. All plants used in this study came from the study area and were transplanted to the islands. Vegetation at the study site included *Pontederia cordata* (pickerelweed), *Canna flaccida* (golden canna), *Schoenoplectus tabernaemontani* (bulrush), *Ludwigia grandiflora* (ludwigia), *Sagittaria lancifolia* (duck potato), *Colocasia esculenta* (wild taro), *Cyperus odoratus* (flat sedge), and others (Table 2.5.1).

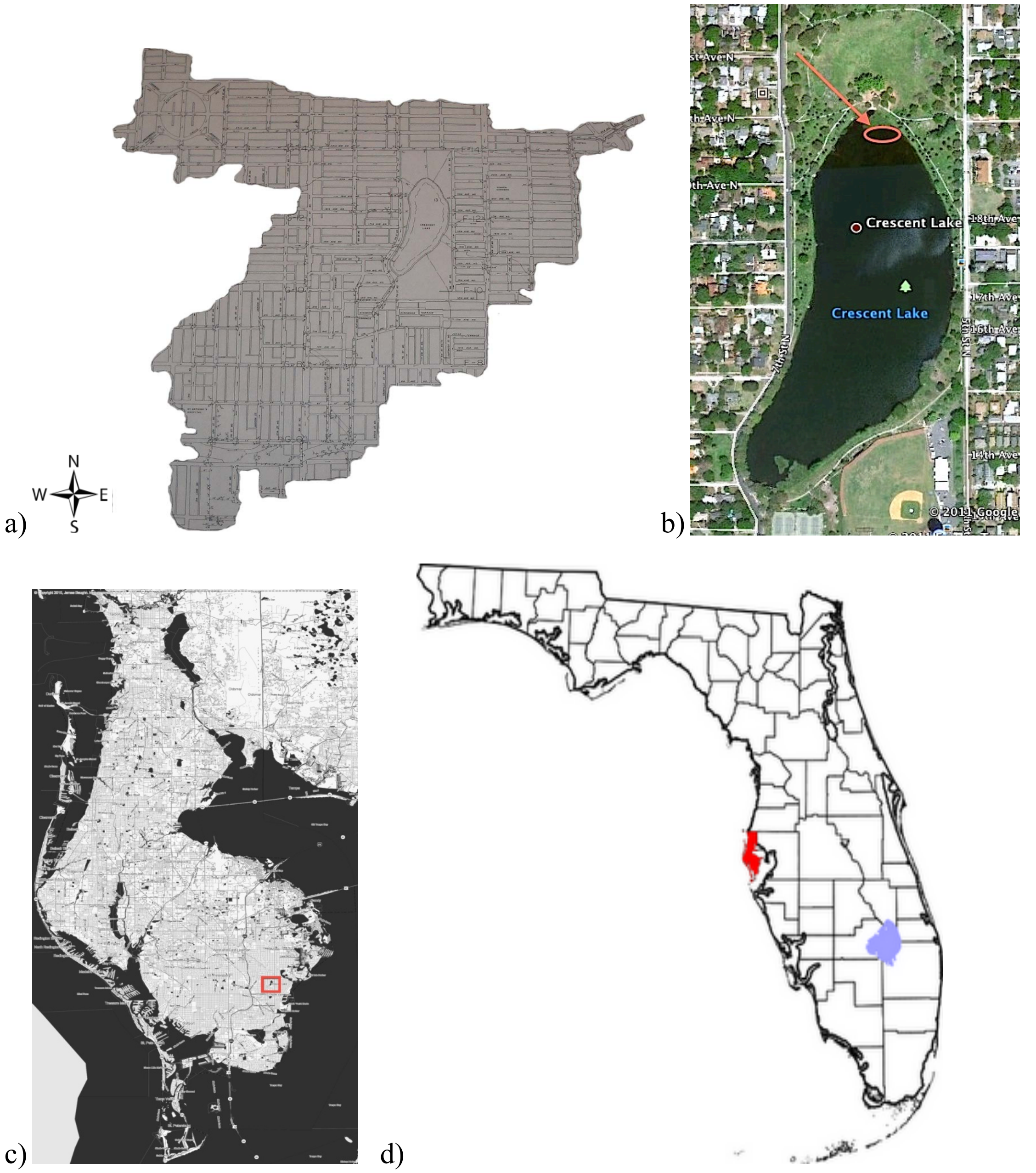


Figure 2.1.1: Crescent Lake study site. a) Crescent Lake Watershed Basin (Dunathan, 2009). b) Satellite image of Crescent Lake (Google Earth) showing study site in red c) Map of Pinellas County highlighting the Crescent lake Watershed Basin. d) Pinellas County, FL shown in red.

2.2. Pilot Study

A pilot study was completed in April 2010 to test island viability. One of each island (Bamboo and PVC) was created and deployed at the study site. After two weeks, eight Bamboo and four PVC islands were positioned at the study site and planted with

native vegetation (Sections *2.3. Island Design* and *2.4. Plants*). The islands were secured using two meter lengths of polypropylene rope attached at two opposite corners of the island to allow for lake volume increase of about a meter throughout the study. The ends of the rope were weighted by 10-15 lb sandbags and were placed approximately three meters from one another (Figure 2.2.1).

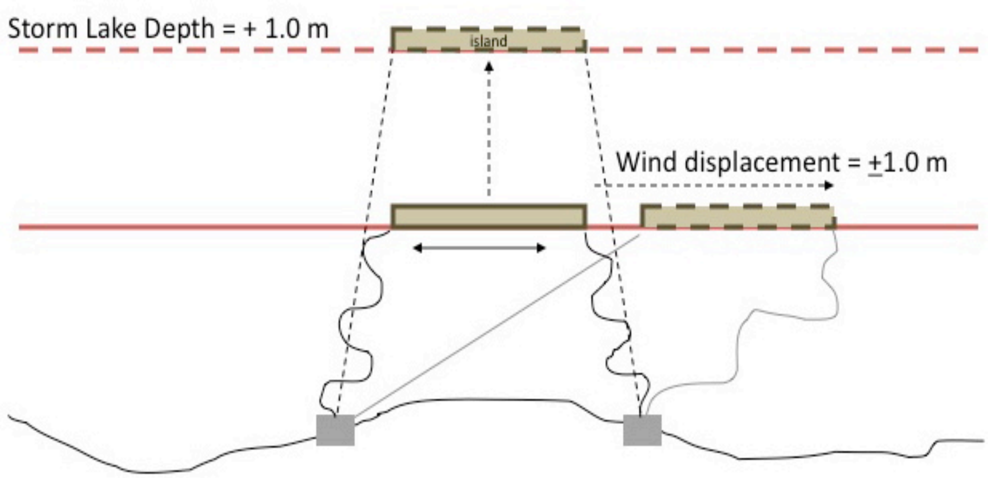


Figure 2.2.1: Island design of compensation for wind displacement and water level rise. Normal mean water death at the study site was 1 m.

2.3. Island Design

Two types of island substrates were used to create natural and synthetic-based constructed floating wetland island (CFWI) substrates. Eight natural Bamboo islands were constructed using Bamboo and natural rope material including hemp, sisal, canvas, and burlap fibers. The natural fibers consisted of a 48 lb. hemp cord and an 8.0 lb. sisal binder twine. The Bamboo poles ranged from 5 cm to 10 cm in diameter, and were cut to

1.2 m. Two layers of burlap were used initially for the substrate in a preliminary experiment, but they disintegrated after one month in the lake (Table 2.3.1). Each Bamboo island was approximately 1 m^2 in area with a 0.25 m^2 opening in the center of the island (Figure 2.3.1a). This area of open water allows for ease of sampling biomass from under each island. Bamboo is a naturally buoyant material and does not require any addition material to promote buoyancy. Flags were placed on each island for identification purposes and labeled accordingly. Birds and wildlife were not excluded from any of the islands.

The second type of CFWI was a completely synthetic island consisting of 1.5 inch PVC pipe, gutter mesh or DuPont 7' x 100' Wildlife Netting, zip ties, and closed cell polyethylene foam cylinders for buoyancy. The PVC islands were constructed in much the same way as the Bamboo islands. Each PVC pipe was cut to a meter in length and formed the perimeter of the island, while a 0.25m hole was left in the middle of the island for ease of sampling. PVC elbows were used to attach each pipe at the corners. Gutter mesh or wildlife netting covered the inside of the island for island substrate. Zip ties were used to secure the gutter mesh to the island perimeter (Figure 2.3.1b). The PVC islands required the addition of foam pipe insulation around the perimeter of each island to insure proper buoyancy. A total of seven PVC islands were constructed. Four PVC islands were constructed and deployed in early April 2010 (PVC 1-4), and the other three were deployed in mid May 2010 (Table 2.3.1) (PVC 5-7).

The other three PVC islands were also used in a different experimental study, as well as this study. The purpose of the second experimental study was to determine the effect of floating wetland islands on lake water quality. The plant species *Pontederia*

cordata (pickerelweed), *Schoenoplectus tabernaemontani* (bulrush), and *Sagittaria lancifolia* (duck potato) were transplanted to these islands. After being placed in an aquatic enclosure, these islands received a nutrient additive in the form of Miracle-Gro® Water Soluble Tomato Plant Food in a 18-18-21 (N:P:K) ratio on October 4, 2010 (Jangrell-Bratli, 2011) (Table 2.3.1). The aquatic enclosure was a cylinder made from plastic that floated on the waters surface and was anchored into the lake bottom. A splashguard made from landscape edging was added to the top of the aquatic enclosure to prevent lake water from splashing over the rim of the enclosure. The islands PVC 5-7 are used in this study to examine percent cover, island weights and biomass but not nutrients.

a) b)

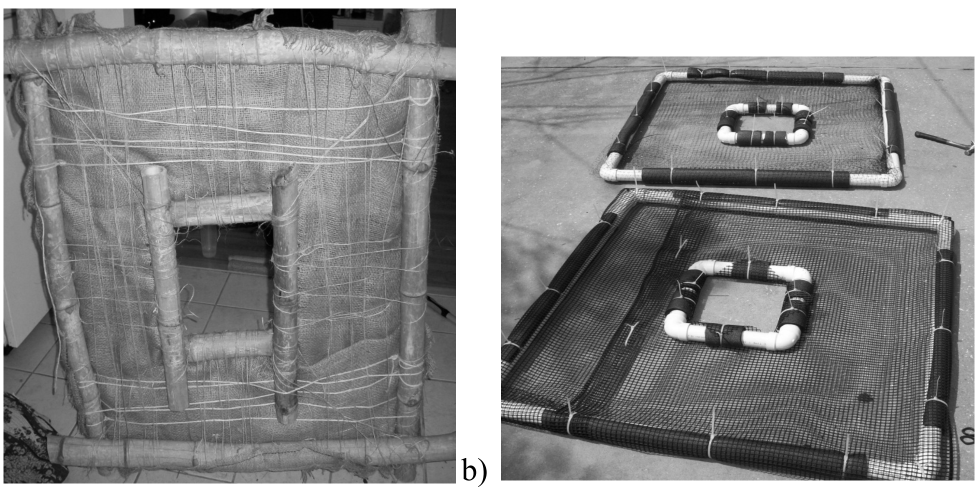


Figure 2.3.1: Island construction. a) Bamboo island construction with initial burlap substrate and sisal rope lashing. b) PVC island construction with gutter mesh, zip ties, and foam pipe insulation for flotation.

Table 2.3.1: CFWI raft type, deployment date, retrieval date, and treatments. The islands PVC 5-7 are used in this study to look at only percent cover, island weights and biomass (not nutrients).

Island Number	Initial Materials	Launch Date	Replant Date and Materials	Nutrient Treatment (October 4, 2010)	End Date
Bamboo 1	Bamboo, burlap, hemp and sisal	Apr-10	May 2010 Sisal Rope	N/A	Dec-4
Bamboo 2	Bamboo, burlap, hemp and sisal	Apr-10	N/A	N/A	Dec-4
Bamboo 3	Bamboo, burlap, hemp and sisal	Apr-10	N/A	N/A	Dec-4
Bamboo 4	Bamboo, burlap, hemp and sisal	Apr-10	May 2010 Sisal Rope	N/A	Dec-4
Bamboo 5	Bamboo, burlap, hemp and sisal	Apr-10	May 2010 Canvas	N/A	Dec-4
Bamboo 6	Bamboo, burlap, hemp and sisal	Apr-10	May 2010 Canvas	N/A	Dec-4
Bamboo 7	Bamboo, burlap, hemp and sisal	Apr-10	May 2010 Canvas	N/A	Dec-4
Bamboo 8	Bamboo, burlap, hemp and sisal	Apr-10	May 2010 Sisal Rope	N/A	Dec-4
PVC 1	PVC, wildlife netting, closed cell polyethylene foam cylinders, zipties	Apr-10	N/A	N/A	Dec-4
PVC 2	PVC, gutter mesh, closed cell polyethylene foam cylinders	Apr-10	N/A	N/A	Dec-4
PVC 3	PVC, wildlife netting, closed cell polyethylene foam cylinders, zipties	Apr-10	N/A	N/A	Dec-4
PVC 4	PVC, gutter mesh, closed cell polyethylene foam cylinders	Apr-10	N/A	N/A	Dec-4
PVC 5	PVC, wildlife netting, closed cell polyethylene foam cylinders, zipties	May-10	N/A	Miracle-Gro® Water Soluble Tomato Plant Food in a 18-18-21 (N:P:K) ratio (Jangrell-Bratli, 2011).	Dec-4
PVC 6	PVC, wildlife netting, closed cell polyethylene foam cylinders, zipties	May-10	N/A	Miracle-Gro® Water Soluble Tomato Plant Food in a 18-18-21 (N:P:K) ratio (Jangrell-Bratli, 2011).	Dec-4
PVC 7	PVC, wildlife netting, closed cell polyethylene foam cylinders, zipties	May-10	N/A	Miracle-Gro® Water Soluble Tomato Plant Food in a 18-18-21 (N:P:K) ratio (Jangrell-Bratli, 2011).	Dec-4

2.4. Plants

Five adult plants of each species, pickerelweed, bulrush, and canna for n= total of 12 islands x 3 species x 5 plants per species = 180 plants, were transplanted from the lake bank to each island in April 2010. In May 2010 the other three PVC islands were transplanted with pickerelweed, bulrush, and duck potato, for n= total of 3 islands x 3 species x 5 plants per species = 45 plants. The initial shoots of pickerelweed and canna ranged from 30-60 cm tall. The initial shoots of bulrush ranged from 90-100 cm tall. The initial total root mat for all covered less than 10% of the total island area, while the estimated percent shoot cover ranged from <1%-35% across all islands per species. The plants were secured to the natural island by poking 3-5cm holes in the burlap and then fitting part of the root into the burlap hole. The adult plants were secured to the artificial substrate islands by entangling the roots into and through the mesh (Figure 2.4). After six weeks, Bamboo islands Bamboo 1, Bamboo 4, Bamboo 5, Bamboo 6, Bamboo 7, and Bamboo 8 were replanted with another stock of pickerelweed, bulrush, canna, and duck potato on May 27, 2010 because lack of significant growth at this time on these islands attributed to island substrate failure (Table 2.3.1). The plant stock for the second transplant were much more hardy than the first, with two to three times the rootstock and shoot mass.

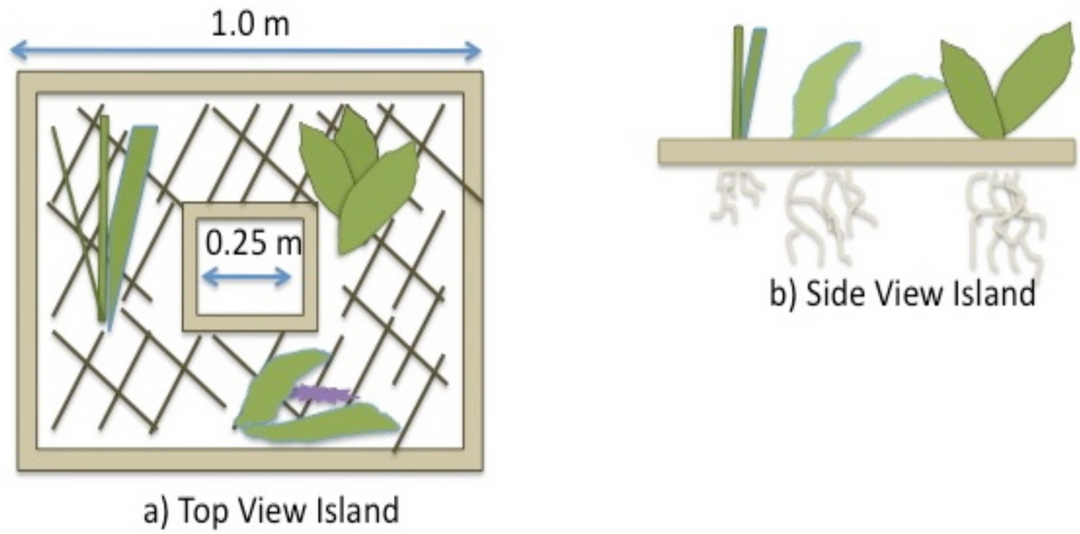


Figure 2.4.1: Island top and side view. a. Top view of island with vegetation b. Side view of island with vegetation

Figure 2.4.2: Initial transplant of *Pontederia cordata, Schoenoplectus tabernaemontani*, *Canna flaccida* on each island substrate type.

2.5 Island Placement

Islands were placed at the study site in a haphazard manner within the boundaries of the previous wetland restoration project at the north end of the lake. All islands were within 1.5 m depth of water to allow for easy sampling access. The islands were grouped by site placement and analyzed with a Fit Model in JMP® to determine if there was an influence from wind and wave on island success. The islands were grouped into lakeward islands (PVC 3 and 4, Bamboo 3-8) or landward islands (PVC 1 and 2, PVC 5-7, Bamboo 1 and 2), by north islands (PVC 3 and 4, Bamboo 1, 2, 3, 5) or south islands (PVC 1 and 2, PVC 5-7, Bamboo 4, 6, 7, 8) and by enclosed (PVC 5-7) or open islands (PVC 1-4, Bamboo 1-8).

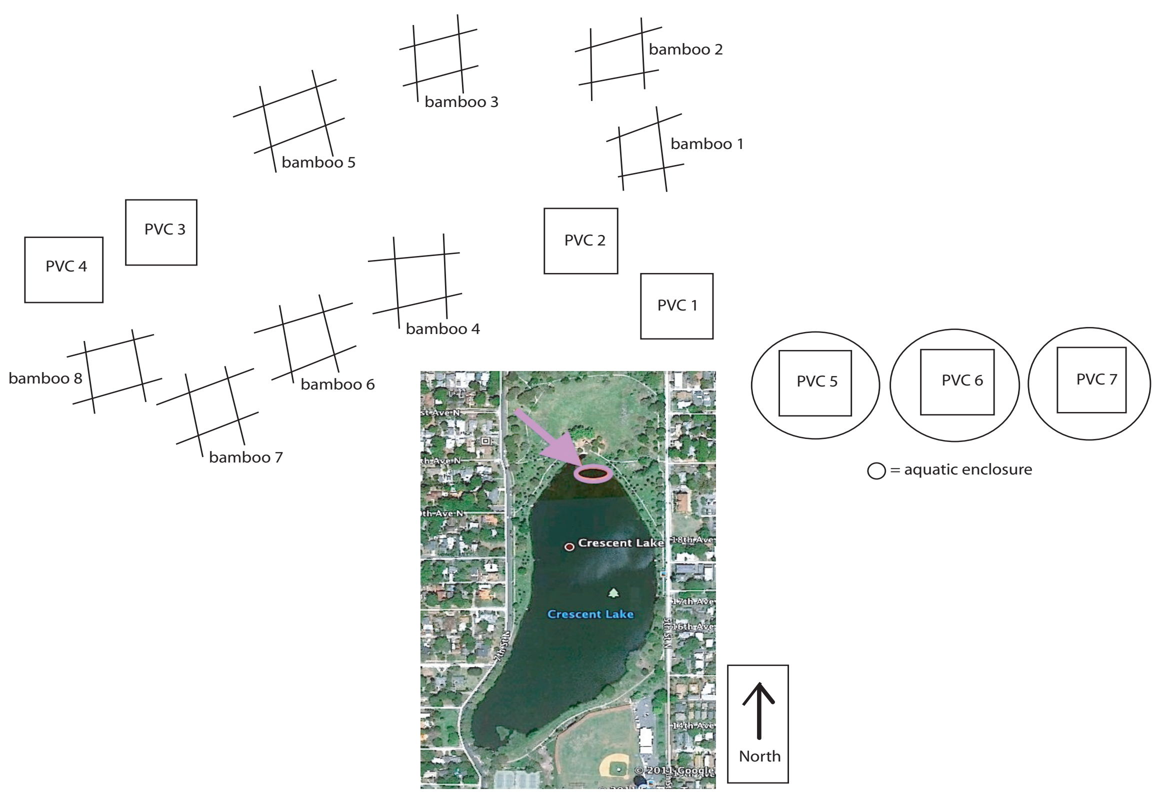


Figure 2.5.1: Map of island placement at study site

2.6. Cover class and biomass estimates

Percent cover was measured on a bi-weekly basis using the Braun-Blanquet cover class method (Table 2.6.1 in red) for both roots and shoots in the field and reaffirmed with photographs taken from the same day. Maximum root and shoot lengths were measured from the tip of the longest living root or living shoot to the substrate base. The time, date, temperature, weather, winds, water depth, cover class, and photograph of the island were all recorded. Presence and abundance of other colonizing species were noted during each sampling interval. Debris and algal cover were also estimated using a grid pattern of the island where each square represented 1% of total cover (Table 2.6.1 in blue). Total percent cover for all floating islands is the amount of island substrate covered on a two dimensional plane. Total cover includes all plants, debris, algae, and trash found on the island. Total cover is essentially a two dimensional aerial view of the island. Percent cover is represented as total absolute percent cover and total relative percent cover. Total absolute percent cover for all floating islands is the amount of island substrate covered on a two dimensional plane. Total absolute percent cover includes all plants, debris, algae, and trash found on the island. It is a top-down view of the island.

Table 2.6.1: Field log with percent cover grid graphic.

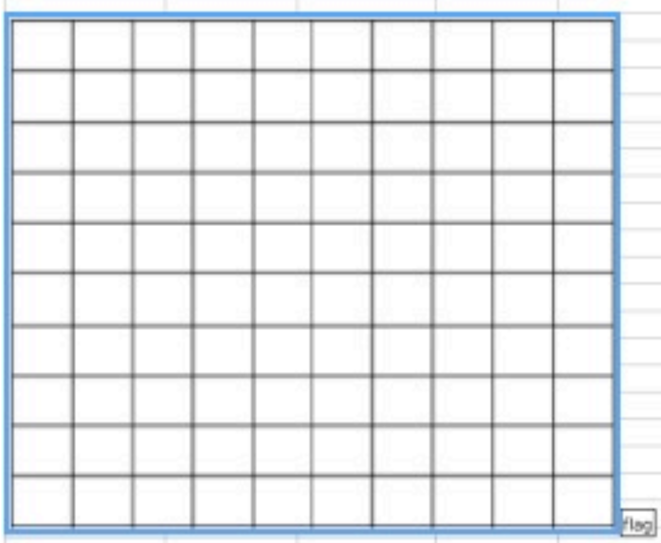
Date		By:			
Island#					
Temperature	°C	Time	0:00		
Weather	Sunny	Ptly Cldy	Cloudy	Rain	Total (in)
Water Depth					
Wind (mph)	0 to 5	6 to 10	11 to 15	16 to 20	

Braun-Blanquet Cover Class	
Cover	Class
Not Present	0
<1	*
1 to 5	1
6 to 25	2
26 to 50	3
51 to 75	4
76 to 95	5
96 to 100	6

Observations:

Species	CC	Root CC	Longest Root	Longest Shoot
Pontederia cordata				
Canna flaccida				
S. tabernaemontani				
Sagittaria lancifolia				

Temperature of samples prior to storage	°C
Temperature of freezer prior to storage	°C
Time placed in freezer	



Notes:

Photograph:					
Comments:					
Wildlife					

For islands PVC 5-PVC 7, total absolute percent cover is distinguished between treatments. On October 4, 2010 these floating islands were spiked with nitrogen and phosphorus (Jangrell-Bratli, 2011) (Table 2.3.1). A Kruskal-Wallis statistical test was performed in Microsoft® Excel on the total percent cover above the floating islands to determine if the treatment was significant at an alpha of 0.05 on total percent cover.

To obtain an estimate of the relative percent cover for each island, plants were grouped into three categories: Emergent, Floating Aquatic Vegetation (FAV), and Algae (Table 2.6.3). The Kruskal-Wallis statistical test was used to determine if there was any variation between categories with regard to above ground percent cover for every island (Table 3.1.1).

After root cover class was established using the Braun-Blanquet cover class method, the median number for each cover class range was analyzed using a Kruskal-Wallis test to determine if the median percents for each cover class range were significant with regards to all islands and plant categories (Table 2.6.2).

Table 2.6.2: Root midpoints used for each range to determine statistical significance between island groups.

Cover Class number	Equivalent percent cover (%)	Midpoint of range (%)
0	0	0
1	1-5	3
2	6-25	15.5
3	26-50	38
4	51-75	63
5	76-95	85.5
6	96-100	98

Table 2.6.3: Relative percent cover categories

Islands	Emergent Vegetation	Floating aquatic vegetation	Algae
PVC 1-PVC 4	*Pontederia cordata* (pickerelweed), *Canna flaccida* (golden canna), *Schoenoplectus tabernaemontani* (bulrush), *Ludwigia grandiflora* (ludwigia) and *Colocasia esculenta* (wild taro)	*Lemna spp.* (duckweed) *Pistia stratiotes* (water lettuce), *Limnobium spongia* (Frog's bit), *Hydrocotyle umbellata* (penny wort)	all types of algae found on the floating islands
PVC 5-PVC 7	*Pontederia cordata* (pickerelweed), *Sagittaria lancifolia* (duck potato), *Schoenoplectus tabernaemontani* (bulrush), *Ludwigia grandiflora* (ludwigia) and *Colocasia esculenta* (wild taro)	*Lemna spp.* (duckweed) *Pistia stratiotes* (water lettuce), *Limnobium spongia* (Frog's bit), *Hydrocotyle umbellata* (penny wort)	all types of algae found on the floating islands
Bamboo 1-Bamboo 8	*Pontederia cordata* (pickerelweed), *Canna flaccida* (golden canna), *Schoenoplectus tabernaemontani* (bulrush), *Ludwigia grandiflora* (ludwigia), *Colocasia esculenta* (wild taro), *Compositae* spp., and *Cyperus odoratus* (flatsedge)	*Lemna spp.* (duckweed) *Pistia stratiotes* (water lettuce), *Limnobium spongia* (Frog's bit), *Hydrocotyle umbellata* (penny wort)	all types of algae found on the floating islands

2.7. Island Weights

Islands were weighed as a whole (all organic and nonorganic components) in the field to measure weight fluctuations over time. This process was repeated three times for each island every other week from July 2010 to December 2010 and the three weights were averaged. An American Weigh H-110 Digital Hanging Scale was used along with an island 'basket' to capture island wet-weight (Figure 2.7.1). The dimensions of the island 'basket' were 1 m^2 with a seine net material attached to PVC perimeter with zip ties. Wench straps were attached at corners of the 'basket' to connect with other straps attached to the scale. The basket was placed underneath the entire island and then raised with straps to attain island weight (Figure 2.7.1c). Weight included all plant biomass, debris, island frame, substrate material, and water weight.

The mean CFWI weights represented for June 26, August 19, October 26 and December 4 are total weights including all plant biomass, debris, island frame, substrate material, and water weight. To get a mean weight for the artificial islands and an average weight

for the natural islands for each sampling date, all individual island weights were averaged together per island type.

The coefficient of variation was taken for groups of islands to determine if one group consistently had a higher or lower weight gain than the other groups. The Kruskal Wallace statistical test was used to determine if there was any significant difference with regard to floating island weight medians.

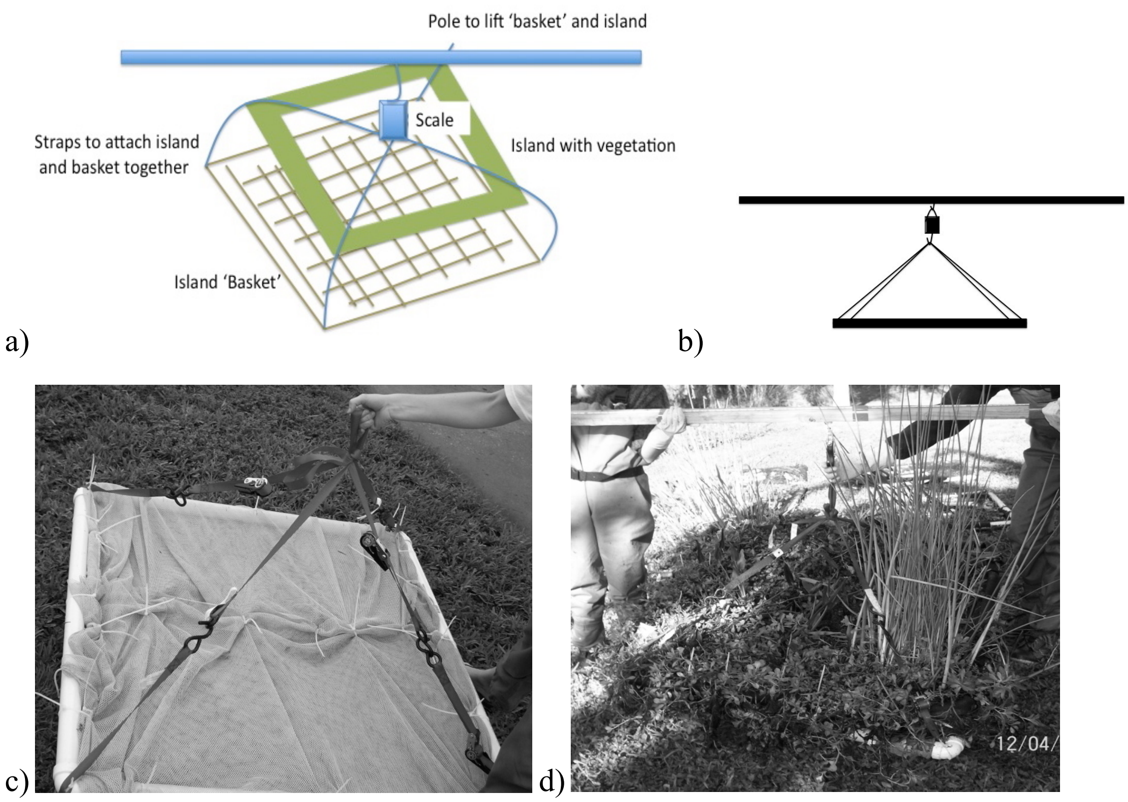


Figure 2.7.1: Island 'basket'. a) Diagram of island 'basket' used to weigh entire wet weight of island including vegetation b) Side view diagram of island basket c) Island basket with PVC frame, zip ties, seine netting, and wench straps. d) Island basket in use. The basket slides under the floating island and is lifted to obtain floating island weight.

2.8. Dry Biomass

After the end of the experiment, plants were separated from the substrate and harvested by species shoots and root quadrants into brown paper bags (Figure 2.8.1). Only viable island biomass was harvested on December 4, 2010 to be oven dried. Viable was defined as having enough island substrate with plants that were able to be weighed and tested. This did not include algae. Viable islands included islands PVC 1-PVC 7, Bamboo 1, Bamboo 2, and Bamboo 4. All other islands (Bamboo 3, Bamboo 5, Bamboo 6, Bamboo 7, and Bamboo 8) lacked substrate and/or plant biomass. Total percent cover was reflected until 12/4/10 for the viable islands and 10/26/10 for the other islands. Root quadrants were used since roots were entangled and had formed a root mat and roots by species could not be separated (Figure 2.8.1). After a brown bag wet weight was established for the total biomass the biomass was allowed to air dry for approximately two weeks before being oven-dried at temperatures between 60 ºC and 70 ºC for at least 48hours to establish a constant dry weight (Visser et al., 2005). After biomass was oven dried, it was placed in resealable storage bags to prevent moisture and weighed to obtain the final dry biomass for each species and root quadrant for each island.

a)  b) 

Figure 2.8.1: Biomass harvested. a) Biomass harvested from islands and placed into labeled brown bags by species and root quadrant. b) Entangled root mat. This is why roots were separated by quadrant instead of species.

2.9. Nutrient Analyses

Subsamples were taken from each dried biomass resealable storage bag and ground in a coffee grinder to obtain a representative homogenous blend of each larger sample (Figure 2.9.1). Sub amples were then weighed and approximately 1 gram was placed in a scintillation vial to be analyzed for percent nitrogen, phosphorus, and carbon at the University of Florida Department of Geological Sciences Stable Isotope Mass Spec. lab by Dr. Jason Curtis and William Kenney. For total carbon and total nitrogen, samples were loaded into tin capsules and placed in a 50-position automated Zero Blank sample carousel on a Carlo Erba NPVC 1500 CN elemental analyzer. After flash combustion in a quartz column containing chromium oxide and silvered cobaltous/cobaltic oxide at 1000°C in an oxygen-rich atmosphere, the sample gas was transported in a He carrier stream and passed through a hot reduction column (650°C) consisting of reduced elemental copper to remove oxygen. The effluent stream then passed through a chemical (magnesium perchlorate) trap to remove water. The stream then passed through a 3 meter gas chromatographic column at 55°C that separated the N_2 and CO_2 gases. Finally the gases passed through a thermal conductivity detector that measured the size of the pulses of N_2 and CO_2. Samples for TP (ca. 50 mg) were digested in 20 ml 5.0% sulfuric acid and 10 ml 5.0% potassium persulfate in an autoclave for 20 minutes. Then, samples analyzed for soluble reactive phosphorus after being neutralized with sodium hydroxide and soluble reactive phosphorus was measured with an auto analyzer (Schelske et al.,1986; Kenney et al., 2010).

Percent nitrogen, carbon, and phosphorus were obtained for natural islands Bamboo 1, Bamboo 2, Bamboo 4 and artificial islands PVC 1, PVC 2, PVC 3, PVC 4.

Other islands, PVC 5, PVC 6, and PVC 7 were excluded from nutrient analyses for this study because these islands received added nutrients (Jangrell-Bratli, 2011). Islands Bamboo 3, Bamboo 5, Bamboo 6, Bamboo 7, and Bamboo 8 were not harvested and did not have nutrient analyses run.

Nutrients were compared for different island substrate types (PVC and Bamboo islands) and each plant species biomass after the December 2010 biomass harvest. Only plant species that existed at the time of harvest were tested for nutrients.

Figure 2.9.1: Dry biomass subsample ground a coffee grinder then placed in a scintillation vial.

2.10. Floating Wetland Island Groups

Floating wetland islands were grouped into classes. Islands PVC 1-PVC 4 did not receive fertilization and remained open throughout the study (PVC open). Islands PVC 5-PVC 7 did receive fertilization and were enclosed with an aquatic enclosure (PVC enclosed) (Jangrell-Bratli, 2011). Islands Bamboo 1, 2 and 4 were the harvested Bamboo

islands and remained open throughout the study (Bamboo harvested), and Bamboo 3, 5-8 were the unharvested islands and remained open throughout the study (Bamboo unsuccessful).

3. Results

3.1. Top (Shoot, Algae, FAV, Debris) Cover by Island Type

Significant differences in percent cover were measured within island group PVC 1-4 (n = 64; DF = 15; Kruskal-Wallis: $X^2 = 26.42$; p = 0.034). Mean percent cover of PVC 1 (76%) was significantly greater than the other islands, which averaged 54% (Figure 3.1.1). PVC 1 was covered by algae and debris consistently during the study, and percent cover did not vary below 60% (Figure 3.1.1). PVC 1 had the only significant trend in percent cover growth out of all the other islands in this group ($y = 0.107x - 4091.2$, $R^2 = 0.35$) (n = 16; DF = 15; F = 7.53; p = 0.017) (Figure 3.1.1). There was a large variation in percent cover between PVC islands 2-4 (Section 3.2). Significant seasonal differences in percent cover were measured within island group PVC 1-4 (n = 24; DF = 5; Kruskal-Wallis: $X^2 = 12.88$; p = 0.025). The mean percent cover increased from 58% to 75% (Figure 3.1.5) by the conclusion of the study. PVC 1-4 ended with the third largest percent cover out of all island groups (Figure 3.1.5), which resulted from the early loss of emergent vegetation and subsequent growth of FAV and algae and an increase in debris (see Section 3.2).

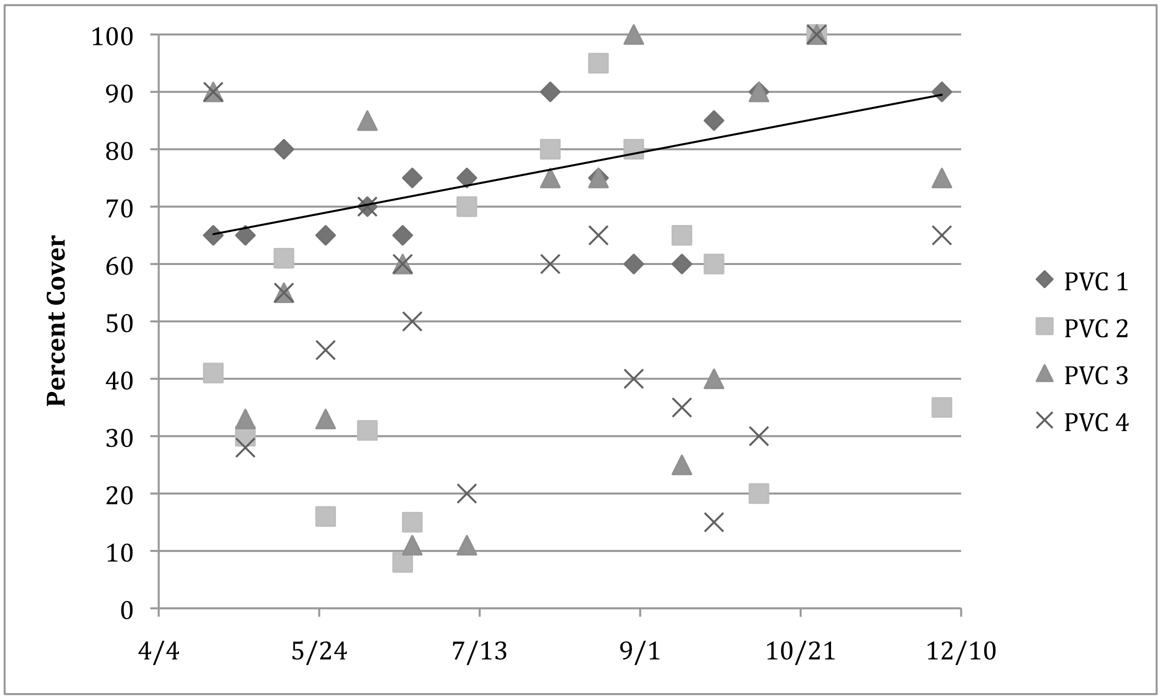


Figure 3.1.1: Percent cover of untreated PVC island group 1-4. PVC 1 shows a significant upward trend in percent cover.

Significant differences in seasonal percent cover were measured within treated island group PVC 5-7 (n = 18; DF = 5; Kruskal-Wallis: $X^2 = 16.09$; p = 0.007). Mean percent cover of PVC 5-7 was 76% in the beginning of the study and 100% by the end (Figure 3.1.2). The increase in percent cover through time is attributed to emergent plant growth (Section 3.2). The mean percent cover for treated PVC islands overall ranged from 83% - 85% for the entire study (Figure 3.1.2). Island group 5-7 reached 100% cover in September before nutrient treatment in October (Figure 3.1.2), and only PVC 7 showed a significant trend in percent cover prior to treatment (PVC 7: $y = 0.1837x - 7067$, $R^2 = 0.53$) (n = 12; DF = 11; F = 7.20; p = 0.019) (Figure 3.1.2). Island group PVC 5-7 attained 100% cover faster than any other island group (Figure 3.1.5) due to the greater initial transplanted biomass stock to these islands (Section 4.1).

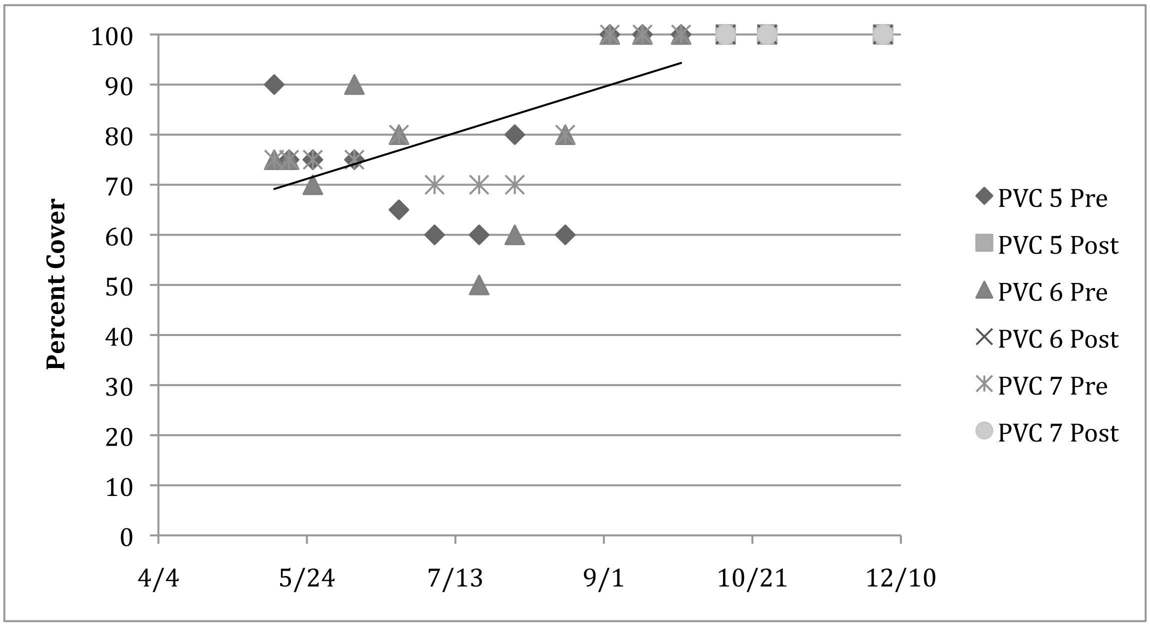


Figure 3.1.2: Percent cover for treated PVC island group 5-7 showing pre and post treatment percent covers. The islands reached 100% cover prior to the nutrient treatment in October.

Significant differences in percent cover were measured within harvested Bamboo islands 1,2,4 ($n = 47$; $DF = 16$; Kruskal-Wallis $X^2 = 23.62$; $p < 0.000$). Bamboo 2 had the highest mean percent cover out of the group (89%), followed by Bamboo 1 (72%) and Bamboo 4 with the lowest mean percent cover (32%) (Figure 3.1.3). Bamboo 2 was colonized quickly by ludwigia and flat sedge, which accounted for the most of the 100% cover (Section 3.2). There was a significant increase in percent cover after the replant for Bamboo 1 (Bamboo 1 post: $y = 0.2173x - 8381.8$, $R^2 = 0.44$) ($n = 12$; $DF = 11$; $F = 8.01$; $p = 0.019$) (Figure 3.1.3). The same positive trend was not observed on Bamboo 4 even though this island received a similar replanting but there was a significant decrease in percent cover before the replant (Bamboo 4 pre: $y = -1.1853x + 46072$, $R^2 = 0.91$) ($n = 4$; $DF = 3$; $F = 19.46$; $p = 0.047$) (Figure 3.1.3). There was a significant positive trend in percent cover without a replant on Bamboo 2 (Bamboo 2: $y = 0.1775x - 6819.5$, $R^2 =$

0.35) (n = 15; DF = 14; F = 6.86; p = 0.023) and this island reached 100% cover in September. Complete cover persisted through the remainder of the study (Figure 3.1.3). This group had the second highest percent cover throughout the study (64%) behind group PVC 5-7 (84%) (Figure 3.1.5).

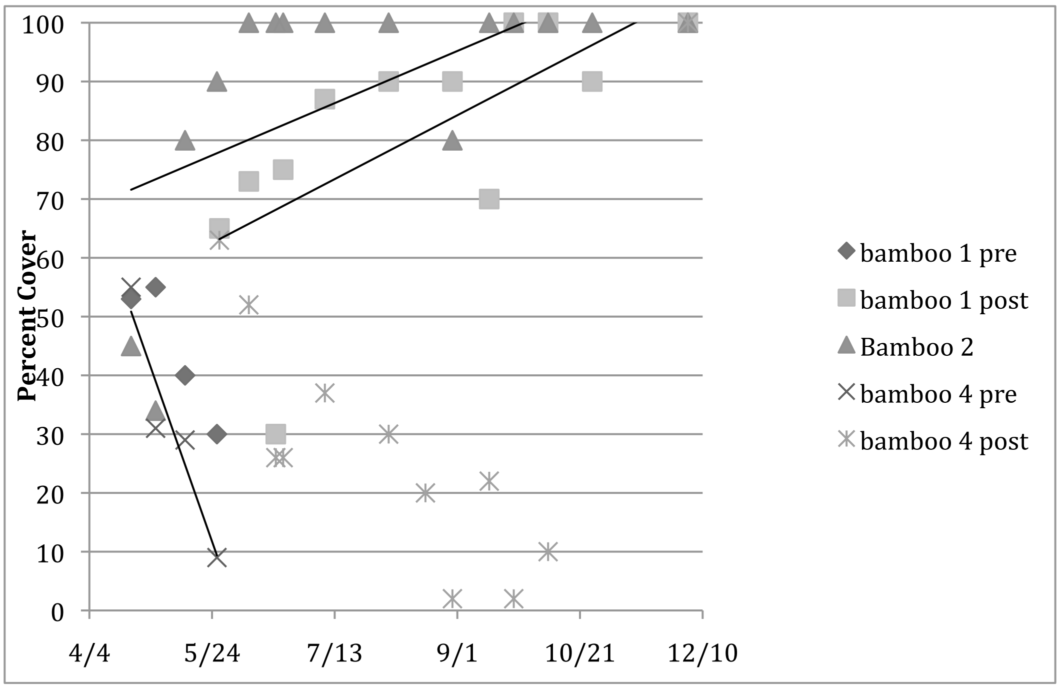


Figure 3.1.3: Percent cover for successful Bamboo islands 1,2,4.

Significant differences were measured within Bamboo island group 3, 5-8 (n = 79; DF = 15; Kruskal-Wallis: X2 = 20.77; p < 0.000). Percent cover for Bamboo island group 3, 5-8 ranged from 0% to 100% with only a general decreasing trend in common, with the exception of Bamboo 5 (Figure 3.1.4). Bamboo 5 was the only island in this group to demonstrate a positive trend in total percent cover after the replant (Bamboo 5: $y = 0.247x - 9551.4$, $R^2 = 0.43$) (n = 12; DF = 11; F = 7.58; p = 0.021) (Figure 3.1.4) mostly from algae and debris (Section 3.2). Bamboo 6 and 7 exhibited decreasing percent

cover trends prior to the replant (Bamboo 6: $y = -1.0459x + 40642$, $R^2 = 0.97$, $n = 4$, $DF = 3$, $F = 58.79$, $p = 0.017$; Bamboo 7: $y = -0.7761x + 30181$, $R^2 = 0.94$, $n = 4$, $DF = 3$, $F = 29.21$, $p = 0.033$) (Figure 3.1.4). Percent cover in Bamboo 6 and 8 decreased after the replant (Bamboo 6: $y = -0.2417x + 9438.8$, $R^2 = 0.76$, $n = 12$, $DF = 11$, $F = 5.94$, $p = 0.035$; Bamboo 8: $y = -0.3887x + 15159$, $R^2 = 0.86$, $n = 12$, $DF = 11$, $F = 61.26$, $p < 0.001$) (Figure 3.1.4). There was no seasonal difference in percent cover for all Bamboo islands since the cover on most islands varied widely due to loss of emergent vegetation and increases in algae and FAV (Section 3.2) (Figure 3.1.5). Bamboo 8 had the lowest mean cover of all islands (23%), followed by Bamboo 7 (24%), and Bamboo 6 (25%) (Figure 3.1.4). This group had the lowest mean percent cover of (33%) out of all groups (Figure 3.1.5).

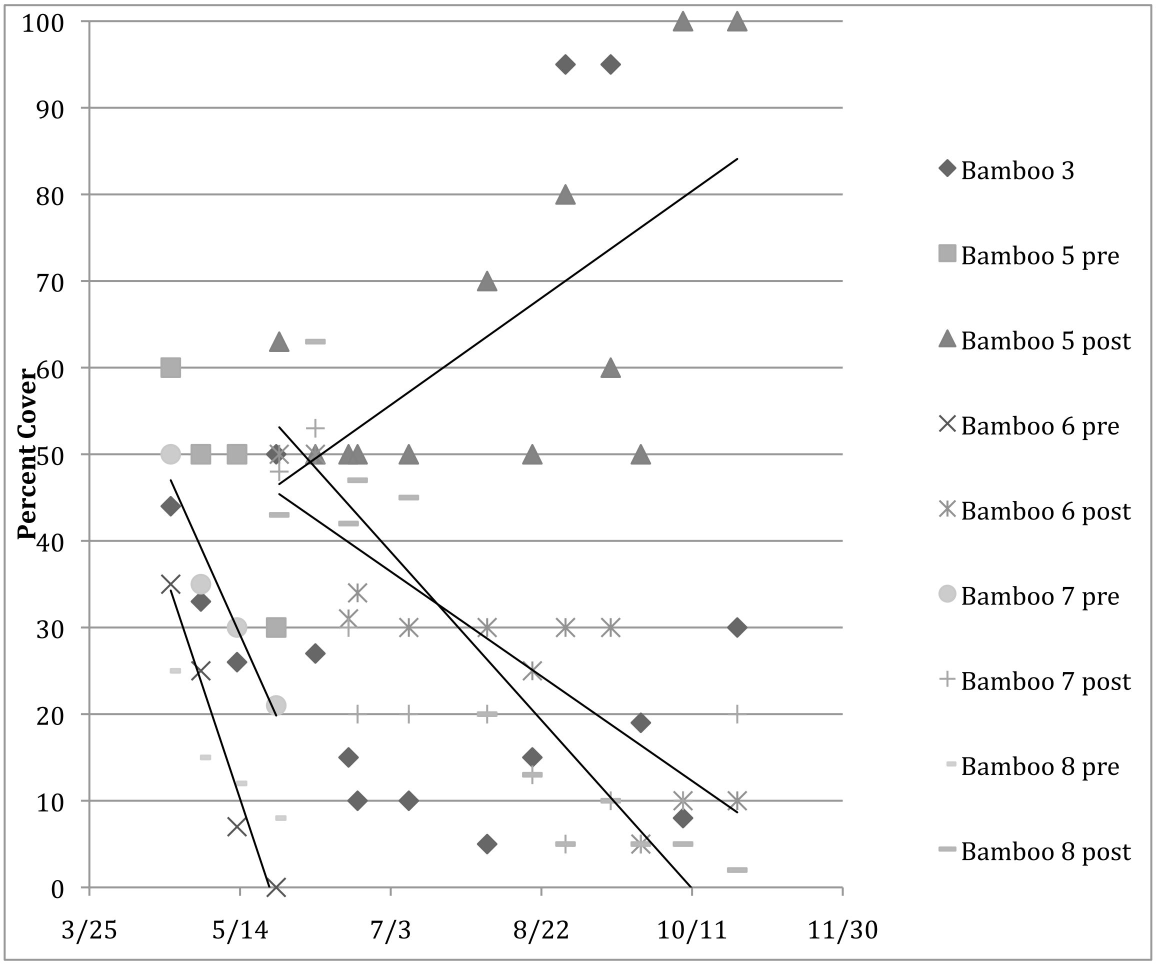


Figure 3.1.4: Percent cover of unsuccessful Bamboo islands.

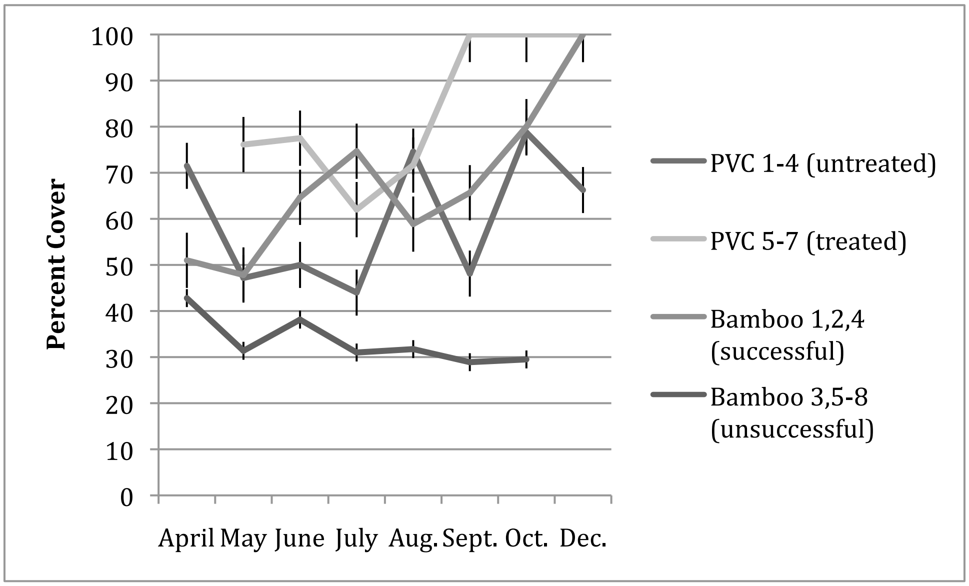


Figure 3.1.5: Average total top percent cover for island groups. The groups PVC 5-7 and Bamboo 1,2,4 showed the largest percent cover by the end of the study. Error bars represent +/- one standard error.

3.2. Percent Cover by Category

Emergent Vegetation

Significant seasonal differences in emergent percent cover were measured within untreated PVC island group 1-4 (n = 32; DF = 7; Kruskal-Wallis $X^2 = 21.61$; p = 0.003). The mean emergent percent cover for this group of 38% in the beginning of the study decreased to 15% by the end of the growing season (Figure 3.2.1). The decrease in emergent vegetation was replaced by an increase in other forms of plant and debris cover (Figure 3.2.10, Figure 3.2.15, Figure 3.2.20). In October there was an increase in emergent percent cover from ludwigia (Figure 3.2.1). Total mean emergent percent cover (21%) was the lowest during the entire study (Figure 3.2.5).

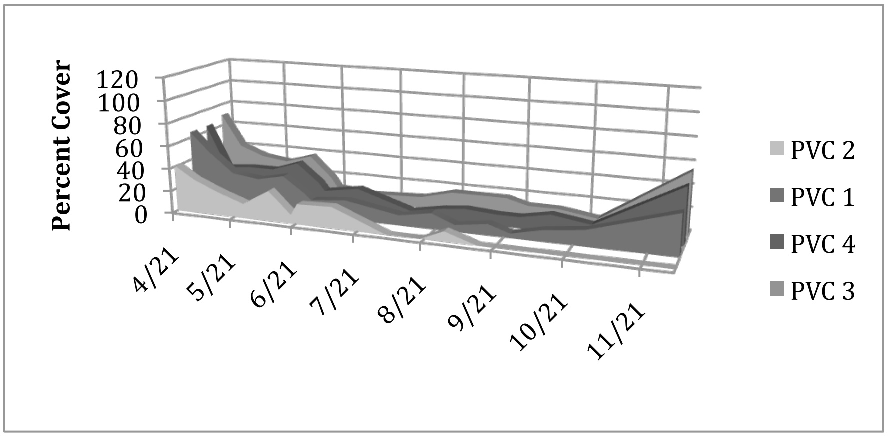


Figure 3.2.1: The emergent vegetation percent cover for islands PVC 1-4

The emergent percent cover for island group PVC 5-7 was significantly different (n = 44; DF = 14; Kruskal-Wallis: $X^2 = 7.8$; p = 0.02) due to the large range in emergent plant cover (31%-119%) (Figure 3.2.2). The emergent cover of 72% at the beginning of the growing season decreased to 60% by the end of the growing season (Figure 3.2.2). The group average emergent cover of 59% was the highest of all island groups. (Figure 3.2.5). The increase in emergent vegetation on PVC 5 in October was from ludwigia (Figure 3.2.2).

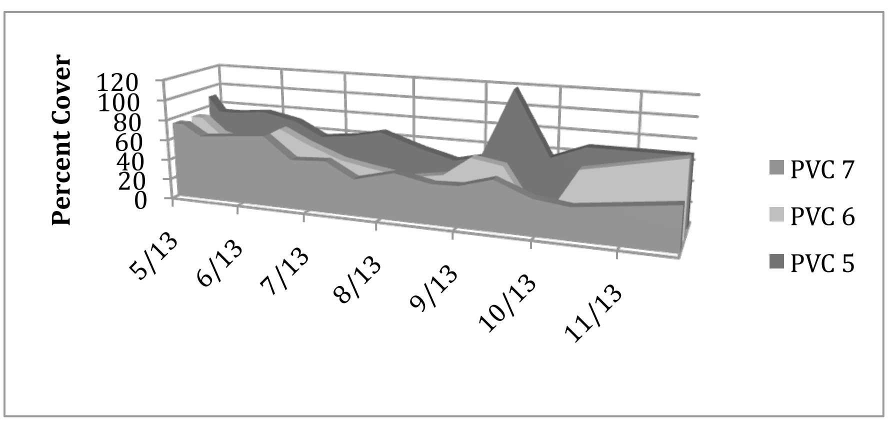


Figure 3.2.2: Emergent vegetation percent cover for islands PVC 5-7.

Significant differences in emergent percent cover were measured within successful Bamboo island group 1,2,4 (n = 48; DF = 16; Kruskal-Wallis: $X^2 = 21.98$; $p < 0.000$). Mean emergent percent cover was highest for Bamboo 2 (80%) and lowest for Bamboo 4 (28%) (Figure 3.2.3). The emergent vegetation cover on Bamboo 4 was 0% from August until October when Bamboo 4 was colonized by ludwigia and reached 100% cover in December (Figure 3.2.3). Bamboo 1 and 2 maintained a larger percent of emergent vegetation within this group throughout the study (Figure 3.2.3 and Figure 3.2.5). At the beginning of the growing season, emergent cover was 45% for all islands in this group and by the end of the growing season this increased to 47% (Figure 3.2.3). This is the only island group in which the emergent percent cover slightly increased from the beginning to the end of the study by 2% (Figure 3.2.5). This island group had the second highest emergent percent cover out of all island groups with 57% overall (Figure 3.2.5).

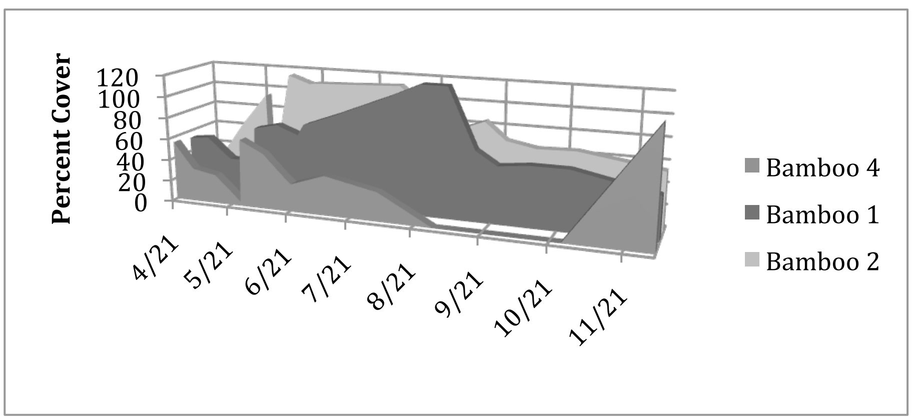


Figure 3.2.3: The emergent vegetation percent cover for harvested Bamboo islands 1, 2 and 4.

Emergent percent cover began at 29% and decreased to 10% for island group Bamboo 3, 5-8 by the end of the growing season (Figure 3.2.4). An increase in emergent

cover on Bamboo 5 due to a rapid colonization by ludwigia at the end of the study accounted for 40% of this islands total percent cover (Figure 3.2.4). The total mean emergent cover for this group was 24% (Figure 3.2.5).

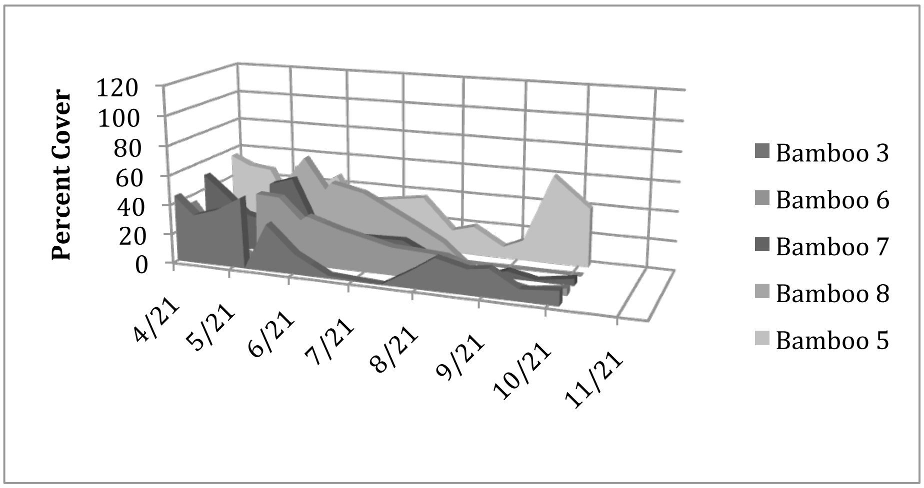


Figure 3.2.4: The emergent vegetation percent cover for unharvested Bamboo islands 3, 5-8. The increase in emergent vegetation in October on Bamboo 5 was due to rapid colonization by ludwigia. Island Bamboo 5 could not be harvested in December due to island frame failure.

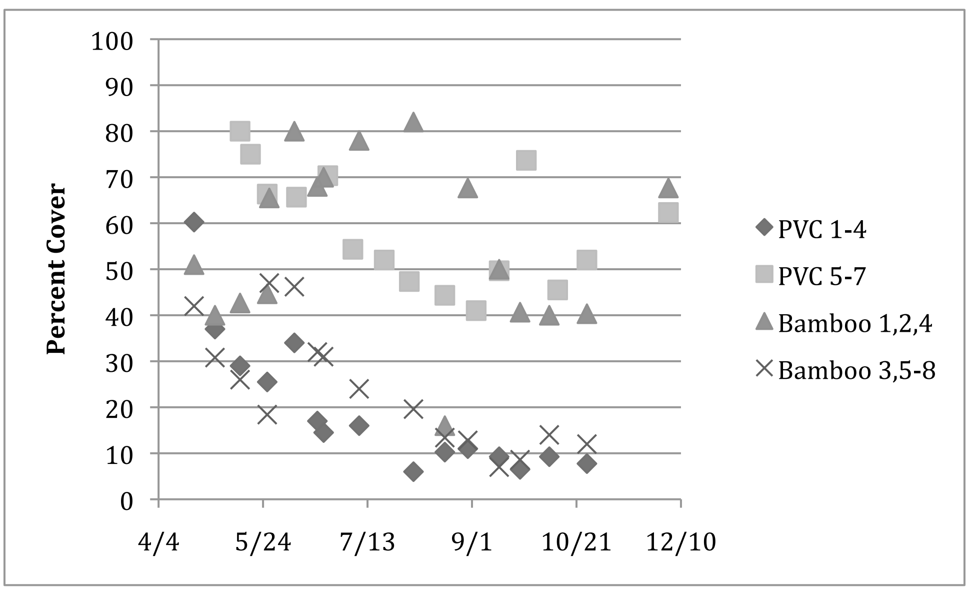


Figure 3.2.5 Average island group emergent percent cover through time. Islands PVC 5-7 and Bamboo 1,2,4 have the highest percent of emergent cover throughout the experiment.

Floating Aquatic Vegetation

Significant seasonal differences in floating aquatic vegetation (FAV) were measured on PVC islands 1-4 (n = 32; DF = 7; Kruskal-Wallis: $X^2 = 17.21$; p = 0.016). Cover by FAV increased from 0% to 17% by the end of the growing season (Figure 3.2.6). The large increase of FAV on PVC 3 in August was due to a short-lived colonization by duckweed (Figure 3.2.6). By the end of the study, PVC 1 was almost completely covered by duckweed and water lettuce whereas the other islands in this group showed little FAV cover at this time. This group had the lowest mean FAV cover overall of 7% (Figure 3.2.10).

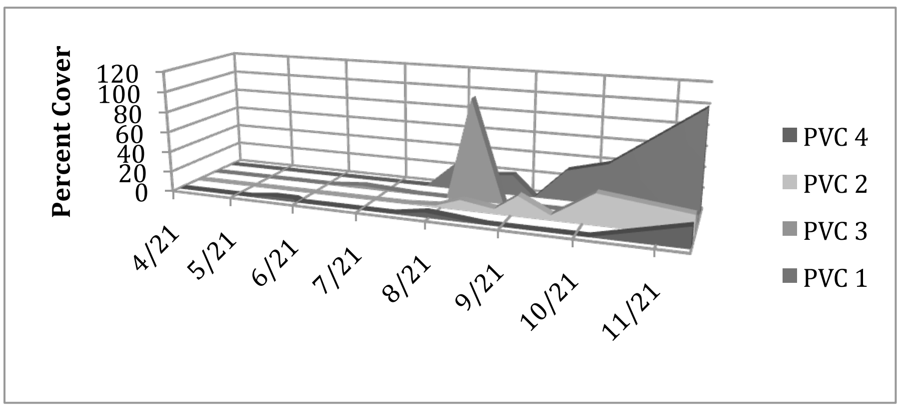


Figure 3.2.6: FAV percent cover for islands PVC 1-4. The large increase in FAV cover on island PVC 3 in August was due to duckweed. At the end of the study, PVC 1 was completely covered by duckweed and water lettuce, accounting for the large increase in FAV at this time.

Significant seasonal differences were recorded within island group PVC 5-7 (n= 24; DF = 7; Kruskal-Wallis: $X^2 = 19.76$; p = 0.006). PVC islands 5-7 had relatively similar FAV percent cover throughout the study and averaged 45% overall (Figure 3.2.7), the highest FAV cover among all island groups (Figure 3.2.10). At the beginning of the study season, FAV cover was 1% (Figure 3.2.7). These islands were placed in an aquatic

enclosure at the end of July, with less than 20% of FAV cover. By mid-August, the FAV cover increased to 100%, mainly due to duckweed, since this floating plant was contained within the enclosure and quickly reached 100% cover. The FAV cover persisted at nearly 100% on every island for the remainder of the study (Figure 3.2.7).

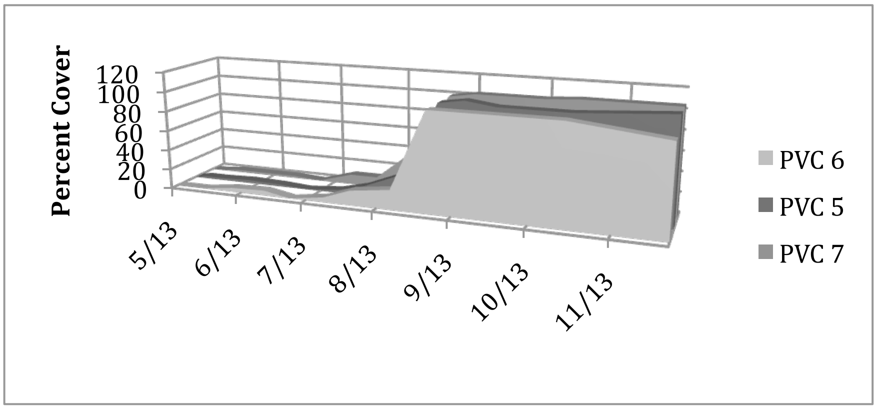


Figure 3.2.7: FAV percent cover for islands PVC 5-7. These islands were placed in an aquatic enclosure at the end of July, with less than 20% of FAV cover. By mid-August, the FAV cover increased to 100%, mainly due to duckweed, since this floating plant was contained within the enclosure and quickly reached 100% cover.

A significant seasonal FAV trend was measured for Bamboo 1, 2, and 4 (n = 24; DF = 7; Kruskal-Wallis: $X^2 = 16.03$; p = 0.025). There was almost no FAV cover on these islands until August when the FAV cover increased on each island to around 20% (Figure 3.2.8). In the beginning of the study season, there was less than 1% of FAV on the islands, but this increased to 25% buy the end of the growing season. Bamboo 1 was colonized by duckweed and water lettuce, which led to the FAV increase (105%) at the end of the study (Figure 3.2.8). Bamboo 2 had 35% FAV cover by December, and Bamboo 4 had the least FAV cover out of the group in December with 25%. This group had the second highest mean FAV cover throughout the study with 9% (Figure 3.2.10).

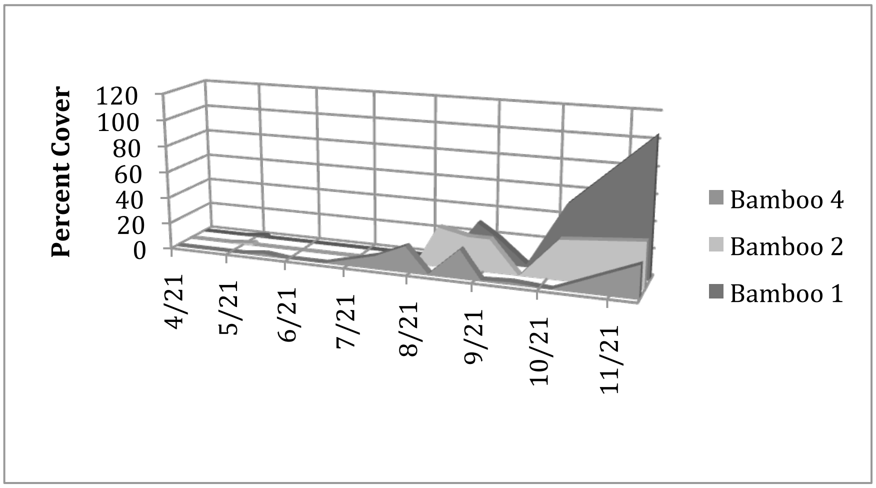


Figure 3.2.8: FAV percent cover for harvested Bamboo 1,2, and 4. Duckweed cover led to the increase in FAV on these islands by the end of the study.

Significant seasonal differences were recorded for island group Bamboo 3, 5-8 (n = 40; DF = 7; Kruskal-Wallis: $X^2 = 23.57$; p = 0.001). Similar to the other groups, the FAV was minimal until August when FAV increased (Figure 3.2.9). The increase in FAV on Bamboo 3 and Bamboo 5 was attributed to duckweed in September (Figure 3.2.9). Also, the percent FAV cover increased to 15% at the end of the study on Bamboo 5 due to water lettuce (Figure 3.2.9). Bamboo 3 had the greatest FAV cover within the group in December (55%), while other islands averaged only (5%). Bamboo 3 was the most sheltered island in this group (Figure 2.5.1). This group had one of the lowest FAV mean percent covers with 9% compared to other island groups (Figure 3.2.10).

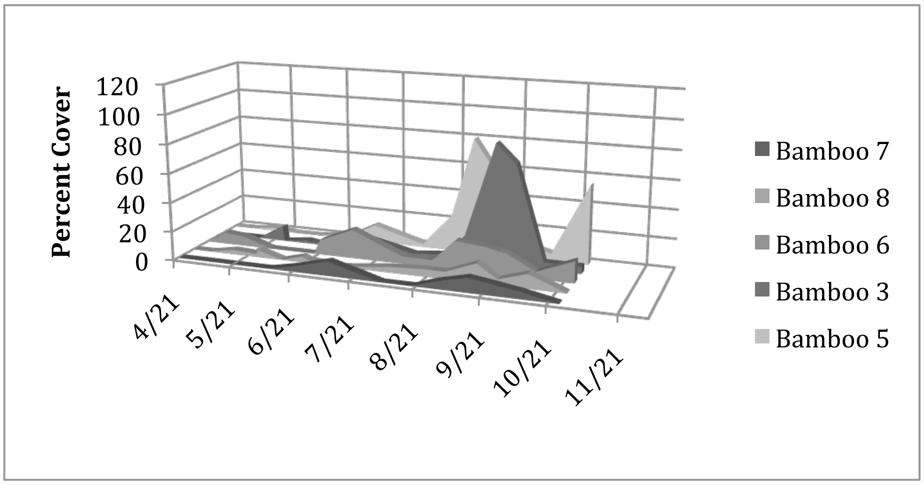


Figure 3.2.9: FAV percent cover for unharvested Bamboo 3, 5-8. The increase in FAV percent in September was attributed to duckweed on islands 3 and 5. Also, the percent FAV cover increased at the end of the study on Bamboo 5 due to duckweed and water lettuce.

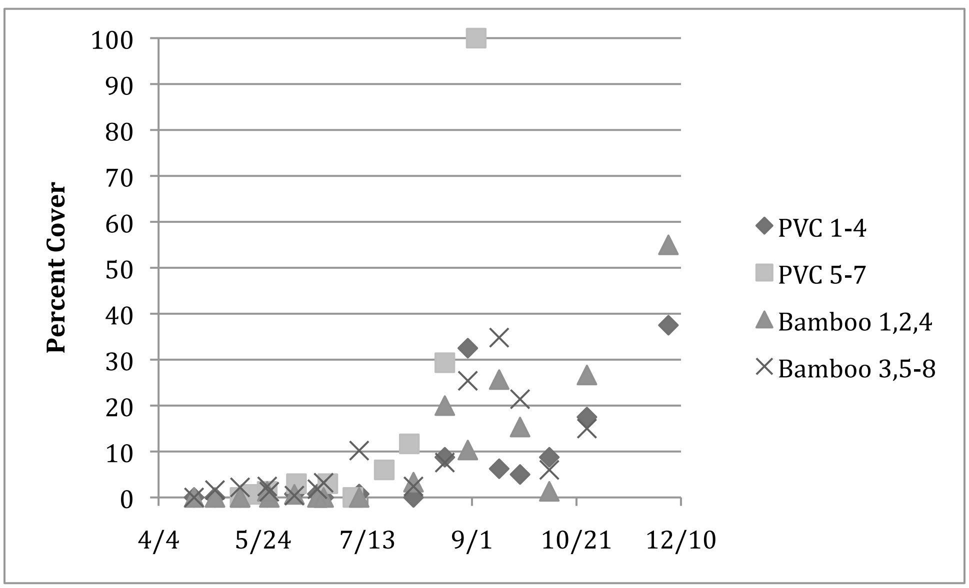


Figure 3.2.10: FAV average percent cover for island group through time. PVC 5-7 had the highest FAV cover from duckweed being trapped in the aquatic enclosure.

Algae

A significant seasonal difference was observed in percent algae cover within island group PVC 1-4 (n = 32; DF = 7; Kruskal-Wallis: $X^2 = 19.65$, $p = 0.006$). Algae quickly colonized PVC group 1-4 and within one month covered nearly half of all islands (Figure 3.2.11). The algae cover was greatest in the beginning of the growing season (16%) and at 55%, by the end of the growing season, was the highest cover of all island groups (Figure 3.2.15). This group had a greater mean algal cover than all other island groups combined (Figure 3.2.15). Mean algae cover on PVC 1 was the greatest at 58% while the other islands averaged 36% (Figure 3.2.11). Emergent vegetation quickly disappeared from this group and algae were able to colonize the mostly bare island substrate.

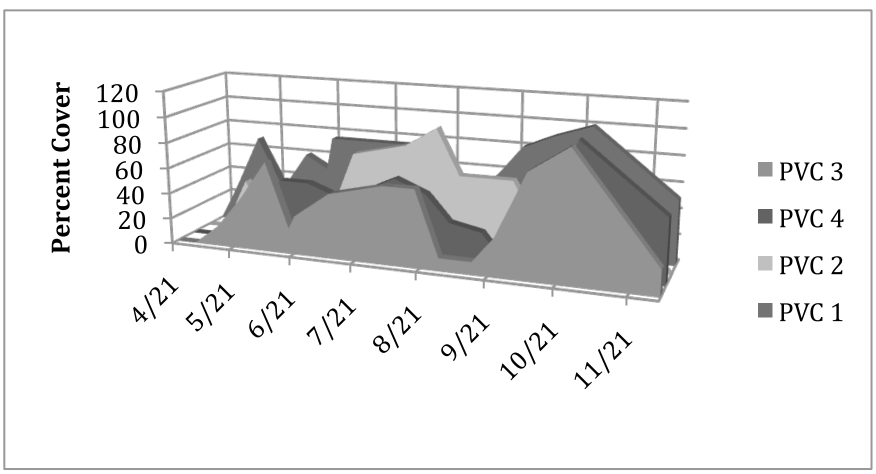


Figure 3.2.11: Algae percent cover for islands PVC 1-4.

Island group PVC 5-7 showed little algal cover over the course of the study (8%) (Figure 3.2.12). Algae was not observed on PVC islands 5-7 because algae was not able to easily colonize these islands due to the established percent cover from emergent

vegetation (Figure 3.2.2) and FAV percent cover (Figure 3.2.6). The algae cover was 5% in the beginning of the study season and increased to 6% by the end of the study (Figure 3.2.12). Island group PVC 5-7 had the least algal cover out of all groups (Figure 3.2.15). An increase in algae was noted in August (Figure 3.2.12).

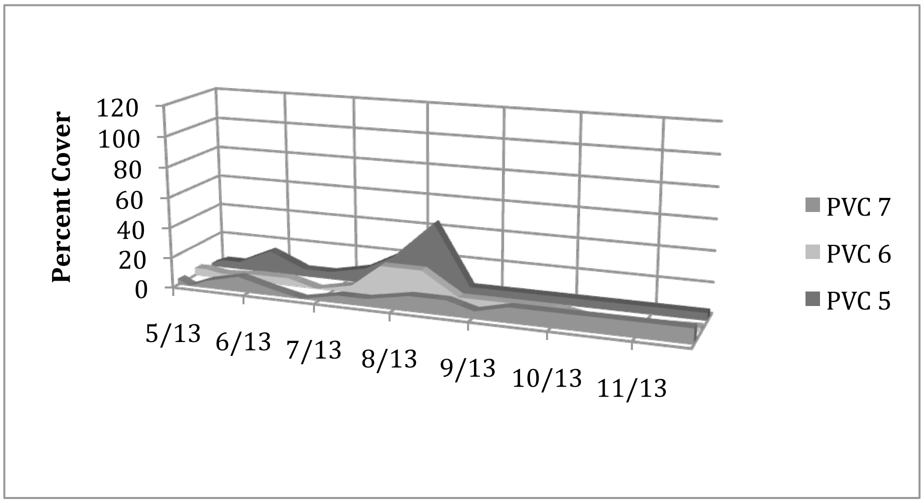


Figure 3.2.12: Algae percent cover for PVC islands 5-7. There was minimal algal cover on these islands throughout the study.

For most of the study, algal cover on Bamboo 1, 2 and 4, was minimal (Figure 3.2.13). There was a large increase in algal cover on Bamboo 1 in September (Figure 3.2.13), but this increase was not substantial enough to cause a significant difference within this island group. Mean algae cover at the beginning of the growing season was 6% and increased to 16% by the end of the study season (Figure 3.2.13). This group averaged 9% algae cover through the entire experiment, which is lower than island groups PVC 1-4 and Bamboo 3, 5-8 (Figure 3.2.15).

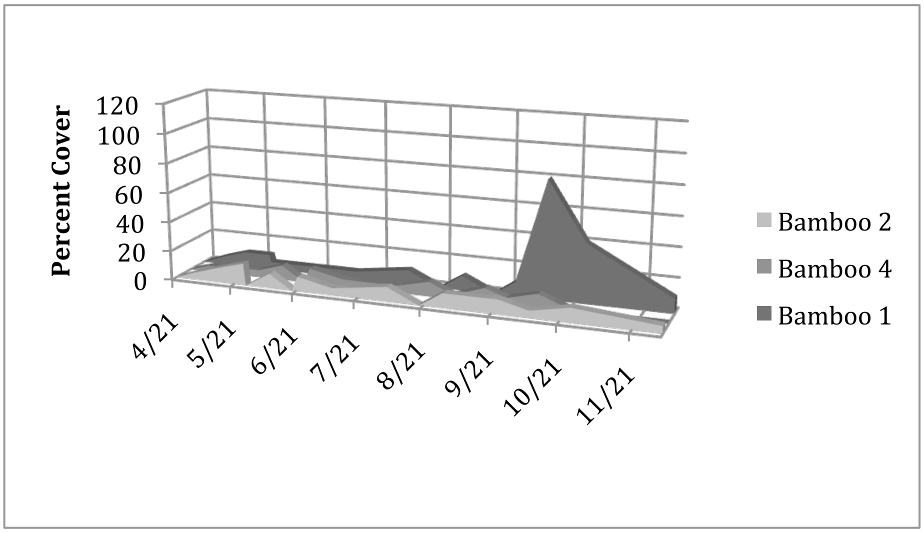


Figure 3.2.13: Algae percent cover for islands Bamboo 1, 2 and 4. There was an algal bloom at the study site in October and algae were found in high percent cover on Bamboo 1 at this time.

Significant differences in algae cover on Bamboo islands 3, 5-8 were measured (n = 79; DF = 15; Kruskal-Wallis: $X^2 = 17.73$; p = 0.001). There was an observed algal bloom at the lake study site in August and October and Bamboo 6, 7, and 8 were affected (Figure 3.2.14). Bamboo 3 had the greatest mean algae cover throughout the entire study (27%) while the total mean for the group was 15% (Figure 3.2.15). For most islands, as temperature decreased over the experimental study, so did algal cover (Appendix E).

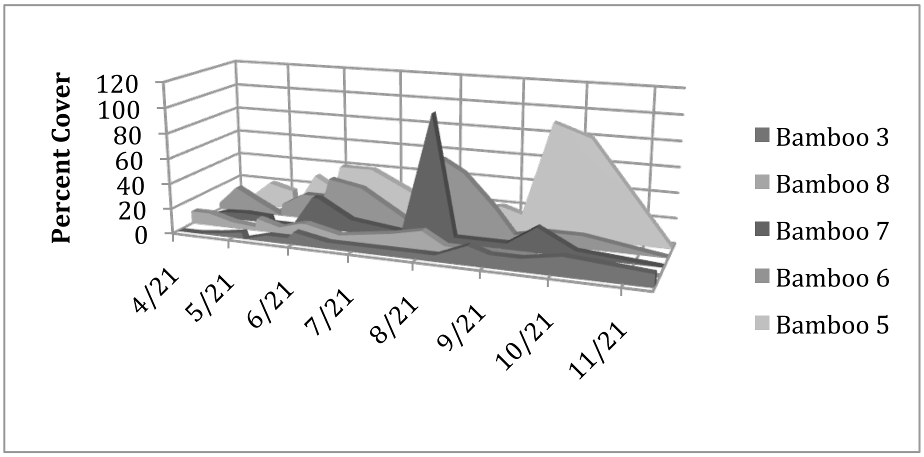


Figure 3.2.14: Percent algae cover for Bamboo islands 3, 5-8. There was an algal bloom in the lake in August and October, islands 6, 7, and 8 were affected. There was minimal algal cover by the end of the study due to the temperature decrease (Appendix E) and lack of island substrate on these islands.

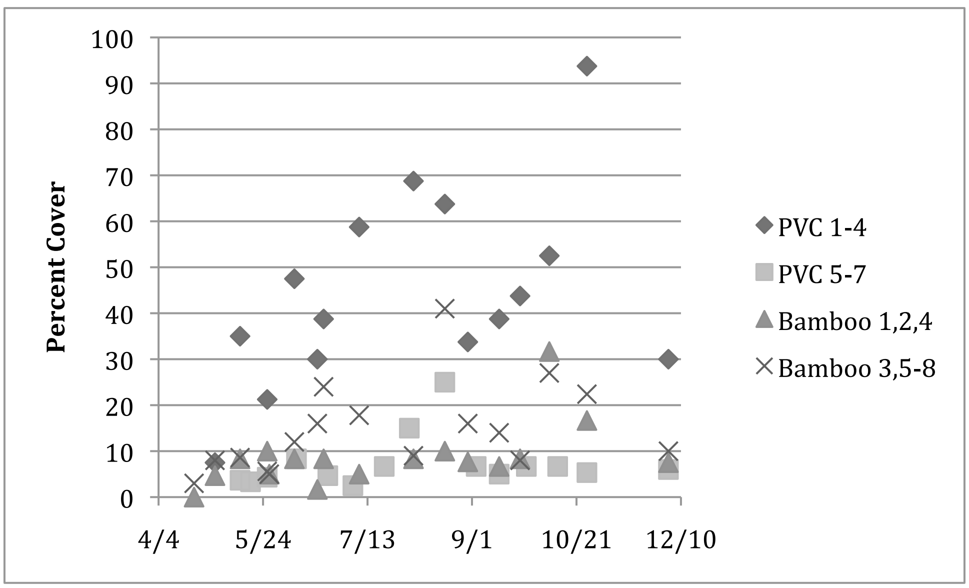


Figure 3.2.15: Average algae percent cover though time for island groups. Island group PVC 1-4 had the largest algal cover out of the island groups.

<u>Debris</u>

A significant difference in debris cover was recorded for PVC islands 1-4 (n= 63; DF = 15; Kruskal-Wallis: X^2 = 15.73; p = 0.001). A storm event in August (Appendix E) that washed a large amount of debris into PVC 3 and PVC 4 (Figure 3.2.16). The mean

debris cover throughout the experiment was 25%, which is comparable to the other island groups (Figure 3.2.20). PVC 1 had the highest mean debris cover with 38% while the other islands in this group averaged almost less than half that (21%) (Figure 3.2.16).

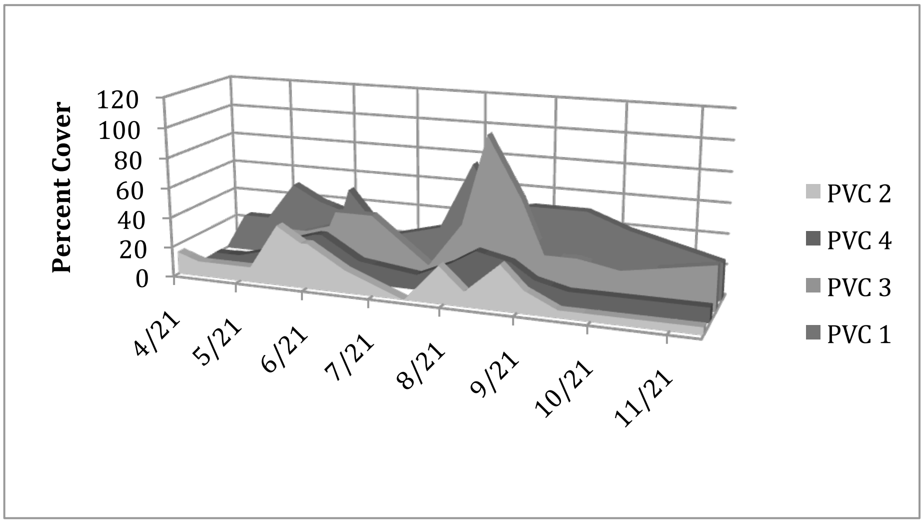


Figure 3.2.16: Debris percent cover for PVC 1-4. In mid August there was a storm event, which washed debris, mainly in the form of detritus, onto islands 3 and 4 (Appendix F).

Storms increased debris cover in May and August on PVC islands 5-7 (Figure 3.2.17 and Appendix E). The debris persisted on the islands after the storm event for a short time before decreasing to less than 20% total by the end of the study (Figure 3.2.17). This group averaged more debris cover at the beginning of the growing season (12%) than the end (9%) (Figure 3.2.17). The total mean debris cover for the group (19%) was the lowest out of all island groups (Figure 3.2.20). This group also had the greatest emergent percent cover at the end of the growing season (Figure 3.2.5).

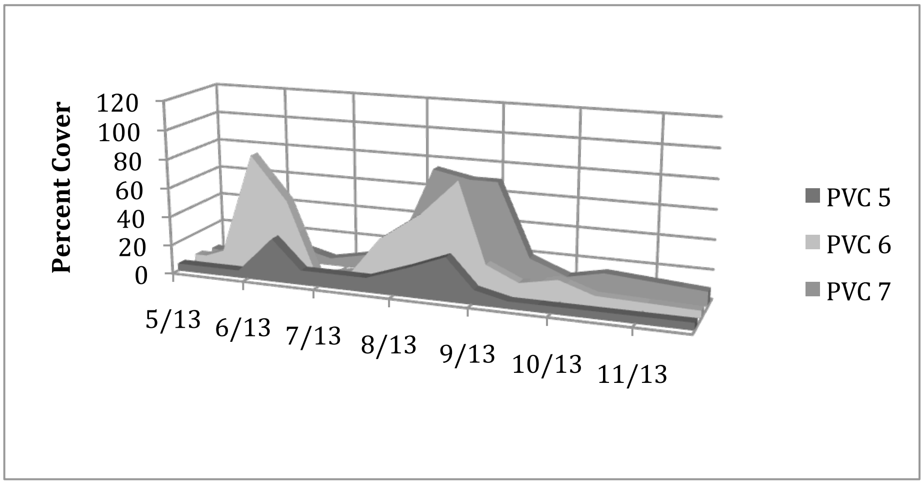


Figure 3.2.17: Total percent cover for debris. A storm event in late May washed debris onto PVC 6 and there was a storm event that washed debris onto PVC 5 and PVC 6 in mid August (Appendix E).

There was a large range of debris cover on Bamboo islands 1, 2 and 4 (0% - 100%) (Figure 3.2.18). Like the other groups, Bamboo 1, 2, and 4 had a large increase in debris cover after the May and August storm events (Figure 3.2.18 and Appendix E). The mean debris cover was highest on Bamboo 1 (39%) while Bamboo 2 (22%) and Bamboo 4 (18%) had almost half the debris coverage (Figure 3.2.18). The debris cover decreased by the end of the study to less than 20% for each island within this group. This group had the highest mean debris percent cover out of all groups with 26% (Figure 3.2.20).

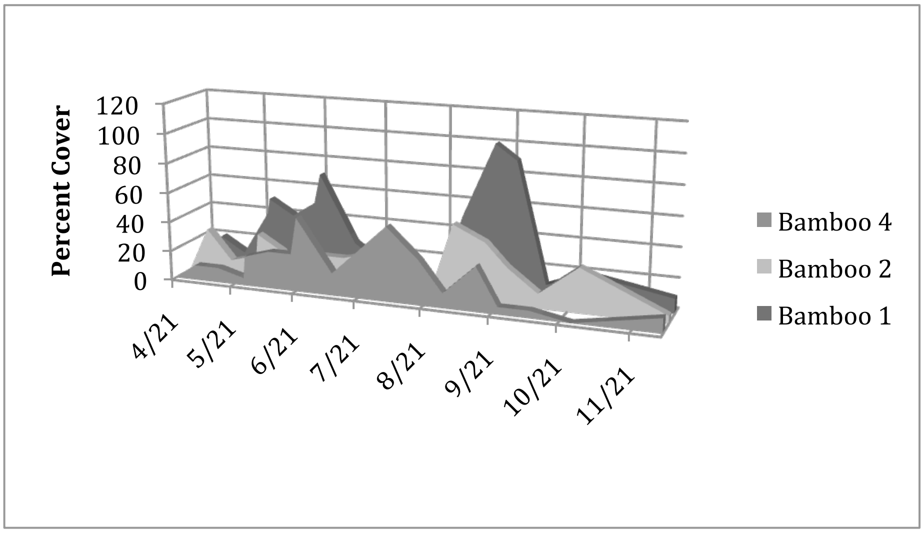


Figure 3.2.18: Debris percent cover for Bamboo islands 1, 2, and 4. There was a storm event, which contributed to the increase in debris cover on islands Bamboo 2 and Bamboo 4 in mid-August (Appendix E).

Significant differences were measured in debris percent cover on Bamboo islands 3, 5-8 (n = 79; DF = 15; Kruskal-Wallis: $X^2 = 17.6$; p = 0.001). Significant seasonal differences in debris cover for these islands were also measured (n = 40; DF = 7; Kruskal-Wallis: $X^2 = 15.11$; p = 0.035). There was a large range in debris cover through time for each island, and a trend was difficult to observe. Bamboo 5 averaged 11% debris cover throughout the study while Bamboo 3 measured 35% (Figure 3.2.19). However, there was an increase in May and August in debris cover due to the storm event as noted for the other island groups (Figure 3.2.19). The total mean debris cover was 22%, which is similar to other island groups (Figure 3.2.20). The percent debris cover followed or tracked the summer rainy season, with months of more rain and thunderstorms leading to a higher debris cover on all islands (Figure 3.2.20 and Appendix E).

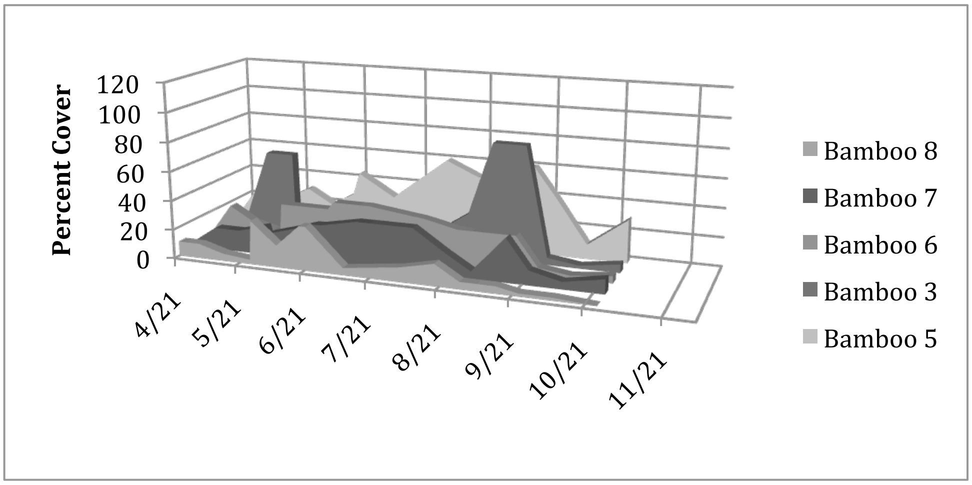


Figure 3.2.19: Debris percent cover for Bamboo 3, 5-8. The increase in debris cover for islands 3 and 5 in mid-August was due to a storm event (Appendix E). There was little to no debris cover for these islands in late October because most of the island frames and substrate were broken and/or missing.

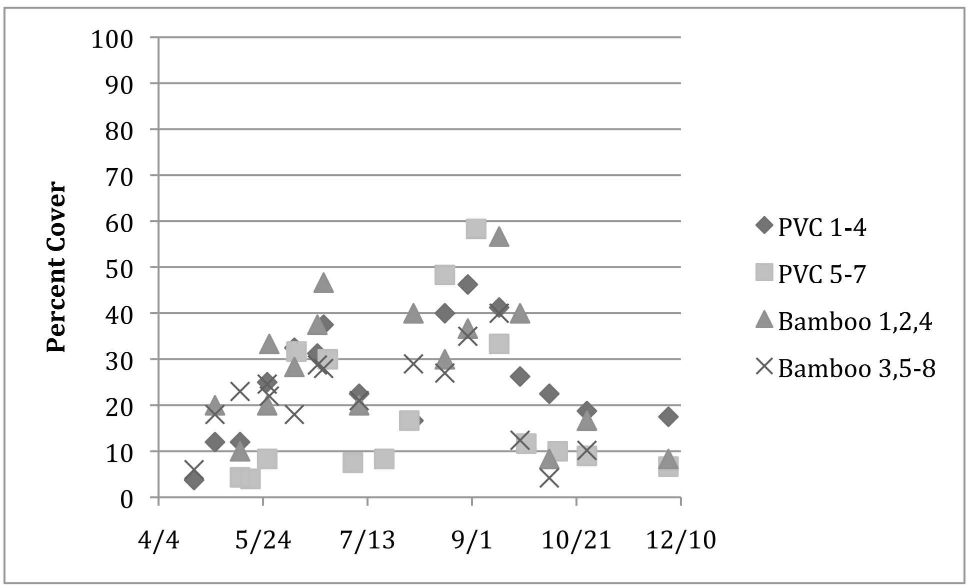


Figure 3.2.20: Average debris cover for island group. The debris cover is highest during the summer rainy season, months June, July, August, and September (Appendix E).

3.3. Root Percent Cover

The root percent cover of island group PVC 1-4 averaged below 20% until December when emergent vegetation increased (Figure 3.3.1). The root percent cover was the lowest for this group out of all island groups (midpoint mean = 7%) (Figure 3.3.2). No seasonal root change was recorded due to the lack of emergent vegetation on this island group throughout the study (Figure 3.2.5).

A significant seasonal change was measured for PVC islands 5-7 ($n = 24$; $DF = 7$; Kruskal-Wallis: $X^2 = 21.81$; $p = 0.003$). The islands steadily increased in root cover class throughout the study with most islands reaching 100% root cover in September and maintaining this cover until the end of the study (Figure 3.3.1). This group had the highest mean root percent cover (58%) out of all island groups (Figure 3.3.2). The initial emergent vegetation plants persisted throughout the study and increased in root cover (Figure 3.2.5). The islands that received the greatest initial root stock (PVC 5-7) were observed to have the greatest root percent cover by the end of the study.

Significant differences in root percent cover were measured within the Bamboo island groups. Bamboo 1, 2, and 4 were significantly different from each other with regard to root percent cover ($n = 79$; $DF = 15$; Kruskal-Wallis: $X^2 = 18.52$; $p < 0.001$). Bamboo 2 had the greatest root cover by the end of the study with a total root cover class of a 6 (100%) (Figure 3.3.1) resulting from the abundant emergent vegetation on this island (Figure 3.2.5). The mean root cover of Bamboo 2 was greatest in the group (55%) followed by Bamboo 1 (21%) and Bamboo 4 (13%). Overall, this group had the second highest root percent cover out of all island groups with 29% (Figure 3.3.2).

Although none of the islands in group Bamboo group 3,5-8 were able to be harvested due to lack of percent cover, a significance difference among this group was measured with regard to root cover (n = 79; DF = 15; Kruskal-Wallis: $X^2 = 18.52$; p = 0.001). Most islands in this group did not have a large emergent plant cover resulting in a low mean root percent cover (10%) (Figure 3.3.2) Due to the limited root cover, small changes within this island group led to a significant difference overall. No seasonal change was measured since there was low root cover throughout the study seasons.

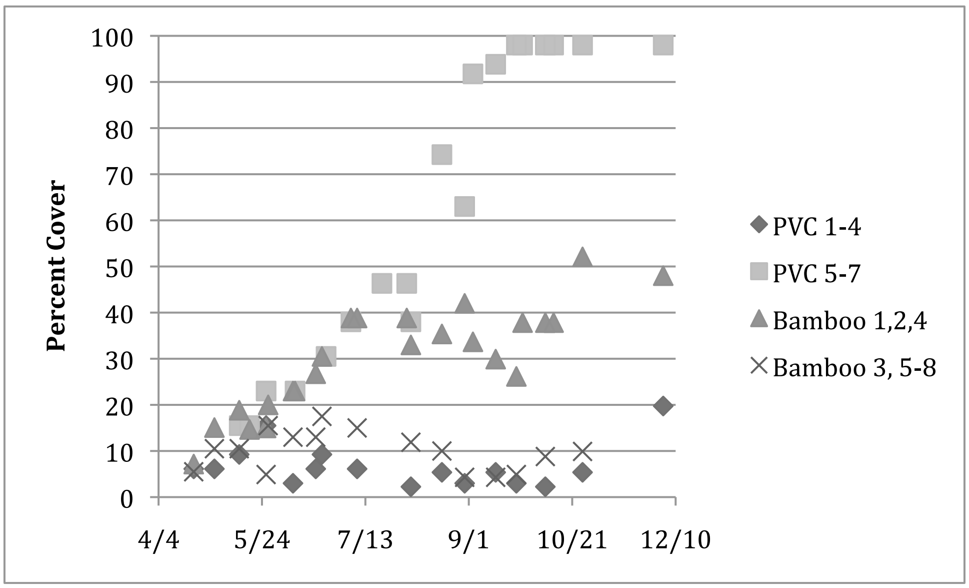


Figure 3.3.1: Time series for root percent cover for all islands. Averages based on midpoint percents. Islands PVC 1-4 were untreated. PVC 5-7 were treated in October. Bamboo 1,2,4 were the harvested Bamboo islands. Bamboo 3, 5-8 were not harvested and therefore had no root percent cover in December.

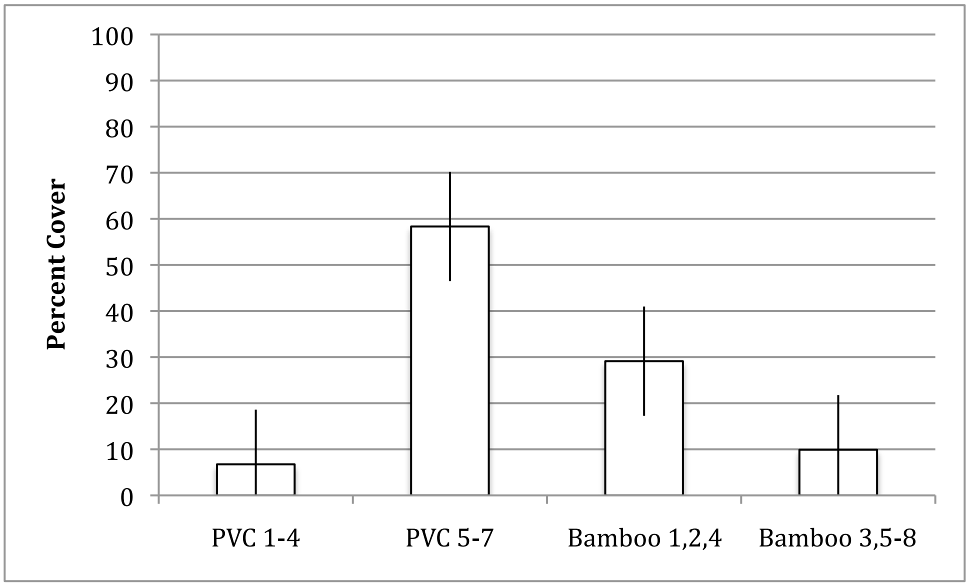


Figure 3.3.2: Island root cover classes using the average midpoint from the root cover class range. Error bars represent +/- one standard error.

3.4. Island Weights

Significant seasonal differences in weights were recorded for island group PVC 1-4 (n = 8; DF = 1; Kruskal-Wallis: $X^2 = 5.33$; p = 0.021). By December, PVC 1-4 gained about 2 kg of water on the interior of the PVC frames. The mean weight for a water logged PVC frame is 10.5 kg. The mean weight for island group PVC 1-4 was 11 kg and was the lowest for all island groups (Figure 3.4.1). The peak mean weight for this group was 15 kg in October before decreasing to 10 kg in December (Figure 3.4.1). PVC 1-4 had the middle mean weight variation of the island groups (mean coefficient of variation = 0.130 kg).

By the end of the study, PVC 5-7 was the heaviest island group resulting from the large increase in vegetative cover throughout the study (Figure 3.1.5). Significant seasonal differences in weight were measured within this group (n = 6; DF = 1; Kruskal-Wallis: $X^2 = 3.86$; p = 0.049). With a mean weight of 23 kg over the course of the

experiment, this group was the heaviest of all groups (Figure 3.4.1). The peak mean weight measured in October for this group was 34 kg and decreased to 28 kg in December (Figure 3.4.1). PVC 5-7 had little weight variation within the group (mean coefficient of variation = 0.096 kg). The PVC frames were very similar in weight, so differences in weight variation resulted from biomass cover and water infiltration within the PVC frame.

Weights for islands within group Bamboo 1, 2, and 4 were not significantly different throughout the study period (Figure 3.4.1). This group had a mean weight (22 kg) slightly lower than PVC 5-7. This is interesting because a saturated Bamboo island frame weighs on average 8 kg more than a comparable PVC frame, but PVC 5-7 still weighed more than group Bamboo 1,2, and 4 (Figure 3.4.1). The PVC islands were heavier on average due to the large biomass on these islands.

Bamboo 3, 5-8 had a mean weight of 18 kg over the course of the study. A saturated Bamboo island frame weighs approximately 18 kg so the weight of these islands is attributed to mostly frame mass alone. There was little vegetated cover on these islands by the end of the study to contribute to a substantial weight gain (Figure 3.1.5). The islands within this group decreased in weight from the beginning of the study to the end of the experiment (Figure 3.4.1). The Bamboo islands had the largest weight variation (mean coefficient of variation = 0.380 kg). The large variation in Bamboo islands resulted from differences in biomass cover, but also natural weight variation in the Bamboo material.

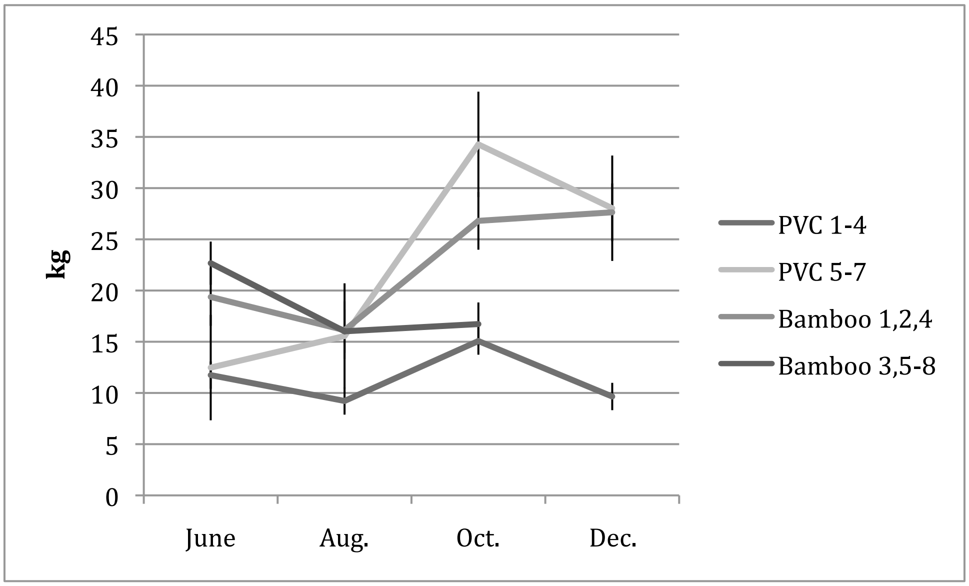


Figure 3.4.1: Mean weight for island group through time. Error bars represent +/- one standard error.

3.5. Biomass Weights

Significant differences were measured for dry biomass within the harvested islands (n = 10; DF = 2; Kruskal-Wallis: $X^2 = 7.00$; p = 0.030). PVC 1-4 yielded the lowest mean dry biomass with 131 g/m^2 out of all island groups (Figure 3.5.1). Mean dry biomass of PVC 1 was lower than other islands within the same group (22 g/m^2) while PVC 3 had the greatest dry biomass (200 g/m^2).

Island group PVC 5-7 had the greatest mean final dry biomass with 1,511 g/m^2; greater than the other groups combined (Figure 3.5.1). Dry biomass within this group ranged between 1,393 g/m^2 (PVC 7) to 1,694 g/m^2 (PVC 6).

Dry biomass for Bamboo 2 (1,461 g/m^2) was greater than the other islands in this group combined (Bamboo 1 = 344 g/m^2; Bamboo 4 = 489 g/m^2) resulting from the

abundant plant cover on this island (Figure 3.1.5). Bamboo 2 biomass was comparable to the biomass on treated PVC islands even though Bamboo 2 was not treated with nutrients. Overall, this group had the second greatest biomass out of other island groups (Figure 3.5.1).

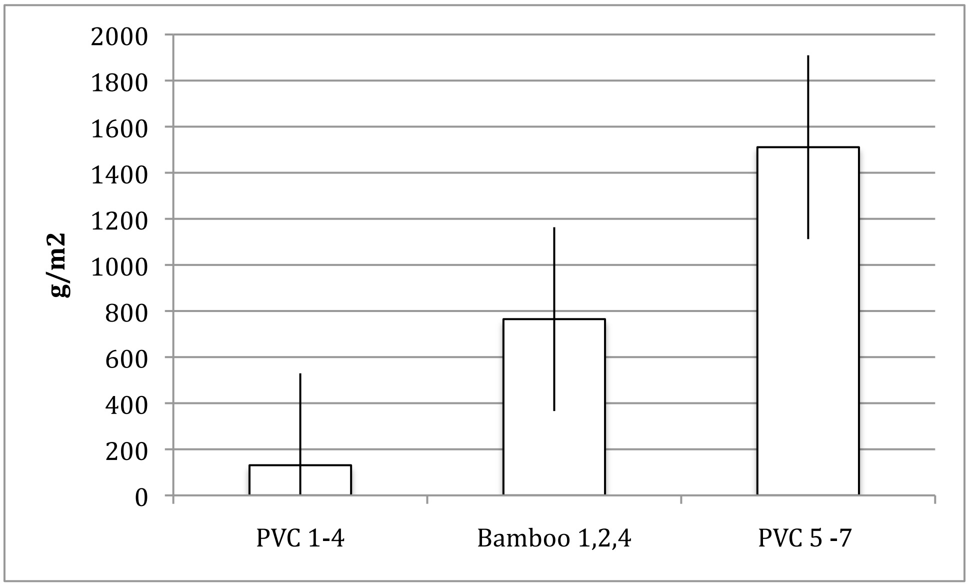


Figure 3.5.1: Mean dry biomass per harvested island group. Group PVC 5-7 were treated with nutrients in October. Error bars represent +/- one standard error.

Plant shoots from all harvested islands had greater biomass (3,697 g/m^2) than the roots (2,369 g/m^2) (Figure 3.5.2). This resulted from the type of vegetation found on harvested islands. Roots were only counted as ‘root vegetation’ if found under the island substrate potentially skewing the data slightly toward the ‘shoot’ category. Ludwigia had the greatest biomass (2,123 g/m^2) across all harvested islands resulting from the extensive ludwigia cover on all harvested islands (Figure 3.5.3) Debris was the second largest group with 1,078 g/m^2 (Figure 3.5.3).

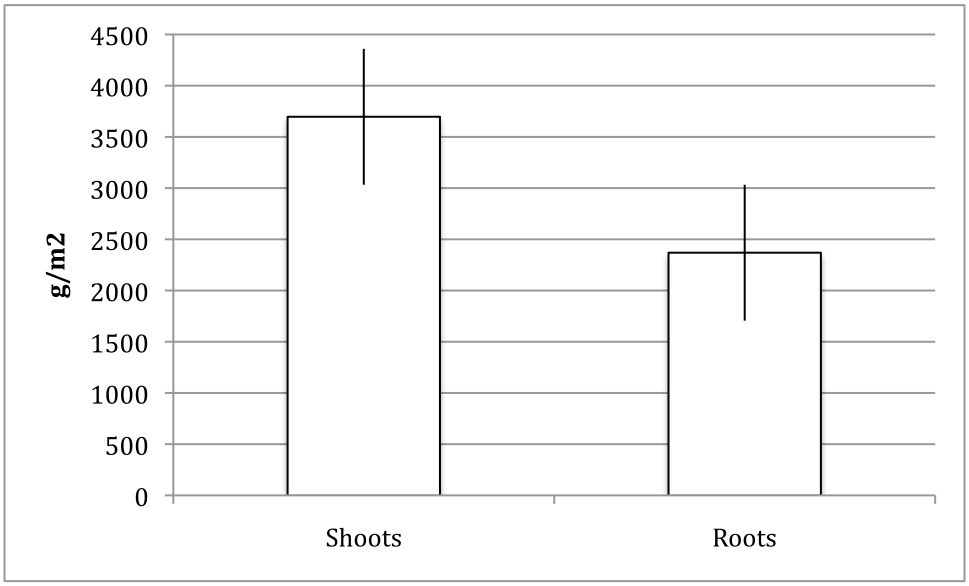


Figure 3.5.2: Harvested island shoot and root biomass combined. Error bars represent +/- one standard error. (Shoots do not contain debris or SAV).

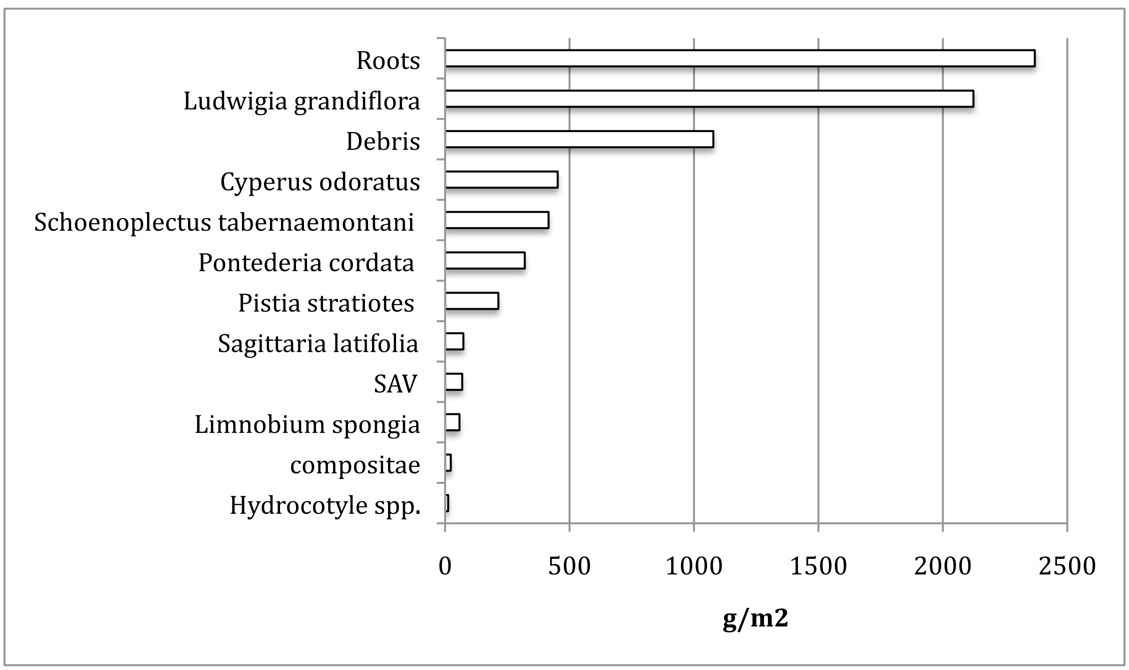


Figure 3.5.3: Island combined biomass by type.

3.6. Island Plant and Substrate Nutrients

Nitrogen

The plants on the bamboo islands had a lower average nitrogen than the PVC islands by 1.34% (Figure 3.6.1). The Bamboo islands had a greater mass of nitrogen (19.84 g/m^2) than the PVC islands (3.92 g/m^2) (Figure 3.6.2) resulting from plant cover variation (Section 3.1 and 3.2). The bamboo island with the most nitrogen was Bamboo 2 (34 g/m^2) resulting from extensive vegetated cover (Figure 3.1.5). Bamboo 1 had the lowest nitrogen (12 g/m^2) in the bamboo group. The PVC nitrogen ranged from 0.58 g/m^2 (PVC 2) to 5.88 g/m^2 (PVC 4). The plant groups that had the most percent nitrogen were the submerged and floating aquatic vegetation groups (4.13%) and the category with the lowest percent nitrogen was the debris group (1.98%) (Figure 3.6.3).

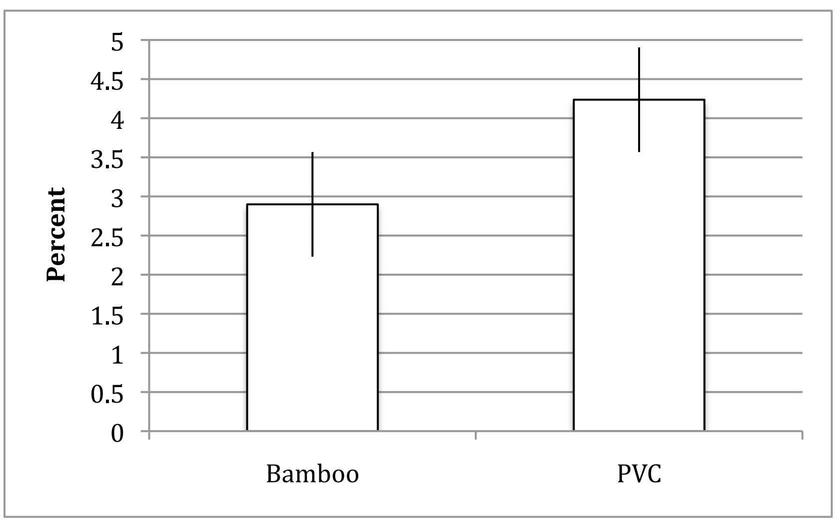


Figure 3.6.1: Percent nitrogen for artificial and natural island substrate types. Error bars represent +/- one standard error.

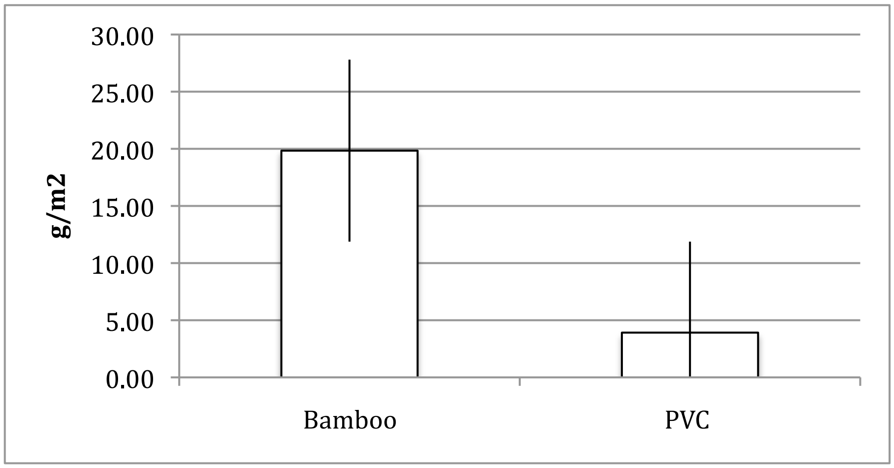


Figure 3.6.2: Nitrogen mass by island type. Error bars represent +/- one standard error.

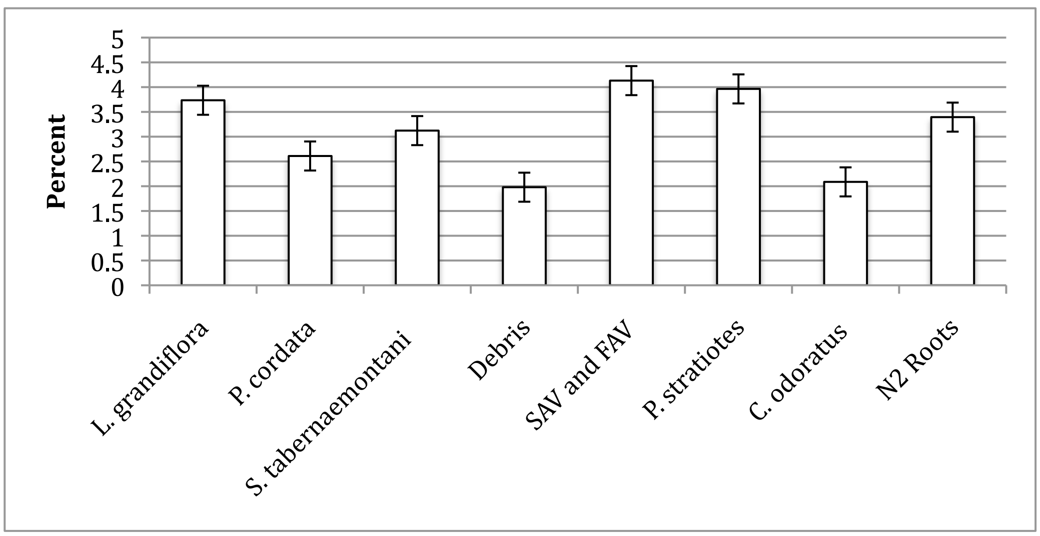


Figure 3.6.3: Percent nitrogen from all plant species and categories existing on all islands in December 2010. Error bars represent +/- one standard error.

Carbon

The Bamboo islands had less percent carbon than PVC islands by 1.96% (Figure 3.6.4). The Bamboo islands had greater carbon mass (318 g/m^2) than the PVC islands (56 g/m^2) (Figure 3.6.5). Bamboo 2 had more carbon (617 g/m^2) than all other islands combined (560 g/m^2). The debris category had the highest percent carbon content out of all the plant species (45.11%) while the water lettuce had the least carbon (37.61%)

(Figure 3.6.6). This is a result of the Bamboo islands having less debris on them at the end of the study than PVC islands (Section 3.2).

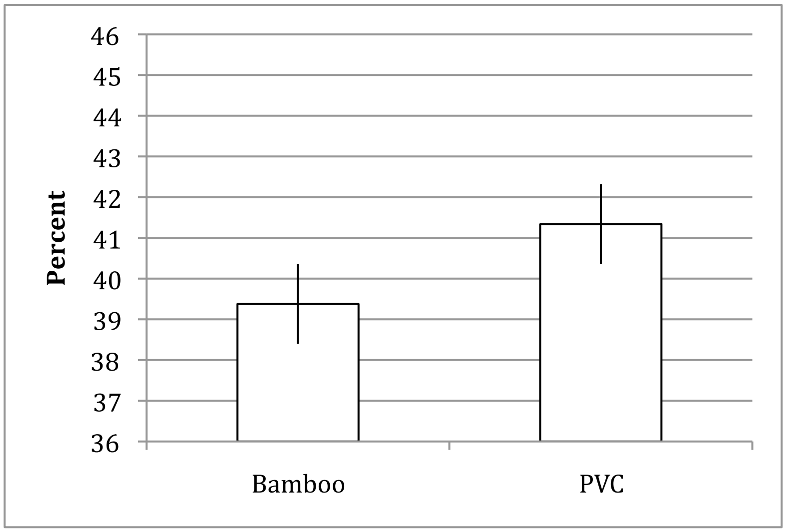


Figure 3.6.4: Percent carbon for artificial and natural island substrate types. Error bars represent +/- one standard error.

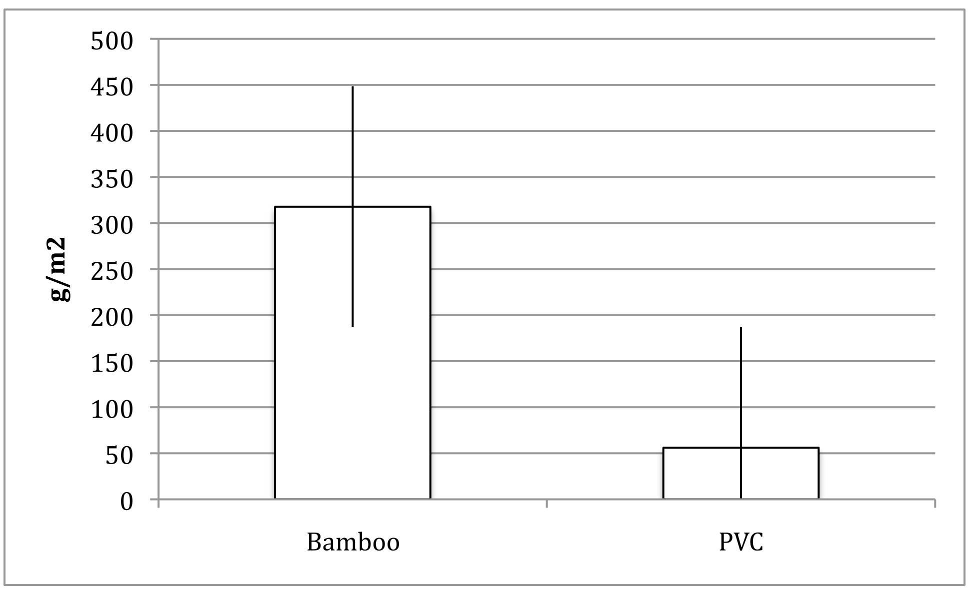


Figure 3.6.5: Carbon mass by island type. Error bars represent +/- one standard error.

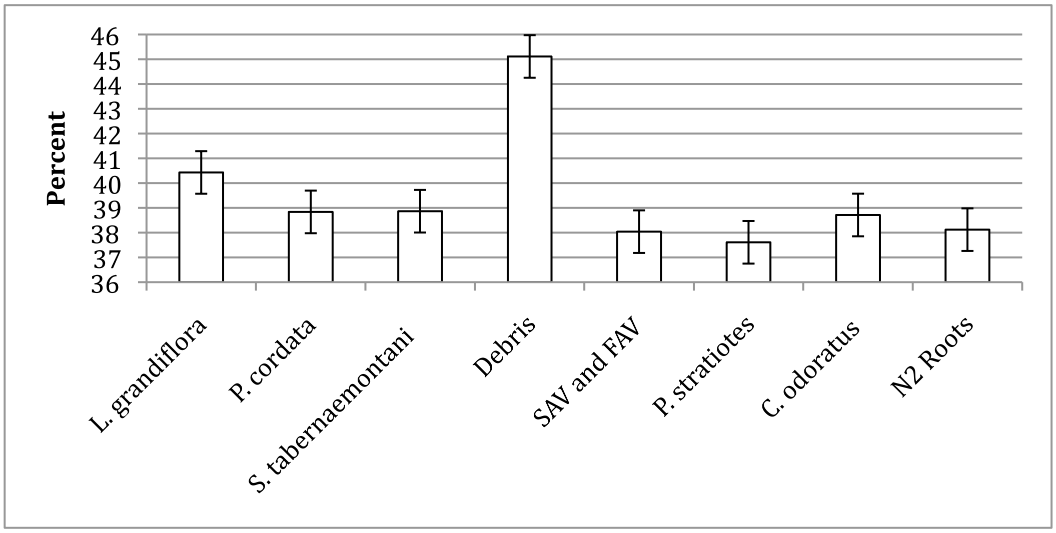


Figure 3.6.6: Percent carbon from all plant species and categories existing on all islands in December 2010. Error bars represent +/- one standard error.

<u>Phosphorus</u>

Bamboo islands had 0.14% less phosphorus content than PVC islands (Figure 3.6.7). Bamboo islands had greater phosphorus mass (0.99 g/m^2) than PVC islands (0.19 g/m^2) (Figure 3.6.8). Bamboo 2 had the greatest phosphorus content with 1.60 g/m^2 out of all harvested and untreated islands while PVC 2 had the lowest (0.02 g/m^2). Water lettuce had the greatest percentage of phosphorus with 0.42% and debris had the least amount with 0.04% (Figure 3.6.9). Overall, Bamboo 2 had the greatest nutrient content in g/m^2 while PVC island 2 had the lowest.

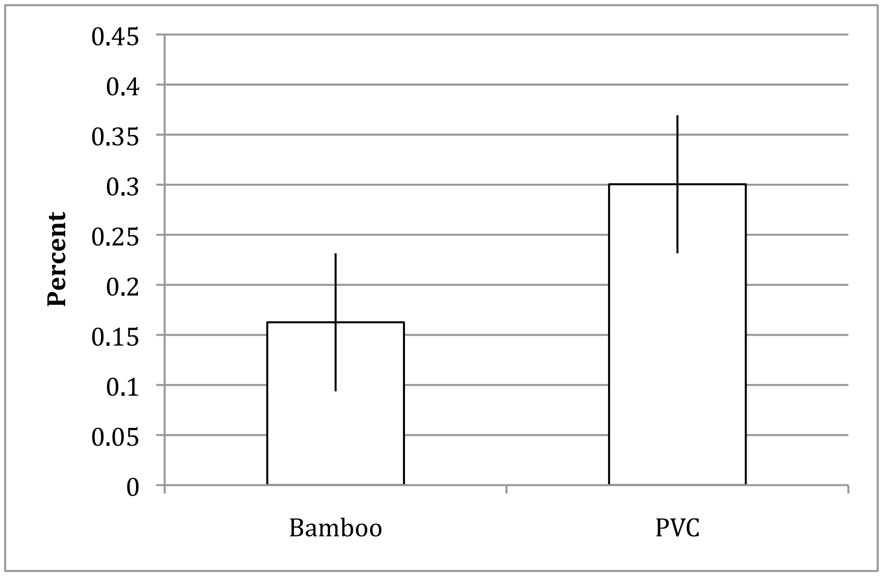


Figure 3.6.7: Percent phosphorus for artificial and natural island substrate types. Error bars represent +/- one standard error.

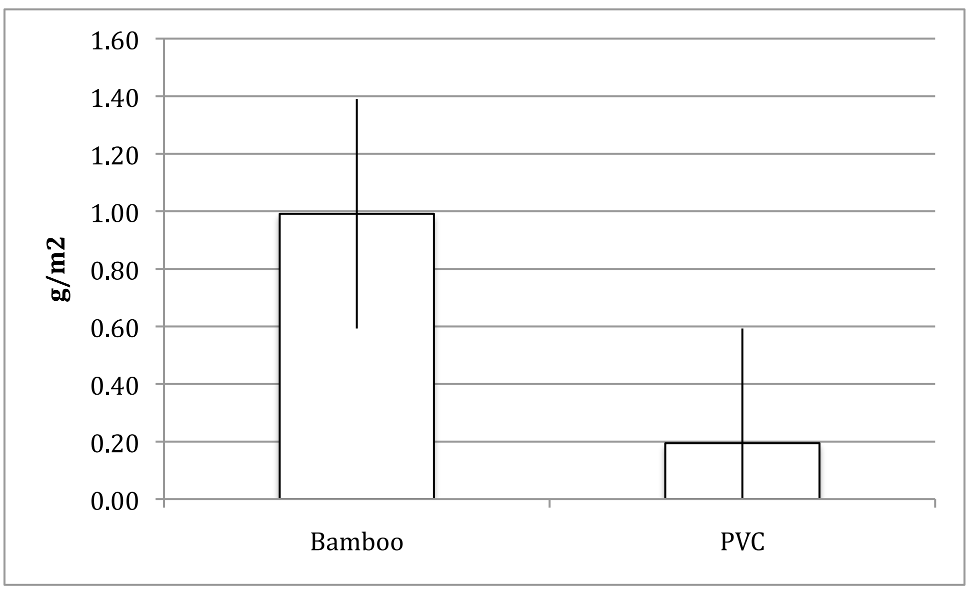


Figure 3.6.8: Phosphorus mass by island type. Error bars represent +/- one standard error.

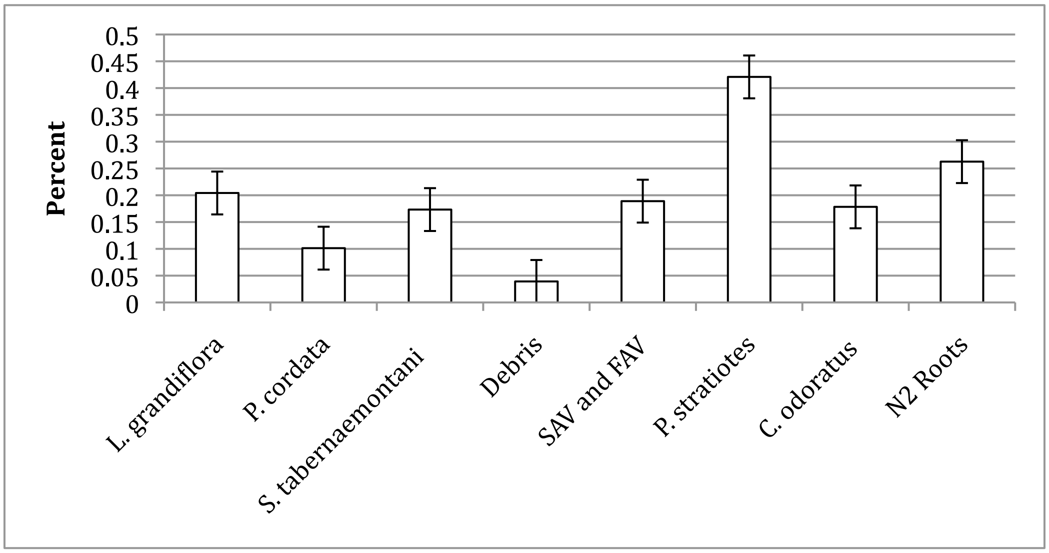


Figure 3.6.9: Percent phosphorus from all plant species and categories existing on all islands in December 2010. Error bars represent +/- one standard error.

3.7. Island Material Durability

The Bamboo frames broke more often than the PVC frames and were slightly submerged more often than the PVC frames (Table 3.7.1). PVC frames were more durable over the course of the study.

Table 3.7.1: Island frame durability over the experimental study. SS is slightly submerged. HS equals half submerged. FS is fully submerged and B equals frame broken.

	April	May	June	July	Aug.	Sept.	Oct.	Dec.
PVC 1					SS	SS	SS	HS
PVC 2						SS	SS	HS
PVC 3								
PVC 4								
PVC 5					SS			
PVC 6				SS	HS			
PVC 7								
Bamboo 1		B		B SS	B SS	B SS	B SS	B SS
Bamboo 2		SS		SS	B SS	B SS	B SS	B SS
Bamboo 3			B	B	B	B	B	B
Bamboo 4		B SS		B	B	B	B	B
Bamboo 5	SS	SS	SS	SS	B SS	B SS	B SS	B SS
Bamboo 6	SS	B SS	SS	SS	B SS	B HS	B	B
Bamboo 7	B SS				B	B	B	B
Bamboo 8	SS	B SS		B	B	B	B	B

3.8. 'Barrier Island' Effect

Significant differences in total mean percent cover occurred based on three island parameters; enclosure and location (north or south and lakeward or landward) (n=15; DF = 14; Fit Model, F= 24.71; p<0.001) (Figure 3.8.1). The parameter of lakeward or landward accounted for 44% of variation in the total mean percent cover (p<0.001). The parameter or north or south accounted for 32% of variation (p=0.002). Enclosure accounted for 24% of variation (p=0.014).

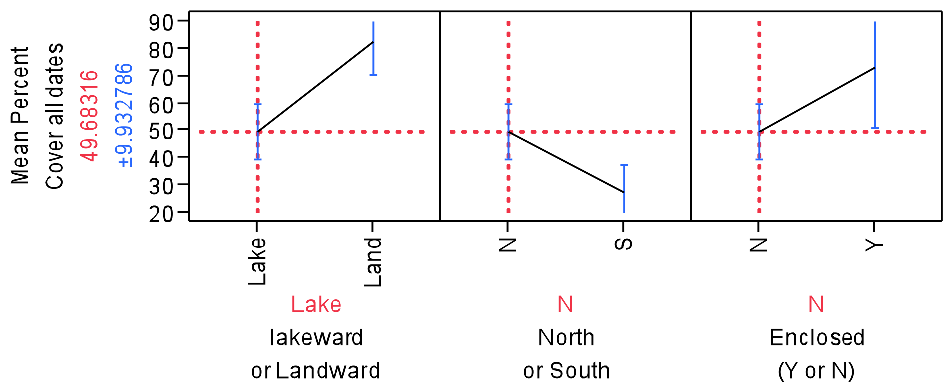


Figure 3.8.1: Island placement effects on total percent cover

4. Discussion

4.1. Percent Cover and Raft Material

Percent cover and raft material are important factors to consider when constructing artificial floating wetland islands. In this study, it was observed that island substrate failure caused percent cover to decrease. Visser and Sasser (2006) observed that if a frame was damaged, the substrate soon failed. For most of the Bamboo islands, the substrate broke apart too quickly for the plants to establish a large percent cover. There was no discernable pattern with regard to replanted Bamboo islands with new substrate versus those that were not replanted. In fact, Bamboo island 2 had the highest percent cover both above and below the island substrate even though the substrate and binding materials broke down very quickly. The plants on island Bamboo 2 were able to take advantage of the remnants of substrate and utilized the buoyant and sturdy Bamboo frame to help form a root mat. This island, however, was an anomaly. Most of the time, if the substrate broke apart the percent cover decreased.

Since there was no observable difference in the PVC raft material durability (Table 3.7.1), it is concluded that the success of PVC 5-7 can be attributed to the initial biomass stock, island placement, and enclosure. While percent cover can decrease by using inadequate materials, using ideal materials will not lead to increase in percent cover alone. Islands PVC 5-7 were planted later than all other islands and received an initial biomass stock of two to three times that of the other islands. One inference is that the island percent cover will be larger if the initial biomass planted is greater. So, if possible, one should fortify the island with a healthy stock of initial vegetation. The initial stock of the transplanted biomass on PVC islands 5-7, was sufficient enough to create a vegetative

cover that would prevent algae cover from increasing. Initial biomass on PVC islands 1-4 was not sufficient to compete with algae growth and cover. The emergent vegetation on PVC islands 5-7 thrived and established a thick root mat.

The differences in percent cover on islands PVC 1-4 and PVC 5-7 were attributable primarily to initial root and shoot biomass. Islands PVC 5-7 had at least twice the initial rootstock than islands PVC 1-4, so these islands were able to withstand the adverse effects of wildlife interference, wave height, wind, and algal mat cover, whereas PVC 1-4 was not able to recover from the initial biomass loss.

Some of the islands fared better than others due to a ‘barrier island effect’. The southernmost and lakeward islands were subject to the greatest influence of wind, water, and wave action (Figure 2.5.1 and Figure 3.8.1). These islands took the brunt of the wind and wave action and, by creating a harbor effect, helped protect the natural islands to the north and landward. The more exposed islands were subject to greater torque forces at the joints of the bamboo frame, which could have lessened the strength of the binding material causing these islands to lose their substrate and vegetation more quickly than the sheltered islands. The sheltered islands maintained a greater percent of biomass and substrate longer than the exposed islands. A similar phenomenon was observed by Kelly and Southwood (2006) when vegetation died on the outside edges of constructed floating rafts due to wind and wave action, but the more protected vegetation on the inside of the large island thrived. Furthermore, it was observed that plants growing on floating islands are more susceptible to wind and wave disturbances then similar bottom-rooted species (Azza et al., 2006). The enclosed islands also benefited from being protected, not by other islands but by the splashguard on the enclosure resulting in the

large percent cover through time. This effect should be accounted for in future applications of constructed floating wetland islands. Researchers could use large constructed islands to protect the vegetation on the inside of the island, smaller vegetated 'barrier islands' could be used to mitigate the disturbance from wind and waves to other floating wetland islands or to protect lakeshore vegetation, or other physical barriers could be used.

4.2. Percent Cover and Plant Category Characteristics

One goal of this experiment was to study plant growth characteristics to determine if there was a difference in percent cover on the islands by plant category. Pickerelweed and golden canna were two of the emergent species transplanted to the islands. Pickerelweed and golden canna cover generally decreased throughout this study, which is consistent with the findings from Medcalf and Rothenburg (2010). They observed a percent cover decline in pickerelweed and golden canna through June to October and observed *Ludwigia spp*. increase from less than 1% to 30% cover in a few months. In this study, it was observed the ludwigia was prevalent on most islands, even though it was not initially planted. In Louisiana, it was not uncommon for *Sagittaria lancifolia* to range from 1% to 75% cover on natural floating marshes, while *Pontederia cordata* and *Ludwigia spp.* were mostly nonexistent (Sasser et al., 1996). Also, the initial species transplanted were usually not the plants with the largest percent cover at the end of the study. In one study, artificial floating islands were initially planted with five emergent species, but within three years the community composition drastically shifted to include 20 different species and were very 'lush' (Nakamura and Mueller, 2008). These observations demonstrate that the percent cover and species composition of island

vegetation was constantly in flux, which is expected of a dynamic littoral system. It is important to account for the dynamics of floating wetland island vegetation when trying to establish and manage plant percent cover and category characteristics.

4.3 Biomass

Islands transplanted initially with the most biomass (roots, shoots, stems, and rhizomes) had the greatest percent cover by the end of the study. These findings match those of Visser and Sasser (2006), who observed that transplanting plant fragments of *Panicum hemitomon* led to greater shoot production then by transplanting only rhizomes or stems. Islands should initially be planted with as much biomass stock (shoots and roots) of the preferred species as possible to increase the chance of percent cover success.

Ludwigia was recorded to have the most biomass on all harvested islands (2,123 g/m^2) and significantly more than pickerelweed (320 g/m^2) (Figure 3.5.3). McGregor et al. (1996) found proportionately similar results where *Ludwigia grandiflora* had the higher biomass (61 g/m^2) when compared against *Pontederia cordata* (3 g/m^2) (McGregor et al., 1996). Ludwigia was not planted on any of the islands initially. This plant colonized new areas quickly and grew over other plants, which is the normal mode of growth for this species (Sears and Meisler, 2006).

Svengsouk and Mitsch (2001) observed *Schoenoplectus tabernaemontani* (softstem bulrush) increase in biomass (above and below ground) more rapidly after the first year of being planted from 150 g/m^2 after one year to 400 g/m^2 after the second year. The softstem bulrush from this experiment ended the 8-month study with 416 g/m^2 biomass. It is assumed that this plant would increase in biomass at a similar rate found by

Svengsouk and Mitsch (2001) if it was left on the floating wetland islands for a longer time period. It is inferred that floating wetland islands could provide more area for emergent species like softstem bulrush to colonize thus increasing the total biomass found in a wetland.

Sagittaria lancifolia was planted on the floating wetland islands in this study, but overall it did not contribute to a large amount of dry biomass (73 g/m^2 or 2%). This is not however, always the case. Mitsch et al. (2004) found that *Sagittaria* spp. could be a dominant wetland plant and accumulated 138 g of dry biomass for this plant. Furthermore, *Schoenoplectus* spp. was measured to have 356 g of dry biomass, the most aside from *Typha* spp. (Mitsch et al. 2004).

There has been little research about the influence of detritus on floating wetland island biomass. In this study detritus and other debris frequently washed onto the floating wetland islands. Debris might act as a substrate for plants, carry seeds, and contain nutrients, but might also impede plant establishment by shading or jostling effects. Debris accounted for a large portion of the biomass found on the floating wetland islands in this study (Figure 3.5.3) and the effect of debris on island vegetation, nutrients, and percent cover should be studied more in the future.

4.4 Plant Succession

There was a successional pattern observed over the course of the study. Although the pattern was not quite the same as stated in the literature (Huffman and Lonard, 1983; Sasser et al., 1996), the islands did undergo succession. Typically, the first colonizers on naturally occurring floating islands are the floating aquatic plants (Russel, 1942; John et

al., 2009). After the floating aquatics form a dense mat, herbaceous plants and shrubs can colonize the mat and complete their life cycles on the island (Adams et al., 2002). Furthermore, floating islands might change the community composition of the dominant lake species and help increase species richness through time (Cherry and Gough, 2006). What has not yet been discussed is the ability of the constructed island to continue the successional process after the loss of emergent vegetation.

As the initial emergent vegetation degraded or disappeared (due to island material failure or lack of a sufficient initial plant stock) FAV and algae began to colonize the island. Once the algae were established, especially in the summer months, it was difficult for the initial emergent vegetation to compete and it would cease to exist on the islands covered in algae or FAV. A similar pattern of a decrease in pickerelweed cover with a simultaneous increase in water lettuce percent cover was observed within an experimental treatment wetland (Hadad et al., 2006). Conversely, the islands with the most emergent vegetation cover usually had the least FAV and algae cover. A similar trend was observed with regard to submerged aquatic vegetation and algae. Algae cover was documented to decrease with the addition of submerged aquatic vegetation (SAV) and increase with the lack thereof (Bayley et al., 2007). In this study, once the algae died back in late summer, emergent colonizers like ludwigia and floating aquatics such as water lettuce and duckweed were able to colonize the island and utilize the floating frame as an anchor. This trend implies that floating islands with the greatest percent cover of emergent vegetation will be influenced less by potential algae blooms in eutrophic lakes due to decreased effects of potential competition.

All islands followed the trend (increase in emergent cover matched by an equivalent decrease in FAV/algae cover) except for PVC islands 5-7. These islands were unique because as the emergent vegetation increased, so did FAV percent cover. Since these islands were enclosed for another research study (Jangrell-Bratli, 2011) all duckweed that was on the island prior to enclosure was trapped then multiplied, which is why these islands didn't follow the trend observed for the other islands.

Another successional trend was observed with seasonal changes in plant category percent cover. Specifically, algae increased in percent cover on the islands during the hot summer months and decreased in the fall. This is another reason for why emergent vegetation might have done poorly on some islands. As the algae grew in the lake study site, it quickly amassed on floating objects like the PVC mesh substrate and persisted until the temperature decreased. After the algae died back, other plant species colonized the islands.

4.5. Islands Weights

It has been assumed that weight does not make much of a difference with regard to plant percent cover, or island durability as long as the island remains buoyant (Kerr-Upal et al., 2000; Visser and Sasser, 2006). The heaviest islands in the beginning of the weighing experiment (Bamboo 4-7) were not the heaviest islands by the end of the study (PVC 5-7 and Bamboo 2) (Figure 3.4.1). This suggests that even with the added water weight by the end of the study, the lighter PVC islands actually showed the most biomass increase. However, it is difficult to correlate island weight alone to the positive increase in biomass for the PVC islands. It is advised that island weight be accounted for in future experimental studies since lighter islands could be subjected to more damage from wind

and storm events. Ideally, there would be a balance between initial island weight and maximum island weight to retain buoyancy and prevent against wind and storm damage.

4.6. Nitrogen, Carbon, and Phosphorus

Nutrients are very important to the overall success of artificial wetland islands and islands are often used to remove excess nutrients (Zhou and Wang, 2010). Nutrients were compared in this study to determine if island type would influence plant nutrient accumulations. Species composition was different between island substrate types, so while raft material might not lead to a significant difference in nutrient concentrations, species composition and biomass accumulation on the islands does.

The PVC islands had a higher nitrogen percentage (4.2%) than Bamboo islands (2.90%) (Figure 3.6.1) resulting from different biomass types on each island type. At the end of the study, ludwigia and water lettuce were the predominant living vegetation on the PVC islands. These plants also had a higher nitrogen and phosphorus percents when compared with other species such as flat sedge, pickerelweed, and softstem bulrush (Figure 3.6.3). The later species were more likely to be found on the Bamboo islands. The Bamboo islands had more total biomass, which resulted in a lesser nitrogen percentage (Figure 3.5.1; Figure 3.6.1). This is expected since biomass is inversely proportional to nitrogen content in plant tissues due to nutrient distribution and dilution within the plant (Reddy and DeLaune, 2008). Also, wetland plants accumulate nitrogen in different ways and rates. Water lettuce tends to thrive in eutrophic environments (Ghavzan et al., 2006) and ludwigia will grow more quickly with increased nitrogen and phosphorous concentrations (Sears and Meisler, 2006). Conversely, softstem bulrush

does not grow as quickly as other emergent plants in eutrophic conditions (Svengsouk and Mitsch, 2001).

The PVC islands had a higher percent carbon (41%) than the Bamboo islands (39%) (Figure 3.6.4). This difference results from the types of cover on each island type. Detritus is high in carbon content since it is mainly composed of lignin, which is resilient to microbial breakdown (Reddy and DeLaune, 2008) (Figure 3.6.6). Normally photosynthetic material has around 45-50% carbon while detritus has about 40% carbon (Reddy and DeLaune, 2008). Therefore, the islands with more photosynthetic material should have a higher carbon percent, but this is not what I observed on the islands. I found that the islands with greater photosynthetic material (Bamboo islands) had less carbon percent than those islands covered in debris (PVC islands). The PVC islands were less covered with emergent vegetation and still had bare island substrate intact. Consequently, more debris in the form of detritus washed onto these islands. They were not completely bare and ludwigia colonized most of the PVC islands by the end of the study increasing the carbon percent of these islands. The Bamboo islands, however, had a greater mass of carbon (317.71 g/m^2) than the PVC islands (56.07 g/m^2) demonstrating that they were in fact covered with greater photosynthetic material. The dominance of ludwigia on the PVC islands led to the increase in carbon because this emergent plant had slightly more mass (39.56 g/m^2) than the emergent vegetation on the Bamboo islands (39.47 g/m^2).

Water lettuce was measured to have more percent phosphorus (0.42%) than other plants (Figure 3.6.9) even through the biomass was relatively low (Figure 3.5.3). Water lettuce was found more often on the PVC islands than Bamboo islands. Water lettuce

tends to thrive in eutrophic environments (Ghavzan et al., 2006) and therefore is adapted biologically to take up large amounts of nutrients. The PVC islands had more percent phosphorus (0.30%) than Bamboo islands (0.16%) (Figure 3.6.7) even through the Bamboo islands had more phosphorus mass (Figure 3.6.8). At the end of the growing season, emergent wetland plants will move tissue phosphorus to the roots to store the nutrient over the winter (Reddy and DeLaune, 2008). Since the biomass was harvested and nutrients measured in December, it is likely the emergent vegetation (in higher quantities on Bamboo islands) had already translocated the nutrient to the root section of the plant resulting in the higher root percent phosphorus on Bamboo islands (Figure 3.6.9). Tanner (1996) observed this when all emergent species had more phosphorus content in the roots than shoot tissue. It should be understood that nutrients will shift concentrations within the floating wetland island based on species composition.

4.7. Floating Island Materials

Materials for the CFWIs were chosen based on the 'natural' versus 'artificial' hypothesis. The use of 'natural' materials chosen (Bamboo, hemp, burlap, sisal rope, and canvas) was meant to mimic naturally occurring tussock islands. All natural materials used were assumed to biodegrade eventually in an aquatic environment. I hypothesized that Bamboo islands would persist long enough for the plants to develop a persistent and buoyant root mat and would no longer need the support from the constructed Bamboo island frame and substrate. Bamboo had been shown to be resilient in an aquatic environment for at least six months (Sasser et al., 2006). The combination of a Bamboo frame with burlap, canvas, or sisal net substrate was never tested before my study. Sasser et al. (2006) noted that in prior studies some substrates failed due to frame submergence,

but Bamboo was not one of those materials. I used the natural rope and burlap, which Sasser et al. (2006) demonstrated to degrade, but attached them to a more buoyant Bamboo frame. I assumed these materials would be ideal if the Bamboo frame remained buoyant.

After six weeks, the bamboo islands 1, 4, 5, 6, 7 and 8 with a burlap substrate failed, even though the Bamboo frame remained buoyant. Even after these islands received new natural fiber substrates, the material failed again before the end of the study while the frame remained buoyant. The binding materials, sisal and hemp, were likely not suitable for the aquatic environment. The substrate broke quickly due to the failure of the binding materials. A more water resistant binding material such as waxed linen might have lasted longer and prevented substrate disintegration.

Bamboo is still recommended as a viable floating island material, but more research would need to be done to find a comparable natural binding material to hold the Bamboo frame together. Other methods could be used rather than lashing Bamboo poles together like rivets, dowel joints, or notches to secure the poles together. Furthermore, it was not entirely concluded that burlap or canvas are not viable substrate options for floating islands. Although these materials did break down very quickly in this experiment, these materials could be manipulated in other ways to reinforce their strength and longevity, such as layering different natural materials on top of each other, or using multiple layers of the same substrate material. The goal for the Bamboo islands was for them to eventually break down *after* the plants had established an intertwined buoyant root mat. If this is the goal of future research, island materials should be chosen that are

durable for at least a year, but would eventually disintegrate and leave only the plants, roots, detritus, and microbes behind.

PVC was used for the 'artificial' islands because it was demonstrated that PVC frame islands were very durable in the aquatic environment (Sasser et al., 2006). The synthetic CFWI materials proved very durable over the course of this study, even though they were waterlogged after eights months in the aquatic environment. Since PVC will last for a long time, it is very important that this material maintain buoyancy or else the whole island could sink to the lake bottom. By adding extra floating devices, such as buoys, to the outside of the PVC island frame buoyancy could be achieved. A liquid foam injection could be used to fill the inside of the PVC pipes so when the foam expands, there are minimal crevices for water to seep in and this will help maintain buoyancy. The differences in plastic material substrate did not seem to make a difference in PVC floating island viability and biomass productivity.

4.8. Wildlife

As mentioned in the introduction, natural and artificial floating islands have been observed to provide wildlife habitat for birds, fish, and other creatures (Oliver and McKaye, 1982; Burgess and Hirons, 1992; Nakamura and Muller 2008). It was observed that various forms of wildlife used the floating wetland islands in this study. Many birds, such as *Butorides* (green heron) and *Gallinula* (common moorhen) would perch on the island frames to bathe, prune, or fish. An urban colony of *Quiscalus major* (boat-tailed grackles) was observed to use the islands (Snyder, 2011). Turtles would use the islands to sun themselves. Minnows utilized the island's protective cover. Many insect and crustacean species were observed under and around the islands. For these reasons, it can

be concluded that many forms of wildlife did benefit from the floating wetland islands at the study site.

5. Conclusion

Overall, the biomass was greater on those constructed floating wetland islands that remained mostly intact, received a large rootstock during the initial transplant, and were protected (mean PVC enclosed: 1,511 g/m^2).

The hypothesis that island substrate does not make a difference in plant growth characteristics was demonstrated to be false. The PVC islands led to more plant growth (emergent, algae, and FAV). Too many of the Bamboo islands fell apart and caused the plants to wash away (Bamboo 3, 5-8). On the Bamboo islands, most of the biomass at the end of the study was emergent vegetation in the form of ludwigia (Bamboo 1,2,4: 57%). On the PVC islands, most of the percent cover was due to floating aquatic vegetation like duckweed, but most of the biomass was from emergent vegetation. This is partly due to the rapid colonization by ludwigia. The hypothesis that the same plant categories would exist in the same distributions regardless of substrate type was incorrect. The islands were dynamic with regard to plant composition and successional changes were observed (emergent transplanted species to FAV and algae to ludwigia).

It was difficult to draw conclusions about island weight affecting biomass percent cover. Since the heavier Bamboo islands broke apart and the lighter PVC islands did not, I could conclude that lighter frames are more durable than heavier frames. However, this is not necessarily the case. The heavy Bamboo islands did not fail because they were too heavy, but rather they were not held together well. I conclude that there should be a balance between island weight and buoyancy.

The hypothesis that plant nutrients would not vary based on island type but by plant category was correct. The island type was not significant with regard to island nutrient accumulation, but rather the plant categories that comprised the island. Ludwigia and water lettuce had the greatest percent nutrients across all islands (N = 3.7% and 3.9%; P = 0.2% and 0.4%). Also, if an island was more open than a completely covered, very dense island, than there was generally more debris occurring on the open island (PVC 1 =38%). This could be a potential nutrient source for other plant colonizers.

The materials for the PVC constructed floating wetland island proved more durable over the course of the study. The materials remained buoyant, even after water seeped into the PVC tubing. The mesh substrate held together and did not break away from the island fame. The Bamboo island frames remained buoyant over the course of the study, but most of the islands broke apart due to the disintegration of the natural binding materials. Bamboo is still recommended as a viable floating island frame material, but other options for connecting the poles together are needed. The hypothesis that PVC was more durable was correct, but the hypothesis that the Bamboo islands would only break apart after vegetation had established a root mat was not.

This research study demonstrated that it is possible to transform an artificial floating wetland island constructed from 'all natural' materials into a self-sustaining floating wetland island after the island frame and materials break down if: 1. the initial plant biomass is hardy and 2. the island is protected from wind and wave activity. In the end, there are many benefits artificial floating wetland islands provide if they are constructed optimally, protected, and plant species are chosen based on local conditions.

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7. Appendices

Appendix A: Biomass weights after harvest and after oven drying.

Bag Number	Corresponding Island	Full Aluminum Foil (g)	Empty Aluminum Foil (g)	Full Brown Bag (kg)	Empty Brown Bag (g)	Before Weight (g)	After Weight with plastic (g)	Plastic bag (g)	Final Dry Weight (After weight minus plastic bag weight) (g)
1	A1	3.3405	1.8097			1.5308	3.67	2.4	1.27
2	A1	30.97	3.63			27.34	31.11	6.39	24.72
3	A1	70.31	4.9267			65.3833	40.32	8.62	31.7
4	A1	11.6315	3.325			8.3065	9.99	2.46	7.53
5	A1	75.2795	3.9601			71.3194	56.01	9.51	46.5
6	A1			16220	7.2	16212.8			0
7	A1	17.0026	3.4578			13.5448	12.18	2.45	9.73
8	A2	3.1245	3.0196			0.1049	2.55	2.47	0.08
9	A2	20.32	2.93			17.39	18.37	2.52	15.85
10	A2	3.1298	2.053			1.0768	3.44	2.47	0.97
11	A2	7.4117	1.7681			5.6436	7.53	2.44	5.09
18	A3	32.6894	4.2214			28.468	17.01	2.626	14.384
19	A3	42.31	4.2235			38.0865	34.33	9.49	24.84
20	A3	37.0804	4.7087			32.3717	20.74	2.44	18.3
21	A3	9.07	1.8097			7.2603			0
22	A3	8.54	2.3			6.24	10.6	4.83	5.77
23	A3	36.84	4.2782			32.5618	13.3	2.46	10.84
24	A3	10.5045	1.6073			8.8972	6.97	2.99	3.98
25	A4	41.73	8.15			33.58	35.27	4.81	30.46
26	A4	113.17	6.6833			106.4867	34.53	9.34	25.19
27	A4	23.28	6.16			17.12	18.02	2.49	15.53
28	A4	12.4103	3.0197			9.3906	9.8	2.2151	7.5849
29	A4		10.0294	167.92	62.31	105.61	107.51	8.69	98.82
30	A4	9.15	2.05			7.1	11.28	8.45	2.83
31	A5		11.6155	172.95	53.12	119.83	109.8	9.08	100.72
32	A5	131.5	5.9148			125.5852	63.13	9.77	53.36
33	A5	140.9	11.568			129.332	113.92	9.36	104.56
34	A5		45.84	2520	54.07	2465.93	577.74	34.92	542.82
35	A5		12.8418	680	56.52	623.48	144.86	8.74	136.12
36	A5		21.68	1760	50.36	1709.64	305.63	18.31	287.32
37	A5		18.4	1480	56.64	1423.36	239.2	18.59	220.61
38	A6		21.91	540			128.2	9.46	118.74
39	A6		9.24	124.98	55.49	69.49	43.75	8.73	35.02
40	A6		17.54	159.28	54.94	104.34	147.5	9.44	138.06
41	A6		24.55	2000	56.42	1943.58	451.68	27.49	424.19
42	A6	165.05	10.06			154.99			0
43	A6	8.25	1.8097			6.4403			0
44	A6	2.9357	2.0518			0.8839	3.25	2.42	0.83
45	A6	5.1387	2.9346			2.2041	4.46	2.47	1.99
46	A6	10.9092	3.3229			7.5863	7.6	2.47	5.13
47	A6	5.2084	4.7696			0.4388	2.9	2.48	0.42

Appendix A: Biomass weights after harvest and after oven drying (continued).

Bag Number	Corresponding Island	Full Aluminum Foil (g)	Empty Aluminum Foil (g)	Full Brown Bag (kg)	Empty Brown Bag (g)	Before Weight (g)	After Weight with plastic (g)	Plastic bag (g)	Final Dry Weight (After weight minus plastic bag weight) (g)
48	A6		11.9183	1000	57.84	942.16	157.08	9.24	147.84
49	A6	9.48	4.91			4.57	10.44	6.33	4.11
50	A6		12.8301	149.45	55.99	93.46	108.65	8.62	100.03
51	A6			3140	61.23	3078.77	621.77	44.59	577.18
52	A7	67.09	8.4			58.69	59.02	5.01	54.01
53	A7			97.83	54.68	43.15	43.35	4.98	38.37
54	A7		11.658	160	50.6465	109.3535	80.08	9.6	70.48
55	A7			186.95	59.42	127.53	297.75	17.60	280.15
56	A7	160.71	9.56			151.15	135.78	9.51	126.27
57	A7			185.47	22.83	162.64	155.54	8.85	146.69
58	A7		8.1483	240	7.5874	232.4126	115.93	9.43	106.5
59	A7	10.3824	3.458			6.9244	9.08	2.47	6.61
60	A7	6.5374	3.2557			3.2817	5.59	2.45	3.14
61	A7	7.65	3.94			3.71	8.27	4.8	3.47
62	A7	9.5531	2.2847			7.2684	7.68	2.45	5.23
63	A7	28.82	3.25			25.57	27.36	4.79	22.57
64	A7	148.59	28.56			120.03	168.43	9.18	159.25
65	A7	8.428	3.5858			4.8422	7.16	2.49	4.67
66	A7	143.05	8.21			134.84	139.05	9.47	129.58
67	A7			162.82	55.64	107.18	253.53	17.43	236.1
68	N1	25.6002	5.64			19.9602	13.21	2.46	10.75
69	N1	77.792	8.2664			69.5256	43.79	9.38	34.41
70	N1			170.84	59.32	111.52	212.05	17.45	194.6
71	N1	27.82	8.28			19.54	19.91	2.5	17.41
72	N1	134.71	6.1582			128.5518	74.38	9.6	64.78
73	N2	13.6964	3.3193			10.3771	15.66	9.54	6.12
74	N2	16.82	4.15			12.67	16.42	4.81	11.61
75	N2			166.67	32.6	134.07	150.45	9.22	141.23
76	N2		20.6954	1040	57.4	982.6	154.76	9.53	145.23
77	N2		19.6885	1440	59.06	1380.94	154.01	8.57	145.44
78	N2	148.46	6.8284			141.6316	117.32	9.43	107.89
79	N2	34.9586	4.1569			30.8017	17.87	2.45	15.42
80	N2	28.246	3.2974			24.9486	11.32	2.38	8.94
81	N2			162.56	55.61	106.95	260.94	17.64	243.3
82	N2		15.6188	520	60.26	459.74	199.69	17.68	182.01
84	N2			2540	155.53	2384.47	296.54	17.59	278.95
85	N2			1220	55.17	1164.83			0

Appendix A: Biomass weights after harvest and after oven drying (continued).

Bag Number	Corresponding Island	Full Aluminum Foil (g)	Empty Aluminum Foil (g)	Full Brown Bag (kg)	Empty Brown Bag (g)	Before Weight (g)	After Weight with plastic (g)	Plastic bag (g)	Final Dry Weight (After weight minus plastic bag weight) (g)
86	N2			153.54	54.93	98.61	96.55	8.85	87.7
87	N4	86.02	4.5889			81.4311	32.27	2.47	29.8
88	N4			136.15	55.46	80.69	60.21	4.8	55.41
89	N4			1320	61.9	1258.1	146.86	8.72	138.14
90	N4	29.1901	3.8248			25.3653	19.1	2.45	16.65
91	N4			179.85	57.87	121.98	192.05	11.24	180.81
92	N4		6.1404	500	83.155	416.845	77.2	8.93	68.27
93	N2	9.66	4.71			4.95	9.27	4.86	4.41
94	A5	2.0409	1.8852			0.1557	2.59	2.43	0.16
95	N1	46.49	3.6232			42.8668	24.6	2.48	22.12
12-17	A3	155.9	11.18			144.72	130.22	8.78	121.44

Appendix B- Percent Cover

Table A.1: Percent cover values for island PVC 1

Sampling Date	*Pontederia cordata*	*Canna flaccida*	*Schoenoplectus tabernaemontani*	*Ludwigia grandiflora*	*Colocasia esculenta*	Algae	*Spirodela polyrhiza*	*Pistia stratiotes*	Debris	**TOTAL**
4/21/10	25	30	10	0		0			0	65
5/1/10	25	11	11		1	30			25	65
5/13/10	12	4	14	0	1	70			25	80
5/26/10	10	3	10	2	3	30			50	65
6/8/10	5	0	21	7	0	60			40	70
6/19/10	8	0	6	5	0	50			35	65
6/22/10	3	0	5	5	1	75			50	75
7/9/10	5	0	5	7	0	75			20	75
8/4/10	0	0	4	5	0	75			30	90
8/19/10	0	0	9	5	0	50	25	3	75	75
8/30/10	0	0	6	0	0	35	15	2	45	60
9/14/10	0	0	10	0	0	60	20		50	60
9/24/10	0	0	4	0	0	80	0		50	85
10/8/10	0	0	10	0	0	90	30		50	90
10/26/10	0	0	4	10	0	100	40		40	100
12/4	0	0	6	30	0	50	50	50	25	90

Table A.2: Percent cover values for island PVC 2

Sampling Date	*Pontederia cordata*	*Canna flaccida*	*Schoenoplectus tabernaemontani*	*Ludwigia grandiflora*	*Colocasia esculenta*	Algae	*Spirodela polyrhiza*	*Pistia stratiotes*	Debris	**TOTAL**
4/21/10	11	16	14			0			15	41
5/1/10	9	10	11			0			10	30
5/13/10	7	6	8			40			10	61
5/26/10	4	4	5			0			10	16
6/8/10	9	0	16		2	10			40	31
6/19/10	0	0	8			0			30	8
6/22/10	0	0	15	3		0			30	15
7/9/10	0	0	15	4		70			15	70
8/4/10	0	0	0			80				80
8/19/10	0	0	0			95		2	25	95
8/30/10	4	0	0	5		60	10		10	80
9/14/10	0	0	0			60	5		30	65
9/24/10	0	0	0			60	20		15	60
10/8/10	0	0	0			20	5		5	20
10/26/10	0	0	0			100	30		5	100
12/4	0	0	0			0	20		5	35

Appendix B- Percent Cover (continued)
Table A.3: Percent cover values for island PVC 3

Sampling Date	*Pontederia cordata*	*Canna flaccida*	*Scirpus* ssp.	*Ludwigia grandiflora*	*Cyperus odoratus*	Algae	Spirodela polyrhiza	Pistia stratiotes	Debris	**TOTAL**
4/21/10	20	25	25	0		0		0	0	70
5/1/10	11	21	10	0		0			3	47
5/13/10	14	18	2	0		15			3	55
5/26/10	16	9	6	0		40			25	33
6/8/10	17	9	12	0		70			25	85
6/19/10	10	0	4	5		20			30	60
6/22/10	7	0	4	0		30			40	11
7/9/10	5	0	3	0		50	3	0	40	11
8/4/10	2	0	3	5		60			10	75
8/19/10	0	0	2	15		60			40	75
8/30/10	0	0	2	15		10	100		100	100
9/14/10	0	0	5	10	2	10			60	25
9/24/10	0	0	0	10	2	30			25	40
10/8/10	0	0	0	10	2	80			25	90
10/26/10	0	0	0	2	5	100			20	100
12/4	0	0	0	50	5	20		10	30	75

Table A.4: Percent cover values for island PVC 4

Sampling Date	*Pontederia cordata*	*Canna flaccida*	*Schoenoplectus tabernaemontani*	*Ludwigia grandiflora*	Algae	*Spirodela polyrhiza*	*Pistia stratiotes*	Debris	**TOTAL**
4/21/10	20	30	15	0	0			0	65
5/1/10	2	18	8	0	0			10	28
5/13/10	5	15	10	0	15			10	55
5/26/10	4	16	10	0	15			15	45
6/8/10	8	18	12	0	50	3		25	70
6/19/10	0	0	2	20	50	3		30	60
6/22/10	0	0	5	10	50			30	50
7/9/10	0	0	5	15	40	0	0	15	20
8/4/10	0	0	0	5	60			10	60
8/19/10	0	0	0	10	50		5	20	65
8/30/10	0	0	2	10	30		3	30	40
9/14/10	0	0	0	10	25			25	35
9/24/10	0	0	0	10	5			15	15
10/8/10	0	0	0	15	20			10	30
10/26/10	0	0	0	10	100			10	100
12/4	0	0	0	50	50		20	10	65

Appendix B- Percent Cover (continued)

Table A.5: Percent cover values for island PVC 5

Sampling Dates	*Pontederia cordata*	*Sagittaria lancifolia*	*Schoenoplectus tabernaemontani*	*Ludwigia grandiflora*	Algae	*Spirodela polyrhiza*	*Pistia stratiotes*	Debris	**TOTAL**
5/13/10	30	30	30	0	2	0		5	90
5/18/10	25	25	25	0	5	2		5	75
5/26/10	25	25	25	0	5	2		5	75
6/9/10	25	25	25	3	15	3		5	75
6/24/10	40	10	11	10	5	2		30	65
7/6/10	12	17	8	20	5	0		10	60
7/21/10	13	17	11	20	10	3		10	60
8/2/10	13	14	10	30	20	10		10	80
8/19/10	5	10	9	30	45	20	6	20	60
9/3/10	4	10	11	20	5	100		30	100
9/14/10	6	7	9	29	5	100	4	10	100
9/27/10	9	11	9	90	5	100		5	100
10/12/10	8	12	9	27	5	100		5	100
10/26/10	6	6	12	45	5	100		5	100
12/4/10	6	6	12	45	5	100	6	5	100

Table A.6: Percent cover values for island PVC 6

Sampling Dates	*Pontederia cordata*	*Sagittaria lancifolia*	*Schoenoplectus tabernaemontani*	*Ludwigia grandiflora*	*Colocasia esculenta*	Algae	*Spirodela polyrhiza*	*Cyperus odoratus*	Debris	**TOTAL**
5/13/10	25	25	25	0	0	5	0	0	5	75
5/18/10	25	25	25	0	0	5	0	0	5	75
5/26/10	22	19	19	0	0	3	0	0	10	70
6/9/10	20	13	14	5	0	5	4	0	80	90
6/24/10	20	10	10	30	0	5	5	0	50	80
7/21/10	13	15	14	15	0	5	5	0	5	50
8/2/10	13	10	6	15	0	20	15	0	30	60
8/19/10	6	7	6	20	0	20	20	0	50	80
9/3/10	5	9	11	8	0	5	100	0	75	100
9/14/10	12	7	6	14	0	5	100	0	20	100
9/27/10	12	11	12	23	0	5	100	0	10	100
10/12/10	18	7	9	19	0	5	100	0	15	100
10/26/10	12	8	12	24	0	1	100	0	7	100
12/4/10	13	13	9	40	0	3	90	5	5	100

Appendix B- Percent Cover (continued)

Table A.7: Percent cover values for island PVC 7

Sampling Dates	*Pontederia cordata*	*Sagittaria lancifolia*	*Schoenoplectus tabernaemontani*	*Ludwigia grandiflora*	Algae	*Spirodela polyrhiza*	*Pistia stratiotes*	Debris	**TOTAL**
5/13/10	25	25	25	0	4	0	0	3	75
5/18/10	25	25	25	0	0	0	0	2	75
5/26/10	25	20	19	0	5	2	0	10	75
6/9/10	25	22	15	5	10	2	0	10	75
6/24/10	25	20	15	10	4	2	0	10	80
7/6/10	15	21	10	3	0	0	0	5	70
7/21/10	19	16	10	6	5	10	0	10	70
8/2/10	13	9	9	5	5	10	0	10	70
8/19/10	10	16	9	11	10	40	2	75	80
9/3/10	8	8	12	11	10	100	0	70	100
9/14/10	10	6	9	15	5	100	4	70	100
9/27/10	14	11	15	9	10	100	4	20	100
10/12/10	14	9	9	3	10	100	4	10	100
10/26/10	9	7	6	9	10	100	6	15	100
12/4/10	12	10	9	12	10	100	6	10	100

Table A.8: Percent cover values for island Bamboo 1

Sampling Dates	*Pontederia cordata*	*Canna flaccida*	*Schoenoplectus tabernaemontani*	*Sagittaria lancifolia*	*Ludwigia grandiflora*	*Colocasia esculenta*	Algae	*Spirodela polyrhiza*	*Pistia stratiotes*	Debris	**TOTAL**
4/21/10	20	23	10		0		0	0	0	0	53
5/1/10	23	18	14				5			20	55
5/13/10	15	10	9			2	10			10	40
5/26/10	19	2	8		7		10		2	40	30
5/27/10	25	0	17	26			5			50	65
6/8/10	20	0	21	22	10		5			40	73
6/19/10	18	0	12	10	25		5			50	30
6/22/10	14	0	12	19	30		5			70	75
7/9/10	20		12	5	50		5			25	87
8/4/10	10	0	12	0	85		10				90
8/30/10	12		15	0	100	2	10	0		50	90
9/14/10	0		25	10	30			30		100	70
9/24/10	4	0	23	11	15		10	20		90	100
10/8/10	6	0	18	12	20		80		2	10	100
10/26/10	4		12	0	40		40	50		20	90
12/4	5	0	6	0	30		10	90	15	10	100

Appendix B- Percent Cover (continued)

Table A.9: Percent cover values for island Bamboo 2

Sampling Dates	*Pontederia cordata*	*Canna flaccida*	*Scirpus* ssp.	*Ludwigia grandiflora*	Cyperus odoratus	Algae	*Spirodela polyhiza*	*Pistia stratiotes*	*Limnobium spongia*	*Hydrocotyle* spp.	Debris	**TOTAL**
4/21/10	20	12	13	0		0	0	0			0	45
5/1/10	20	5	9			5					30	34
5/13/10	16	3	6	40		10					10	80
5/26/10	13	0	6	75		15	2				15	90
6/8/10	13	0	12	90		10					30	100
6/19/10	8	0	10	90							20	100
6/22/10	11	0	8	90		10					20	100
7/9/10	11	0	9	90		5					20	100
8/4/10	8	0	4	100		10					30	100
8/30/10	8	0	6	60	5	10	30				50	80
9/14/10	6	4	15	60	25	10	25				40	100
9/24/10	8	0	11	50	50	10	25				25	100
10/8/10	8	0	11	45	60	5					10	100
10/26/10	12	0	13	40	60	10	30			20	30	100
12/4/10	6	0	8	40	80	5	25	10	10	20	5	100

Table A.10: Percent cover values for island Bamboo 3

Sampling Dates	*Pontederia cordata*	*Canna flaccida*	*Schoenoplectus tabernaemontani*	*Ludwigia grandiflora*	*Colocasia esculenta*	Algae	*Spirodela polyrhiza*	*Pistia stratiotes*	Debris	**TOTAL**
4/21/10	18	16	10	1		0	0		0	44
5/1/10	13	17	3						10	33
5/13/10	8	12	1	15	2	2			60	26
5/26/10	19	14	5	10		5	10		60	50
6/8/10	15	3	4	10		5	2		5	27
6/19/10	10	0	3	5		5			5	15
6/22/10	7	0	0	5	2	10			5	10
7/9/10	0	0	0	2		5	2	7	5	10
8/4/10	0	0	0	0		5	1		15	5
8/19/10	10	0	0	2		5	15	2	30	15
8/30/10	17	0	0	5		5	80	2	80	95
9/14/10	15	0	0	2		15	70	3	80	95
9/24/10	19	0	0	0		10	5		5	19
10/8/10	8	0	0	0		10	5		2	10
10/26/10	0	0	0	10		15	10		6	30

Appendix B- Percent Cover (continued)

Table A.11: Percent cover values for island Bamboo 4

	Pontederia cordata	*Canna flaccida*	*Schoenoplectus tabernaemontani*	*Ludwigia grandiflora*	Algae	*Spirodela polyrhiza*	*Pistia stratiotes*	Debris	**TOTAL**
4/21/10	15	20	8					0	43
5/1/10	10	14	7	0	4			10	31
5/13/10	9	10	8		5			10	29
5/26/10	4	0	0		5			5	9
5/27/10	20	33	10		5	0		20	63
6/8/10	18	26	8	0	10	2	0	25	52
6/19/10	16	5	10	0				25	26
6/22/10	10	7	9	0	10			50	26
7/9/10	15	10	12		5			15	37
8/4/10	17	0	10	0	5	10	0	50	30
8/19/10	6	0	10		10	20		30	20
8/30/10	0	0	0	0	3	1	0	10	2
9/14/10	0	0	0	0	10	20	2	30	22
9/24/10	0	0	0	0	5	1	0	5	2
10/8/10	0	0	0	0	10	2	0	5	10
10/26/10	0	0	0	0	0	0	0	0	0
12/4/10	0	0	8	100	10	25		10	100

Table A.12: Percent cover values for island Bamboo 5

Sampling Dates	*Pontederia cordata*	*Canna flaccida*	*Schoenoplectus tabernaemontani*	*Sagittaria lancifolia*	*Ludwigia grandiflora*	Algae	*Spirodela polyrhiza*	*Pistia stratiotes*	Debris	**TOTAL**
4/21/10	25	20	10	0	0	0	0	0	10	60
5/1/10	19	13	7	0	10	5			30	50
5/13/10	22	12	8	0	5	20	2	0	20	50
5/26/10	15	0	0			15			30	30
5/27/10	22	19	10	0	0	0	0	0	30	63
6/8/10	15	15	8	0	0	30	0	0	20	50
6/19/10	18	19	10	0	0	20	2		30	50
6/22/10	14	17	9	0	0	40			45	50
7/9/10	15	5	12	7	0	40	10	2	30	50
8/4/10	17	5	10	15	5	20	2	0	60	70
8/19/10	6	0	10	12	0	25	10	15	50	50
8/30/10	10	0	0	5	10	15	80		60	80
9/14/10	8	0	0	7	0	20	50	0	60	60
9/24/10	10	0	0	7	4	15	5	5	40	50
10/8/10	10	0	0	10	50	90	5	0	10	100
10/26/10	0	0	0	10	40	80	50	5	30	100

Appendix B- Percent Cover (continued)

Table A.13: Percent cover values for island Bamboo 6

	Pontederia cordata	*Canna flaccida*	*Sagittaria lancifolia*	*Schoenoplectus tabernaemontani*	*Ludwigia grandiflora*	Algae	*Spirodela polyrhiza*	*Pistia stratiotes*	Debris	**TOTAL**
4/21/10	10	15	0	10	0	5	0	0	5	35
5/1/10	5	8	0	0	5	20	4	4	25	25
5/13/10	6	0	0	1	0	10	6	0	15	7
5/26/10	0	0	0	0	0	0	0	0	10	0
5/27/10	11	0	15	20	0	10	0	0	30	50
6/8/10	12		16	17		20			30	50
6/19/10	8	0	9	14	0	20		0	30	31
6/22/10	10	0	11	13	0	35	10		35	34
7/9/10	10	0	7	10	0	30	20		35	30
8/4/10	9	0	4	6		5	5		30	30
8/19/10	10	0	3	5	0	60	5		25	60
8/30/10	10	0	2	0	5	50	20		25	50
9/14/10	10	0	0	0	0	25	15	3	25	30
9/24/10	0	0	0	0	5	5	15	0	5	5
10/8/10	0	0	0	0	1	10	5	0	2	10
10/26/10	0	0	0	0	5	10	10	5	5	10

Table A.14: Percent cover values for island Bamboo 7

	Pontederia cordata	*Canna flaccida*	*Sagittaria lancifolia*	*Schoenoplectus tabernaemontani*	*Ludwigia grandiflora*	Algae	*Spirodela polyrhiza*	*Pistia stratiotes*	Debris	**TOTAL**
4/21/10	20	20	0	10	0	0	0	0	5	50
5/1/10	16	12	0	6	5	5	0	0	15	35
5/13/10	11	9	0	5	0	6		0	15	30
5/26/10	12	2	0	7	0	5		0	20	21
5/27/10	19	0	16	13	0	0	0	0	15	48
6/8/10	21	0	21	11		0	0	0	20	53
6/19/10	12	0	0	10	0	25	3	0	25	30
6/22/10	16	0	0	4	0	25	4	0	25	20
7/9/10	12	0	0	5	0	10	10	0	30	20
8/4/10	12	0	0	6		5		0	30	20
8/19/10	8	0	0	0	0	100		0	15	100
8/30/10	0	0	0	0	5	5	5	0	5	5
9/14/10	0	0	0	0	0	5	10	0	30	10
9/24/10	0	0	0	0	5	5	4	4	10	5
10/8/10	0	0	0	0	1	20	5	0	5	10
10/26/10	0	0	0	0	5	5		0	10	20

Appendix B- Percent Cover (continued)

Table A.15: Percent cover values for island Bamboo 8

	Pontederia cordata	*Canna flaccida*	*Sagittaria lancifolia*	*Schoenoplectus tabernaemontani*	*Ludwigia grandiflora*	Algae	*Spirodela polyrhiza*	*Pistia stratiotes*	Debris	**TOTAL**
4/21/10	10	10	0	5	0	10	0	0	10	25
5/1/10	2	10	0	3		10		0	10	15
5/13/10	3	0	0	8	2	5	3	0	5	12
5/26/10	0	0	0	8	0	3	2	0	3	8
5/27/10	13	0	16	14	0	10	5	0	30	43
6/8/10	21	0	20	22	0	5		0	15	63
6/19/10	15	0	7	20	0	10	4	0	30	42
6/22/10	20	0	7	20		10	2	0	30	47
7/9/10	15	0	12	15		4		0	5	45
8/4/10	6	0	5	13		10	4	0	10	20
8/19/10	0	0	0	13	0	15	5	0	15	13
8/30/10	0	0	0	0		5	5	0	5	5
9/14/10	0	0	0	0	0	5	10	3	5	10
9/24/10	0	0	0	0	0	5	4		2	5
10/8/10	0	0	0	0	0	5	10	0	2	5
10/26/10	0	0	0	0	0	2		0	0	2

Appendix C- Root Cover Class for Each Island

Table A.16: Root cover values for island PVC 1

Root CC					
PVC 1 Sampling Dates	*Pontederia cordata*	*Canna flaccida*	*Schoenoplectus tabernaemontani*	*Ludwigia grandiflora*	Total
4/21/10	1	1	1		2
5/1/10	1	1	1		2
5/13/10	1	1	1		2
5/26/10	1	1	1		2
6/8/10	1	0	2	1	1
6/19/10	1		1	1	1
6/22/10	1		1	1	1
7/9/10	1		1	1	1
8/4/10	0		1	1	1
8/19/10	0		2		2
8/30/10	0		1		1
9/14/10	0		1		1
9/24/10			1		1
10/8/10			1		1
10/26/10	0		1	2	2
12/4/10	0		1	2	3

Table A.17: Root cover values for island PVC 2

Root CC					
PVC 2 Sampling Date	*Pontederia cordata*	*Canna flaccida*	*Schoenoplectus tabernaemontani*	*Ludwigia grandiflora*	Total
4/21/10	1	1	1		1
5/1/10	1	1	1		1
5/13/10	1	1	1		2
5/26/10	1	1	1		2
6/8/10	1		1		1
6/19/10			1		1
6/22/10			2		2
7/9/10			2	1	2
8/4/10					0
8/19/10					0
8/30/10	1			1	1
9/14/10					0
9/24/10	1				1
10/8/10					0
10/26/10					0
12/4					0

Appendix C- Root Cover Class for Each Island (continued)

Table A.18: Root cover values for island PVC 3

Root CC						
PVC 3 Sampling Date	*Pontederia cordata*	*Canna flaccida*	*Schoenoplectus tabernaemontani*	*Ludwigia grandiflora*	*Cyperus odoratus*	Total
4/21/10	1	1	1			1
5/1/10	1	1	1			1
5/13/10	1	1	1			1
5/26/10	2	1	1			2
6/8/10	1	1	1			1
6/19/10	1		1	1		1
6/22/10	1		1			1
7/9/10	1		1			1
8/4/10	1		1	1		1
8/19/10			1	1		1
8/30/10			1	1		1
9/14/10			1	2	1	2
9/24/10				1	1	1
10/8/10				1	1	1
10/26/10					1	1
12/4				3	1	3

Table A.19: Root cover values for island PVC 4

Root CC					
PVC 4 Sampling Dates	*Pontederia cordata*	*Canna flaccida*	*Schoenoplectus tabernaemontani*	*Ludwigia grandiflora*	Total
4/21/10	1	1	1		1
5/1/10	1	1	1		1
5/13/10		1	1		1
5/26/10	1	2	1		2
6/8/10	1	1	1		1
6/19/10			1	2	2
6/22/10			1	2	2
7/9/10			1	1	1
8/4/10				1	1
8/19/10				1	1
8/30/10			1	1	1
9/14/10				1	1
9/24/10				1	1
10/8/10				1	1
10/26/10				1	1
12/4				3	3

Appendix C- Root Cover Class for Each Island (continued)

Table A.20: Root cover values for island PVC 5

Root CC					
PVC 5 Sampling Dates	*Pontederia cordata*	*Sagittaria lancifolia*	*Schoenoplectus tabernaemontani*	*Ludwigia grandiflora*	Total
5/13/10	1	1	1		2
5/18/10	1	1	1		2
5/26/10	1	1	1		2
6/9/10	2	1	2	1	2
6/24/10	2	2	2	1	2
7/6/10	3	2	3	2	3
7/21/10	2	2	2	2	3
8/2/10	2	2	2	2	3
8/19/10	3	2	3	2	4
9/3/10	2	2	3	2	5
9/14/10	2	3	3	2	6
9/27/10	2	3	3	4	6
10/12/10	2	2	3	3	6
10/26/10	2	3	4	3	6
12/4/10	3	3	4	3	6

Table A.21: Root cover values for island PVC 6

Root CC					
PVC 6 Sampling Dates	*Pontederia cordata*	*Sagittaria lancifolia*	*Schoenoplectus tabernaemontani*	*Ludwigia grandiflora*	Total
5/13/10	1	1	1		2
5/18/10	2	1	1		2
5/26/10	1	1	1		3
6/9/10	3	1	1		2
6/24/10	3	2	3	2	3
7/21/10	2	2	2	2	4
8/2/10	2	2	3	2	4
8/19/10	2	3	3	2	5
9/3/10	2	2	3	2	6
9/14/10	2	2	3	2	6
9/27/10	2	2	2	3	6
10/12/10	3	3	4	3	6
10/26/10	3	3	4	3	6
12/4/10	3	3	4	3	6

Appendix C- Root Cover Class for Each Island (continued)

Table A.22: Root cover values for island PVC 7

Root CC					
PVC 7 Sampling Dates	*Pontederia cordata*	*Sagittaria lancifolia*	*Schoenoplectus tabernaemontani*	*Ludwigia grandiflora*	Total
5/13/10	1	1	1		2
5/18/10	1	1	1		2
5/26/10	2	1	1		2
6/9/10	3	1	2	1	3
6/24/10	3	2	3	2	3
7/6/10	3	2	3	1	3
7/21/10	2	2	2	2	3
8/2/10	1	1	2	1	3
8/19/10	1	1	2	2	3
9/3/10	3	1	3	2	4
9/14/10	2	2	3	2	5
9/27/10	2	2	3	2	6
10/12/10	2	2	4	1	6
10/26/10	2	3	4	1	6
12/4/10	2	3	4	2	6

Table A.23: Root cover values for island Bamboo 1

Root CC						
Bamboo 1 Sampling Dates	*Pontederia cordata*	*Canna flaccida*	*Schoenoplectus tabernaemontani*	*Sagittaria lancifolia*	*Ludwigia grandiflora*	Total
4/21/10	1	1	1			1
5/1/10	1	1	1			1
5/13/10	1	1	1			1
5/26/10	1	1	1		1	1
5/27/10	2		1	2		2
6/8/10	2		2	2	1	2
6/19/10	2		2	2	2	2
6/22/10	2		2	2	1	3
7/9/10	2		2	1	3	3
8/4/10	2		2		3	3
8/30/10	2		2		4	4
9/14/10	0		3		2	3
9/24/10	1		2	2	2	2
10/8/10	2		2	2	2	2
10/26/10	1		2		2	2
12/4	1		2		2	2

Appendix C- Root Cover Class for Each Island (continued)

Table A.24: Root cover values for island Bamboo 2

Root CC						
Bamboo 2 Sampling Dates	*Pontederia cordata*	*Canna flaccida*	*Schoenoplectus tabernaemontani*	*Ludwigia grandiflora*	*Cyperus odoratus*	Total
4/21/10	1	1	1			1
5/1/10	1	1	1			2
5/13/10	2	1	1	3		3
5/26/10	1		1	3		3
6/8/10	2		2	3		3
6/19/10	2		2	3		3
6/22/10	2		2	3		3
7/9/10	2		2	4		4
8/4/10	2		1	5		4
8/30/10	1		1	5	1	4
9/14/10	2		2	4	1	4
9/24/10	2		2	4	3	4
10/8/10	2		2	4	4	6
10/26/10	2		2	4	4	6
12/4/10	2		2	4	4	6

Table A.25: Root cover values for island Bamboo 3

Root CC					
Bamboo 3 Sampling Dates	*Pontederia cordata*	*Canna flaccida*	*Schoenoplectus tabernaemontani*	*Ludwigia grandiflora*	Total
4/21/10	1	1	1		1
5/1/10	1	1	1		2
5/13/10	2	2		2	2
5/26/10	1	2	1	2	2
6/8/10	2	2	1	1	2
6/19/10	2		1	1	1
6/22/10	2			1	1
7/9/10					1
8/4/10					0
8/19/10	2				1
8/30/10	2				1
9/14/10	1	**1**			1
9/24/10	2				1
10/8/10	1				1
10/26/10				2	2

Appendix C- Root Cover Class for Each Island (continued)

Table A.26: Root cover values for island Bamboo 4

Root CC					
Bamboo 4 Sampling Dates	*Pontederia cordata*	*Canna flaccida*	*Schoenoplectus tabernaemontani*	*Ludwigia grandiflora*	Total
4/21/10	1	1	1		1
5/1/10	1	1	1		2
5/13/10	1	1	1		2
5/26/10	1				1
5/27/10	2	2	1		2
6/8/10	2	2	1		2
6/19/10	2		2		2
6/22/10	1	1	2		2
7/9/10	2	2	2		2
8/4/10	2		2		2
8/19/10	2		2		2
8/30/10					0
9/14/10					0
9/24/10					0
10/8/10					0
10/26/10					0
12/4/10			1	5	5

Table A.27: Root cover values for island Bamboo 5

Root CC						
Bamboo 5 Sampling Dates	*Pontederia cordata*	*Canna flaccida*	*Schoenoplectus tabernaemontani*	*Ludwigia grandiflora*	*Sagittaria lancifolia*	Total
4/21/10	1	1	1			1
5/1/10	1	1	1	1		2
5/13/10	2	1	1	1		2
5/26/10	1	0	1			1
5/27/10	2	2	1			2
6/8/10	2	2	2			2
6/19/10	2	2	2			2
6/22/10	2	2	2			3
7/9/10	2	1	2		1	3
8/4/10	2	2	2	1	1	3
8/19/10	2	2	3		2	3
8/30/10	2	0	2	1	1	2
9/14/10	2	0	2		2	2
9/24/10	2	0	2	1	2	2
10/8/10	2	0	3	3	2	3
10/26/10	0	0	1	2	2	2

Appendix C- Root Cover Class for Each Island (continued)

Table A.28: Root cover values for island Bamboo 6

Root CC						
Bamboo 6 Sampling Dates	*Pontederia cordata*	*Canna flaccida*	*Schoenoplectus tabernaemontani*	*Ludwigia grandiflora*	*Sagittaria lancifolia*	Total
4/21/10	1	2	1			2
5/1/10	1	2		1		2
5/13/10	1		1			1
5/26/10						0
5/27/10	2		1		2	2
6/8/10	2		2		2	1
6/19/10	2		2		2	2
6/22/10	2		2		2	2
7/9/10	2		2		1	2
8/4/10	2		1			1
8/19/10	2		1		1	1
8/30/10	1			1		1
9/14/10						1
9/24/10				1		1
10/8/10						0
10/26/10				1		1

Table A.29: Root cover values for island Bamboo 7

Root CC						
Bamboo 7 Sampling Dates	*Pontederia cordata*	*Canna flaccida*	*Schoenoplectus tabernaemontani*	*Ludwigia grandiflora*	*Sagittaria lancifolia*	Total
4/21/10	1	1	1			1
5/1/10	1	1	1			1
5/13/10	2	2	1	1		2
5/26/10	2	1	1	1		1
5/27/10	2		1		2	2
6/8/10	2		2		2	2
6/19/10	2		2			2
6/22/10	2		2		1	2
7/9/10	2		1			1
8/4/10	2		2			1
8/19/10	2			1		1
8/30/10						0
9/14/10						0
9/24/10				1		1
10/8/10				1		1
10/26/10				2		2

Appendix C- Root Cover Class for Each Island (continued)
Table A.30: Root cover values for island Bamboo 8

Root CC					
Bamboo 8 Sampling Dates	*Pontederia cordata*	*Canna flaccida*	*Schoenoplectus tabernaemontani*	*Sagittaria lancifolia*	Total
4/21/10	1	1	1		1
5/1/10	1	2	1		1
5/13/10	1		1		1
5/26/10	0		1		1
5/27/10	2		1	2	2
6/8/10	2		2	2	2
6/19/10	2		2	1	2
6/22/10	2		1	1	2
7/9/10	2		2	2	2
8/4/10	1		2	1	2
8/19/10			2		1
8/30/10					0
9/14/10					0
9/24/10					0
10/8/10					0
10/26/10					0

Appendix D- Nitrogen, Carbon, and Phosphorus (percent and g/m²)

Table A.31: PVC Island Nutrients

Corresponding Island	Species or Source	Final Dry Weight (After weight minus plastic bag weight) (g)	wt %N	wt %C	wt %P	Nitrogen (g/m2)	Carbon (g/m2)	Phosphorus(g/m2)
A1	Schoenoplectus tabernaemontani	1.27	3.93	32.81	0.2375	4.9911	41.6687	0.301625
A1	Ludwigia grandiflora	24.72	3.3	39.37	0.1782	81.576	973.2264	4.405104
A1	Ludwigia grandiflora	31.7	3.61	34.67	0.2	114.437	1099.039	6.34
A1	SAV	7.53	3.63	31.36	0.2395	27.3339	236.1408	1.803435
A1	Debris	46.5	1.93	44.83	0.026	89.745	2084.595	1.209
A1	Pistia stratiotes	9.73	4.22	37.16	0.6505	41.0606	361.5668	6.329365
TOTAL A1		121.45	20.62	220.2	1.5317	359.1436	4796.2367	20.388529
A2	Ludwigia grandiflora	0.08	5.59	42.76	0.3129	0.4472	3.4208	0.025032
A2	debris	15.85	1.77	47.09	0.0355	28.0545	746.3765	0.562675
A2	water lettuce	0.97	4.7	39.61	0.361	4.559	38.4217	0.35017
A2	SAV	5.09	4.96	39.93	0.2406	25.2464	203.2437	1.224654
TOTAL A2		21.99	17.02	169.39	0.95	58.3071	991.4627	2.162531
A3	SAV	14.384	3.31	44.03	0.1244	47.61104	633.32752	1.7893696
A3	Debris	24.84	2.16	48.15	0.0153	53.6544	1196.046	0.380052
A3	Debris	18.3	1.42	46.53	0	25.986	851.499	0
A3	Cyperus odoratus	5.77	2.99	36.28	0.1138	17.2523	209.3356	0.656626
A3	Cyperus odoratus	10.84	2.24	37.41	0.3405	24.2816	405.5244	3.69102
A3	Pistia stratiotes	3.98	4.52	36.27	0.495	17.9896	144.3546	1.9701
A3	Ludwigia grandiflora	121.44	3.08	41.71	0.1514	374.0352	5065.2624	18.386016
TOTAL A3		199.554	19.72	290.38	1.2404	560.81014	8505.34952	26.8731836
A4	Ludwigia grandiflora	30.46	4.09	43.46	0.2297	124.5814	1323.7916	6.996662
A4	Ludwigia grandiflora	25.19	4.34	41.12	0.2902	109.3246	1035.8128	7.310138
A4	Ludwigia grandiflora	15.53	4.2	40.59	0.3429	65.226	630.3627	5.325237
A4	SAV	7.5849	7.11	41.16	0.2663	53.928639	312.194484	2.01985887
A4	Debris	98.82	2.25	47.87	0.0533	222.345	4730.5134	5.267106
A4	Pistia stratiotes	2.83	4.48	36.57	0.4857	12.6784	103.4931	1.374531
TOTAL A4		180.4149	26.47	250.77	1.6681	588.084039	8136.168084	28.29353287

Appendix D- Nitrogen, Carbon, and Phosphorus (percent and g/m^2)(continued)

Table A.32: Bamboo Island Nutrients

Corresponding Island	Species or Source	Final Dry Weight (After weight minus plastic bag weight) (g)	wt %N	wt %C	wt %P	Nitrogen (g/m2)	Carbon (g/m2)	Phosphorus(g/m2)
N1	pickerelweed	10.75	3.23	43.01	0.1294	34.7225	462.3575	1.39105
N1	Schoenoplectus tabernaemontani	34.41	3.56	41.41	0.2049	122.4996	1424.9181	7.050609
N1	Ludwigia grandiflora	194.6	3.92	38.27	0.1937	762.832	7447.342	37.69402
N1	SAV	17.41	3.09	41.45	0.1467	53.7969	721.6445	2.554047
N1	Debris	64.78	2.1	33.03	0.0926	136.038	2139.6834	5.998628
N1	Pistia stratiotes	22.12	3.79	38.29	0.3749	83.8348	846.9748	8.292788
TOTAL N1		344.07	19.69	235.46	1.1422	1193.7238	13042.9203	62.981142
N2	Pontederia cordata	6.12	1.64	40.33	0.0065	10.0368	246.8196	0.03978
N2	Schoenoplectus tabernaemontani	11.61	1.83	38.67	0.1222	21.2463	448.9587	1.418742
N2	Ludwigia grandiflora	141.23	2.36	40.71	0.0349	333.3028	5749.4733	4.928927
N2	Ludwigia grandiflora	145.23	3.14	42.51	0.0764	456.0222	6173.7273	11.095572
N2	Ludwigia grandiflora	145.44	3.56	41.1	0.1953	517.7664	5977.584	28.404432
N2	Debris	107.89	2.26	46.2	0.0497	243.8314	4984.518	5.362133
N2	composite	15.42	3.11	36.7	0.2262	47.9562	565.914	3.488004
N2	Hydrocotyle spp.	8.94	3.04	43.07	0.1818	27.1776	385.0458	1.625292
N2	Cyperus odoratus	243.3	1.82	41.5	0.133	442.806	10096.95	32.3589
N2	Cyperus odoratus	182.01	1.3	39.66	0.1262	236.613	7218.5166	22.969662
N2	Q1	278.95	2.44	46.43	0.0789	680.638	12951.6485	22.009155
N2	Q2	0	2.54	44.82	0.116	0	0	0
N2	Q4	87.7	1.22	44.36	0	106.994	3890.372	0
N2	Limnobium spongia	4.41	3.7	37.08	0.3416	16.317	163.5228	1.506456
N2	Pistia stratiotes	83	2.88	34.79	0.2972	239.04	2887.57	24.6676
TOTAL N2		1461.25	36.84	617.93	1.9859	3379.7477	61740.6206	159.874655
N4	Pontederia cordata	29.8	2.96	33.17	0.168	88.208	988.466	5.0064
N4	Schoenoplectus tabernaemontani	55.41	3.17	42.57	0.1286	175.6497	2358.8037	7.125726
N4	Ludwigia grandiflora	138.14	3.63	38.89	0.2453	501.4482	5372.2646	33.885742
N4	SAV	16.65	2.69	30.31	0.1165	44.7885	504.6615	1.939725
N4	Debris	180.81	1.95	47.2	0.0412	352.5795	8534.232	7.449372
N4	Pistia stratiotes	68.27	3.16	40.58	0.2817	215.7332	2770.3966	19.231659
TOTAL N4		489.08	17.56	232.72	0.9813	1378.4071	20528.8244	74.638624

Appendix E: Weather Conditions

Table A.33: Weather Conditions for Sampling Dates. Weather data retrieved from Weather Underground's History Data for St. Petersburg, Fl.

Sampling Date	Mean temperature (Celsius)	Precipitation (millimeters)	Wind (m/sec)	Events
4/21/10	22.22	0.25	2.68	Rain
5/1/10	27.78	0	4.92	
13-May	26.67	0	5.81	
5/18/10	27.78	0	1.79	
5/26/10	26.67	0	4.92	
5/27/10	26.67	14.99	2.68	rain, thunderstorm
6/8/10	31.11	0.76	4.47	
6/9/10	29.44	0	6.71	
6/19/10	28.89	0.25	3.13	rain, thunderstorm
6/22/10	30.00	9.91	4.92	rain, thunderstorm
6/24/10	31.11	0	5.36	
7/6/10	27.22	7.62	4.47	Rain
7/9/10	30.00	0	2.24	
7/21/10	31.11	0	6.71	
8/2/10	30.00	1.52	1.79	rain, thunderstorm
8/4/10	28.89	21.08	4.02	fog, rain, thunderstorm
8/18/10*	28.50	38.10	2.68	Fog, rain, thunderstorm
8/19/10	30.00	0	2.24	
8/30/10	29.44	0	7.15	
9/3/10	28.89	0	1.34	
9/14/10	30.00	0	6.26	
9/24/10	29.44	3.05	4.92	rain
9/27/10	29.44	5.59	4.47	rain
10/8/10	24.44	0	1.79	
10/12/10	26.11	0	2.24	
10/26/10	27.78	0	4.47	
12/4/10	16.67	0	1.79	
*not a sample date				

Appendix F- Photos of Islands Through Study

Figure A.1: Floating Island PVC 1

Floating island PVC 1 on 5/13/10. This island was outfitted with a wildlife netting substrate. Algae were covering island and plants. PVC 1 did not recover from this event and emergent plant biomass decreased. Initial emergent percent cover was 65% and dropped to 31% on 5/13/10.

Initial algae bloom on 5/13/10 died but left behind biomass that clung to wildlife netting substrate. As seen on 8/4/10. At this time the only emergent vegetation that remained was one *Scripus* sp. plant.

On December 4, 2010 island PVC 1 was harvested. At this time, most of the biomass was in the form of *Spirodela polyrhiza* (duckweed), *Pistia stratiotes* (water lettuce) and *Ludwigia* sp. The one *Scripus* sp. plant persisted but did not increase in biomass through time. The end emergent plant percent cover was 36% with 30% being from *Ludwigia* sp.

Appendix F- Photos of Islands Through Study (continued)

Floating island PVC 2 was covered with a gutter mesh substrate. Initial total percent cover for A2 was 41% and dropped to 30% demonstrated by this photo taken on 5/1/10. At this time, most of the island cover was from emergent species (*Pontederia cordata, Canna flaccida, and Scirpus* spp.). The plants roots did not anchor well in the substrate and caused most of them to float on top of the island.

This picture taken on 7/9/10 shows that without plant roots anchoring them in the substrate, they floated off the island. Also, debris from Crescent Lake, mainly dead leaf matter, was able to float onto PVC 2. One *Scirpus* spp. plant was able to sustain itself by growing roots through the substrate and anchoring onto the island frame edge.

On 10/26/10 algae had covered the entire island substrate. There was no emergent vegetation left from initial planting in April 2010, and the total percent cover dropped to 35% on 12/4/10, which consisted mainly of debris and *Spirodela polyrhiza* that drifted onto PVC 2.

Figure A.2: Floating Island PVC 2

On 5/1/10, the vegetation is representative of the initial planting of emergent vegetation, down 13% from April 21. Debris started to accumulate on this date, but is a small percent of the overall island cover.

As with the previous Artificial islands, *Pontederia cordata, Canna flaccida, and Scirpus* spp. were not able to fasten their roots to the island substrate before being washed off the island from wave activity or blown away from wind. As a result, other colonizers like *Ludwigia* sp. and Sedge were able to take advantage of the substrate and grow. Debris continued to accumulate on island.

Floating island PVC 3 was not initially close enough to the *Ludwigia* colony but after the growing season, *Ludwigia* was in close enough proximity to PVC 3 to take advantage of the substrate. As a result, PVC 3 was quickly covered with it. Also, the Sedge was able take root at the corner of PVC 3, perhaps due to the build up in debris allowing the Sedge roots to anchor.

Figure A.3: Floating Island PVC 3

Initial plant stock of *Pontederia cordata, Canna flaccida, and Scirpus* spp. on 4/21/10. Total initial emergent plant percent cover was 65%.

In June 2010, plants started to degrade and debris accumulated. In August 2010, debris continued to accumulate and an algal bloom occurred in the lake and persisted on PVC 4.

By harvest day (Dec. 2010) all initial planted emergent plants had died or floated off PVC 4. *Ludwigia* was able to take advantage of the substrate and colonize the floating island. Also, algae covered most of the island substrate. *Pistia stratiotes* was also found on A4 in December with a cover of 20%.

Figure A.4: Floating Island PVC 4

Appendix F- Photos of Islands Through Study (continued)

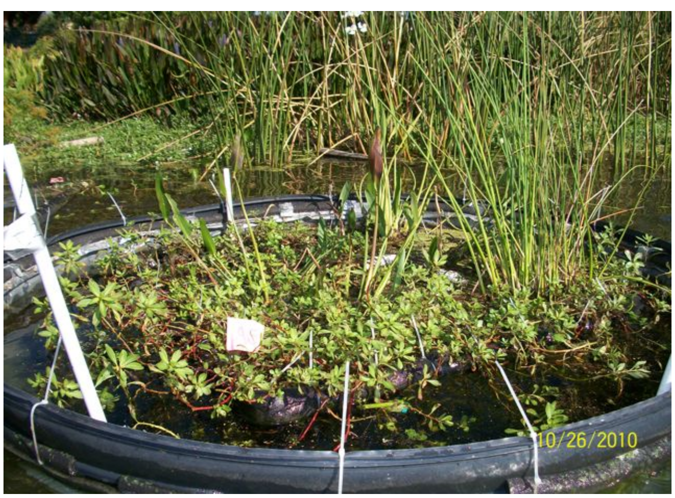


Figure A.5: Floating Island PVC 5

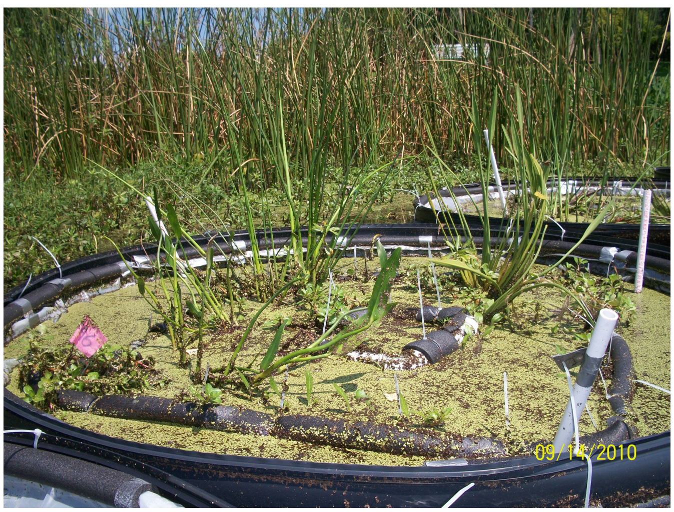
Islands PVC 5-7 were initially planted on 5/13/10. Due to the lack of success for Artificial islands PVC 1-4, islands PVC 5-7 were planted with a greater root and shoot stock than PVC 1-4 to encourage roots to anchor in the wildlife netting substrate. The total percent cover for 5/18/10 was 75% being mostly planted emergent vegetation.

By July 2010, *Pontederia cordata, Sagittaria lancifolia, and Scirpus* spp. shoots were erecting themselves and roots were growing through the substrate. *Ludwigia* was also starting to colonize PVC 5 in July 2010.

PVC 5 was placed in an aquatic enclosure late July 2010. PVC 5 received a nutrient addition treatment on October 4, 2010. Before and after treatment, emergent vegetation was at 100% total cover.

Appendix F- Photos of Islands Through Study (continued)

Island PVC 6 initial replant. Emergent vegetation (*Pontederia cordata, Sagittaria lancifolia, and Scirpus* spp.) was 75% of the total cover of the island. After one month, the roots were anchored in the wildlife netting substrate and shoots were becoming erect.



PVC 6 was placed inside a aquatic enclosure at the end of July 2010. Due to the constraints of the aquatic enclosure, *Spirodela polyrhiza* could not escape and began to proliferate. Debris and *Spirodela polyrhiza* caused PVC 6 to have a total percent cover of 100% from September to December of 2010. The emergent plant cover was 39% on September 14, 2010.

By October 2010, the emergent vegetation was doing very well with over half of the island covered. By December, *Pontederia cordata, Sagittaria lancifolia, Scirpus* spp., *and Ludwigia* totaled 75% cover with *Ludwigia* accounting for 40%.

Figure A.6: Floating Island PVC 6

Figure A.7: Floating Island PVC 7

PVC 7 two weeks after initial planting shoots were growing towards the sun and roots are beginning to descend through the wildlife netting substrate into the water column. Debris was catching on the island substrate as well. Total debris cover is 10% and emergent vegetation is 64%.

By 7/6/10, *Pontederia cordata, Sagittaria lancifolia, and Scirpus* spp. have adapted to the floating island conditions as demonstrated by new shoots and root growth.

In September 2010, *Spirodela polyrhiza* covers PVC 7, but did not hinder emergent plant growth. The total emergent plant cover is 49%.

Appendix F- Photos of Islands Through Study (continued)

Figure A.8: Floating Island Bamboo 1

Bamboo 1 two week after initial planting (5/1/2010). Leaves started to discolor and new shoots were apparent. Burlap substrate is very easily torn and showed signs of wildlife interaction. Debris started to accumulate on island. The hemp and sisal rope used for lashing Bamboo poles together was also easily torn and showed signs of wildlife interference.

On May 27, 2010 Bamboo 1 received new substrate and a restock of plant biomass. By this point, the burlap had disintegrated and most of the emergent plant had floated off the island, which is consistent with Sasser et. al, 2006. New substrate was a sisal netting. New emergent plant biomass consisted of *Pontederia cordata, Scirpus* spp.*, and Sagittaria lancifolia.* It was thought that if the substrate would sustain long enough, these species would be able to colonize Bamboo 1.

By September, sisal netting had fallen apart, due to the aquatic environment and wildlife interaction. Plants were corralled inside Bamboo frame, but were not growing sustainably. By the end of the study, Bamboo 1 had only a small portion of the restocked plants (from 36% down to 11%). Bamboo 1 was harvested in December 2010.

Bamboo 2 two weeks after initial planting (5/1/2010). Debris is already starting to accumulate on Bamboo 2. Pontederia cordata demonstrated resilience to transplant and maintained a constant 20% cover after two weeks. *Canna flaccida and Scirpus* spp. lost biomass after the initial transplant. *Canna flaccida* never recovered after initial die back, but *Scirpus* spp. did with an end cover similar to initial transplant.

By August 2010, Ludwigia heavily colonized Bamboo 2 due to the islands close proximity to a *Ludwigia* stand. Also, by this time all burlap substrate and natural rope had disintegrated and the island frame was being help together by plant root biomass only.

At the end of August a sedge plant was observed, and occupied 5% of the total cover of the island. This plant was probably deposited by wildlife or seed may have washed onto Bamboo 2. By the end of October, the sedge grew rapidly and covered 60% of Bamboo 2. It was observed that as the transplanted plants died back, *Ludwigia* was the first prolific colonizer but was outcompeted by the sedge plant. Bamboo 2 was harvested in December 2010.

Figure A.9: Floating Island Bamboo 2

Appendix F- Photos of Islands Through Study (continued)

By mid-May, the Bamboo 3 burlap substrate was showing signs of stress. The material was easily broken and pieces had fallen away from the Bamboo frame. Large amounts of debris were found on the island and Ludwigia was starting to colonize Bamboo 3. However, the emergent species *Pontederia cordata, Canna flaccida, and Scirpus* spp. were still viable and demonstrating shoot and root growth. It was because of this positive growth that Bamboo 3 did not receive new substrate or a restock of plants.

Bamboo 3 continued to function through June, however in July had completely broken apart and most all plants had floated off the island. Conversely, *Pistia stratiotes* had floated into the center of Bamboo frame.

By October, Bamboo 3 had no substrate and the Bamboo poles had to be retied at the corners with sisal rope. The only plants on Bamboo 3 in October were ones that had floated into Bamboo 3 (*Spirodela polyrhiza)* or could take advantage of a floating frame like *Ludwigia*. Bamboo 3 was not harvested in December due to the lack of emergent plant species and substrate.

Figure A.10: Floating Island Bamboo 3

Appendix F- Photos of Islands Through Study (continued)

Bamboo 4 received an initial substrate of burlap lashed together with sisal and hemp rope. Initial total percent cover was 40%.

After one month, the burlap substrate failed and Bamboo 4 was replanted with a greater biomass consisting of *Pontederia cordata, Canna flaccida, and Scirpus* spp. on top of a new sisal mesh substrate. The sisal mesh substrate did not hold up well in the aquatic environment and showed signs of wildlife interaction.

By August, the island substrate had completely disintegrated and plants were not corralled well within the Bamboo frame. Debris, algae, and *Spirodela polyrhiza* were free to float over Bamboo frame to occupy the center of Bamboo 4.

Figure A.11: Floating Island Bamboo 4

Appendix F- Photos of Islands Through Study (continued)

By early May 2010, planted emergent substrate had fallen from 55% total cover to 49% total cover. The debris cover had increased from none to 30%. Also, *Ludwigia* had started to colonize the island.

At the end of the same month, The burlap substrate was almost completely broken apart from the Bamboo frame and plants were floating within the frame.

On May 27, 2010 Bamboo 5 received a new canvas substrate with a restock of, *Pontederia cordata, Canna flaccida, Scirpus* spp., and *Sagittaria lancifolia.* On this date, the total percent cover was 63% mainly due (51%) to the restock of emergent biomass. Debris cover accounted for the other percent cover of Bamboo 5.

At the end of October 2010, N5 had lost the canvas substrate due to the aquatic environment and had drifted closer to a *Ludwigia* colony, where the *Ludwigia* was able to take advantage of the floating Bamboo and cover about 40% of Bamboo 4 by December 2010. Algae covered much of this island for the extent of the growing season. *Spirodela polyrhiza* was also able to take advantage of the open nature of Bamboo 4. This island was harvested in December 2010.

Figure A.12: Floating Island Bamboo 5

Appendix F- Photos of Islands Through Study (continued)

At the beginning of May 2010, Bamboo 6 had already showed signs of stress. The burlap substrate was weak and easily torn and all the initial planted biomass all decreased in percent cover. *Scripus* spp. completely disappeared from Bamboo 6 in the first two weeks of the project.

Due to the diminished potential of Bamboo 6 in early May, on May 27 2010, Bamboo 6 received a new canvas substrate and a restock of *Pontederia cordata, Sagittaria lancifolia, and Scirpus* spp.

After six weeks, the canvas substrate was slowing starting to deteriorate, especially around the island frame where it was attached with sisal rope. Plants were showing signs of growth with extended shoots and new root matter.

By mid-September, most of the canvas substrate detached from the Bamboo frame and dispersed the plants in the process. The island continued to decline and was not harvested in December 2010.

Figure A.13: Floating Island Bamboo 6

Appendix F- Photos of Islands Through Study (continued)

The first photograph was taken in 4/21/10 shortly after plants had been transplanted. The initial combined percent cover for, *Pontederia cordata, Canna flaccida,* and *Scirpus* spp. was 50%.

Bamboo 7 did not do well from April 21 to mid-May 2010 and received a new canvas substrate and restock of, *Pontederia cordata, Sagittaria lancifolia* and *Scirpus* spp. By June 8, plants were showing signs of stress and old shoots were dying. *Pontederia cordata* was the only plant that showed signs of positive growth in June.

By August, most on the canvas substrate had broken away from the Bamboo frame and plants were no longer attached to any substrate. Within one month, there were no emergent species left on Bamboo 7 and were replaced periodically with blooms of algae and *Spirodela polyrhiza.* This island did not get harvested in December due to lack of biomass and island substrate.

Figure A.14: Floating Island Bamboo 7

Appendix F- Photos of Islands Through Study (continued)

Less than a month after initial planting, Bamboo 8 had lost almost all of its burlap substrate and most of the plants. The *Pontederia cordata* and *Scirpus* spp. plants that were left were anchored to a scrap of burlap substrate clinging to the Bamboo frame. Eventually, this burlap disintegrated as well and the island was replanted with *Pontederia cordata, Sagittaria lancifolia* and *Scirpus* spp. and given a new sisal netting substrate.

In July 2010, *Pontederia cordata, Sagittaria lancifolia* and *Scirpus* spp. were doing well with a combined percent cover of 42%.

The sisal netting substrate did not prove to last long enough in the aquatic environment, and the plants did not have adequate time to establish a root mat to sustain the island. Bamboo 8 never recovered from the loss of substrate, and no colonizers took advantage of the Bamboo frame. This island was not harvested in December, 2010.

Figure A.15: Floating island Bamboo 8