Removal of Aquatic Vegetation for Nutrient Credits in the Indian River Lagoon (IRL) Basin September 2012

Mechanical removal or harvest of aquatic vegetation rather than treatment with herbicides or other control mechanisms may be one method of removing nutrient loads from the Indian River Lagoon (IRL) and its tributaries. The use of aquatic plants for nutrient management has been considered since at least the 1960s (Boyd, 1970). The harvest of aquatic vegetation removes nutrients from the waterbody rather than recycling them through decomposition and sedimentation of the plant material into the sediment. Most fresh water plants do not tolerate the salinity of the IRL and upon release to the lagoon from tributaries will die and decompose adding a nutrient load directly to the lagoon.

Harvest of aquatic vegetation is under consideration as an additional best management practice (BMP) that can receive credits for nutrient removal in the IRL Basin. However, harvest of aquatic vegetation should not be considered as the sole management practice for controlling aquatic vegetation. Other chemical and biological controls should be applied, as needed, although those methods are not eligible for nutrient removal credit.

Definition of Aquatic Vegetation

For purposes of project credit, aquatic vegetation is defined as freshwater plants that live in water or on the surface of water. Aquatic vegetation generally includes plant material that is typically herbaceous and predominately angiosperms (flowering plants) and algae.

Plants can be categorized by their growth form as free-floating and floating leaved, submersed, or emergent. Free-floating plants are not rooted in the substrate, but float or drift on the surface of the water. This growth form absorbs its nutrient from the water column. Examples of common native plants that are free floating are duckweed (*Lemna spp*.), bladderwort (*Utricularia spp*.), and coontail (*Ceratophyllum demersum*). Common invasive plants that are free floating are water hyacinth (*Eichhornia crassipes*), water lettuce (*Pistia stratiotes*), and *Salvinina spp*. Floating leaved aquatic plants may or may not be rooted in the substrate, but their leaves float on the water surface. Common native plants are water lily (*Nymphaea spp*.), spatterdock (*Nuphar lutea*), American lotus (*Nelumbo lutes*), and water shield (*Brasenia schrebeii*).

Submersed aquatic plants are rooted to substrate and stay submerged in the water column. They obtain nutrients predominately through the sediment, though there is evidence of uptake of nutrients through leaves (Dhote and Dixit, 2009). Common native submersed plants are eelgrass (*Vallisinaria*) and watermilfoils (*Myriophyllum spp*.). The invasive plant hydrilla (*Hydrilla verticillata*) belongs to this category.

Emergent or emersed aquatic plants are rooted to substrate, but emerge or break the water surface. Like submersed plants, they obtain nutrients from the sediment. Cattails (*Typha spp*.), bulrush (*Scirpus spp*.), and maidencane (*Panicum hemitomon*) are native plants displaying this growth form.

Algae are also present in the water column, either attached to surfaces or free floating and may be submersed or take emergent forms. Filamentous algae can form mats or long strings. Some common species of macro algae are *Cladophora* spp, *Lynbya* spp, and *Chara* spp.

Common Aquatic Plants in the IRL and Their Distribution

Aquatic vegetation can occur either in mixed stands or as largely monocultures. It is not uncommon for invasive plants to form largely monotypic stands. The plant material can form dense floating mats that prevent light diffusion into the water column, thus shading the bottom and limiting benthic habitat. The dense layer of vegetation also limits exchange of gases across the water surface and can cause depletion of dissolved oxygen under the mat. At greater densities, vegetation may also form floating islands or tussocks and incorporate woody plants.

Common invasive plants present in waterways in the IRL Basin are hydrilla, water lettuce, and water hyacinth, and these three plants present the greatest opportunity for harvest and removal of nutrients through plant biomass. However, native vegetation can be intermixed with exotics. Examples of common native aquatic vegetation that may also be removed includes cattails, duckweed, coontail, bladderwort, and water lilies.

Harvesting of Aquatic Vegetation

The removal of aquatic vegetation may be accomplished in several ways. For canals or waterbodies with small surface area, booms laid across the water surface can divert flow to screening and sorting facilities for removal of floating vegetation. An example is the PC Main Canal in Vero Beach where sets of screens of varying sized openings are used to remove material as small as 1/16 inch. Also in canals, drag lines or back hoes can be used for removal of submersed vegetation or modified front end loaders with baskets can collect floating plant material. There are specifically designed harvesters and shredders that move through the water and cut and chop vegetation. The shredders and harvesters are capable of handling woody material.

Requirements for Credits

Water hyacinths can weigh 200-300 tons per acre (Haller, 2009) and a surface mat of hydrilla can weigh 10 tons or less per acre (Haller, 2009); however, a large portion of this weight is water. Nutrient removal credit is not given for the plant's water weight. It is the nutrient content of the dry mass of the plant material removed that is the basis for credits. A standardized method for measuring plant weight and calculating nutrient content is outlined in the next sections.

Factors that influence the growth of aquatic vegetation are light, water clarity, plant age, temperature, pH, nutrient availability, organic matter, and sediment fertility, composition, and stability (Henry-Silva et al., 2008; Reddy, 1983; Barko et al., 1991. Boyd, 1969). Nutrient content of the plant material may be variable among harvesting locations because of the previously listed factors along with seasonal changes in nutrient content for any given species. Comparisons of cattails and sawgrass in the Everglades found substantial differences in tissue concentration of TP between impacted sites and reference sites (Miao and Sklar, 1998).

Credits for Aquatic Vegetation Removal

The following are steps needed to calculate and receive credit. These methods need further refinement and additional detail will be provided in the next version of this guidance document. To calculate plant nutrient content, an estimate of the types of plants collected, weight of plant material, nutrient content, and percent dry matter are needed.

1. **Identification of Type of Vegetation.** Identification of plant or algal species and estimate of percent dominance. Methods used to measure diversity within plant communities may be useful for identifying vegetation type and dominance.
2. **Measurement of Weight of Plant Material.** Description of how mass of plant material was estimated is needed. An example protocol for measuring the weight of material is provided as Figure 1. There are two important considerations for obtaining a reasonably accurate weight of plant material. First there will be water adhered to the outside of the plant and also caught within the mass of plant material. This water will need to be shed before a weight is obtained. Second the plants are composed of largely water so care should be taken to avoid crushing the plant material to the extent possible.
3. **Measurement of Nutrient Content and Percent Dry Matter.**
    a. Method 1. Samples collected from the harvest site that are representative of the material removed would be sent to a laboratory for analysis of total nitrogen (TN) and total phosphorus (TP) content and percent of dry matter. Labs will typically report nutrient content on a dry weight basis as mg/kg. Because of the variability of nutrient content temporally and spatially, it is recommended that nutrient content and percent dry matter be reported with each harvest until adequate data are available to describe the harvest site.
    b. Method 2. Compilation of a library of locally collected and literature averages for TN and TP content that represent average nutrient content and percent dry matter for the IRL or at least Florida would be used. This method may be more useful where multiple harvests occur per year and there are largely monotypic stands of plant material. Water hyacinth and water lettuce are well documented in the literature. Table 1 lists some reported values of TN and TP by plant species and provides a reference for values obtained from laboratory analysis.
4. **Calculating Nutrient Removal**
    a. Method 1. Dry weight basis of mg or g/kg
    Example calculation
    lbs plant material x % dry matter (decimal) x conc. TN or TP x (1 kg/1000g)
    (5000 lbs water lettuce x 0.057 x 25 g/kg TN)/1000 = 7.1 lbs TN

    b. Method 2. TN or TP as a percent of the dry weight mass of plant material
    Example calculation:
    lbs water lettuce x % dry matter (decimal) x % TN or TP dry weight basis
    5000 lbs water lettuce x 0.057 x 2.5% TN = 7.1 pounds TN
5. **Time Period for Credit.** Credits are provided with each harvest event, and an annual average will be calculated for BMAP credit.
6. **Disposal of Plant Material.** Where material is disposed, based on the distance from a waterbody, may influence how much credit can be given for removal. Available land, cost of removal, cost of transport, and access may limit disposal options. Proximity of

the disposed material to a waterbody and the potential for nutrients to be released back into the waterbody are important considerations. A vegetated buffer strip between the disposal site and waterbody will help prevent or reduce surface runoff generated from decomposed plant material or sub surface discharge from reaching the waterbody. In general the following rules apply, but additional research on effective distance for disposal is needed:

a. 100% credit -Disposal at a landfill or other location outside the waterbody drainage area or adequate distance from waterbody to eliminate surface and sub surface discharge.
b. >5 % - <100% – Credit rated by increasing distance from the waterbody. This will be evaluated on a case-by-case basis, but it will be assumed that the material is spread out to expedite drying and decomposition. Presence of a vegetated buffer strip is taken into consideration. Wide buffer strips are more effective than narrow (Mayer et al., 2006).
c. 0%-5% credit – Disposal of material on canal/stream bank receives 0 credit. Disposal within a few feet of water may receive limited credit up to 5%. Material should be spread out to expedite drying and decomposition.

Sites Eligible for Credit for Aquatic Vegetation Harvesting

This guidance is focused on the harvest of fresh water aquatic vegetation, primarily invasive exotics. As such, waterbodies such as canals and large connected ditches are the most appropriate places to apply this BMP. Small ditches or networks of ditch/canal structures that are not well connected to tributaries of the IRL or the lagoon proper would not qualify for credit. Credit would not be awarded where vegetation removal is a requirement of another BMP that is receiving credit or condition of a permitted activity. While removal of plant material is often conducted as a maintenance-activity needed to allow water to move through the canals and not obstruct control structures used for flood control, the harvesting also removes a nutrient source to the water column. An Aquatic Plant Removal Permit from the Fish and Wildlife Conservation Commission may be needed unless an activity is exempted by rule or statute.

Potential for Negative Impacts

Harvesting of aquatic vegetation does have the potential for negative impacts. Excessive harvesting of aquatic vegetation could have environmental impacts and this fact should be considered in determination of frequency and method of plant removal balanced against the need for flood control. Vegetation removal operations are not selective and do not discriminate between the native and invasive plants. Removal of submersed and emersed plants does disturb sediment which can result in water quality issues with water clarity and nutrient releases.

Aquatic plants, including exotics, do provide habitat for fish and other aquatic organisms and are part of the food web that supports an aquatic ecosystem. There is a by catch of fish and invertebrates associated with plant harvesting. A study of Hydrilla harvesting found that up to 32% of the young of year fish were also removed with the plant biomass, though many of the organisms that would be disturbed by harvesting are locally abundant.

Hydrilla, water hyacinth, and other exotic plants may recover faster than native plants from harvesting, giving the exotic plants a competitive advantage over native species. Additionally, the physical breaking of exotic plants into smaller pieces may actually help their spread.

These potential adverse impacts should be considered when aquatic plant harvesting is planned and implemented. FDEP will only provide nutrient credits for harvesting efforts that meet all applicable permit requirements and minimize adverse impacts to water clarity, sediment nutrient releases, young fish and aquatic species, and minimize the spread of exotic plant species.

References

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- Take a sample of plant material and place in a water tight container of known tare weight and known volume.
- Weigh sample. Also record starting volume of material.
- Transfer the sample to a container of known tare weight that will allow drainage of water. Examples are a large colander or 5 gallon bucket with holes drilled in it to allow water to escape.
- Take weight of sample and colander after transferring to colander.
- Continue to take weights of sample and colander till the weight stabilizes to a constant weight. The constant weight will still fluctuate, but try to get within 5-10% of a constant weight.
- Once at a constant weight, that is the weight of the wet plant material.
- This sample goes to the lab for analysis. The lab will dry it further before analyses are run.
- Take replicate samples for obtaining a weight.
- Drying time will vary by type of plant, its size, and leaf shape. Start at 15 minute intervals for recording weights. Some experimentation may be needed.
- This technique works best for smaller amounts of plant material, but may be adaptable to larger amounts of plant material. Large volumes of material may be stacked in piles and then subsampled for weight estimates.

Figure 1: Example protocol for obtaining weight of wet plant material

Table 1: Literature Values of Nutrient Content and Percent Water (under development)

Study	Hydrilla			Water Lettuce			Water Hyacinth		
Study Name	N (g/kg) Dry weight	P (g/kg) Dry weight	%Dry matter	N(g/kg) Dry weight	P(g/kg) Dry weight	% Dry Matter	N(g/kg) Dry weight	P(g/kg) Dry weight	% Dry Matter
Lu et al., 2010 St. Lucie Basin comparison of treatment ponds	Not applicable	Not applicable	Not applicable	17 (average)	3 (average)	Not applicable	Not applicable	Not applicable	Not applicable
Reddy and DeBusk, 1985	Not applicable	Not applicable	Not applicable	36.2, 40.3	8.0, 11.2	Not applicable	30.5, 35.3	5.8, 6.8	Not applicable
Reddy and DeBusk, 1987	Not applicable	Not applicable	Not applicable	12-40 range	1.5-11.5 range	Not applicable	10-40 range	1.4-12 range	Not applicable
D. L. Sutton and K.H. Portier, 1983 mean of 10 samples collected from Lake Okeechobee	2.51%	8.259	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
Sutton and Portier, 1983 mean of 10 samples collected from North New River	1.91%	2.062	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
P.V. Zimba, M. S. Hopson, and D. E. Colle, 1993. Lake Okeechobee taken from 60 transects	33.24	1.87	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
McCully, K, 2011 Indian River County PC Main Canal	Not applicable	Not applicable	Not applicable	25.838 (average)	6.24 (average)	5.7	Not applicable	Not applicable	Not applicable

Table 2: Literature Values for Percent Nutrient Content and Dry Matter (under development)

Study	Data (Values for N and P are percent of dry weight)
Wheeler et al., 1998. Water lettuce collected from 8 locations in South Florida. Data are for field plants without fertilizer.	Water lettuce leaves - N: 1.5% -2.9%; Orthophosphate: 0.26%-0.54%; dry weight: 6.7%-8.9%
Parra and Hortenstine, 1974. Nutritional content of Florida water hyacinths from 19 locations.	Water hyacinth – N: 1.61%; P: 0.31%
Boyd, C. E. 1969. Samples collected from South (Ft. Lauderdale) and Central Florida (60-mile radius of Orlando) for water hyacinth, water lettuce, and hydrilla. Percent N calculated from crude protein estimate.	Water hyacinth - dry matter: 5.9%; P ~0.42%; N: 4.15% (average of 2 samples) Water lettuce - dry matter 5.9%; P~0.3%; N: 3.66% (average of 2 samples) Hydrilla - dry matter: 8.0%; P: ~0.27%; N: 2.8% (average of 2 samples)

Study	Data (Values for N and P are percent of dry weight)
Tuan et al., 1994. Fresh whole plants from Vietnam.	Water hyacinth: 5.8% dry matter; 2.14 % N
Matai and Bagchi, 1980. Fresh whole plants.	Water hyacinth: 4.5% dry matter; 1.34% N; 0.74% P
Gunnarsson and Petersen, 2007. Fresh whole plants from various locations.	Water hyacinth: 6.2-9.4% dry matter; 1.9-3.2 % N; 0.53% P
Hertrampf and Piedad-Pascual, 2000. Mean from various sources.	Water hyacinth: 8.1% dry matter; 2.48% N; 0.6% P
Allenby, K.G., 1968. Mean of several analyses.	Duck weed (Lemna minor): 3.7% N Elodea canadensis: 3.2% N
Boyd, C.E., 1968. Review of many aquatic plants.	Myriophyllum brasiliense: 13.7% dry matter; M. spicatum: 12.8% dry matter; 1.57% N M. heterophyllum: 10% dry matter; 1.36% N Ceratophyllum demersum: 5.2% dry matter; 3.47% N Alternathera philoxeroides: 14.5% dry matter; 2.5% N Typha latifolia: 22.9% dry matter; 1.65 %N
Boyd, C. E., 1969.	Water hyacinth: 5.9% dry matter; 0.15% N; 0.43% P Water lettuce: 5.9% dry matter; 0.12% N; 0.3% P Hydrilla: 8.0 % dry matter; 0.22 % N; 0.28% P

Table 3: Results from Study Comparing Cattails and Sawgrass in the Everglades

Study	Plant	Impacted Site (mg/kg TP)	Reference Site (mg/kg TP)
Miao and Sklar, 1998. Studies of cattails and sawgrass along nutrient gradients in the Everglades in 1994. Range of plant nutrient concentration based on nutrient gradient from higher (impacted) to reference or background areas.	Cattail roots	1100	798
	Cattail shoots	2990	433
	Cattail leave	1175	556
	Cattail rhizome	1390	380
	Sawgrass roots	698	181
	Sawgrass shoot	5412	400
	Sawgrass leaf	605	248
	Sawgrass rhizome	1139	142