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Taxonomic Characteristics Of Aquatic Plants From The Alimentary Tract Of Grass Carp

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ABSTRACT

Ten aquatic macrophytes and one high algae were evaluated for key characteristics for alimentary tract identification of grass carp (*Ctenopharyngodon idella* Val.) masticated material for the construction of a taxonomic key to aide in identification of vegetation selectivity. Discernible masticated fragments were compared to both photographs and live samples of each species. Key characteristics of discernible material were noted and photographed. The eleven hydrophytes investigated were as follows: Brazilian elodea (*Egeria densa* Planch); hydrilla (*Hydrilla verticillata* Royle); eelgrass (*Vallisneria americana* Michx.); pondweed (*Potomogeton illinoensis* Morong.); fanwort (*Cabomba caroliniana* Gray); Eurasian watermilfoil (*Myriophyllum spicatum* L.); common bladderwort (*Utricularia* spp.); southern naiad (*Najas quadalupensis* (Sprengel) Mangus); coontail (*Ceratophyllum dermersum* L.); dwarf arrowhead (*Sagittaria subutala* (L.) Buchenau); and muskgrass (*Chara* sp.).

INTRODUCTION

The grass carp (*Ctenopharyngodon idella*) has been the subject of wide interest due to its potential for biological control of aquatic macrophytes. Its ability to consume large quantities of aquatic plants is well documented (3, 4, 5). If a biological control is to be effectively utilized it is necessary to discern the selectivity of the vegetation. Aquatic macrophytes serve many functions in a lake basin. They provide food, shelter, attachment surfaces for other organisms, dissolved oxygen under favorable light conditions, a temporary removal and storage bank for nutrients, and spawning and nursery areas for various economically valuable sport fish species. The rate at which aquatic habitats beneficial to sport fish and wildlife, have deteriorated in recent years has increased at an unprecedented scale. With the advent of intensive agricultural practices, artificial water level stabilization, and urbanization, nutrient addition to lakes has resulted in accelerated eutrophication of surface waters and ultimately the lake basin itself. Aquatic weed infestation, whether exotic or native, beneficial or nuisance, has caused serious biological and economic problems, exemplified by the billions spent annually for their control (2). Feeding selectivity through ingestion identification has been investigated (1, 6, 7), however, when working with masticated material, subtle minute characters are usually the discernible keys. Previous investigations contained indices for various selection parameters, but there was no mention as to key characters in identifying the macrophytes when masticated. The object of this study was to construct a taxonomic key to aide in the identification of various plant species ingested by grass carp.

METHODS AND MATERIALS

Ten aquatic macrophytes and one high algae were selected for investigation. These were as follows: Brazilian elodea; hydrilla; eelgrass; pondweed; cabomba; Eurasian watermilfoil; common bladderwort; southern naiad; coontail; dwarf arrowhead; and muskgrass. Each plant when collected was stored in a separate holding pool at the Eustis Fisheries Research Lab to insure pure species for the tests. The plants were then observed visually and microscopically to discern key characters that could possibly be identified in the gut of the grass carp. These discernible segments were then microscopically photographed.

Four 380 liter aerated tanks were set up and stocked at a ratio of two grass carp per unit for each aquatic plant tested. Grass carp used were 20-22 cm standard length for all plants except feeding studies for pondweed and eelgrass, where larger carp were used (36 cm standard length) due to greater leaf size and difficulty of feeding by smaller carp. For each series of tests the two carp were fed continuously for three weeks to insure a single species diet.

Plants were either disseminated throughout the tank or planted in flats (eelgrass and dwarf arrowhead) and placed on the bottom of the tank to simulate natural feeding conditions.

The carp were then collected and placed in ice immediately upon capture, to prevent regurgitation and digestion of food within the digestive tract. The entire digestive tract was then removed and preserved in a stock solution consisting of 4 ml of 40% formaldehyde, 5 ml of 20% solution of clear detergent, 1 ml of saturated cupric sulfate solution, and distilled water added to obtain a standard volume of 100 ml. The alimentary tracts were later dissected, contents washed, and disseminated across either a gridded perti dish and examined under a dissecting scope or placed in the reservoir of a Palmer Counting Cell and observed

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through a compond microscope. Discernible masticated fragments were then compared to both photographs and live samples of each species.

RESULTS AND DISCUSSION

Each plant is dealt with separately in the following discussion and then compiled into a single key for taxonomic identification of the masticated material.

Fanwort. After gut examination, the major discernible characters of this species were leaf-tip and spine formation. The leaves are palmately dissected into linear-filiform segments. The segments are long and narrow (thread-like), very slender and cylindrical, exhibiting a distinguishable midrib. The leaf apex is rounded portraying usually four spines about the tip. Spines are also located along the leaf margin in regular succession (Figure 1).

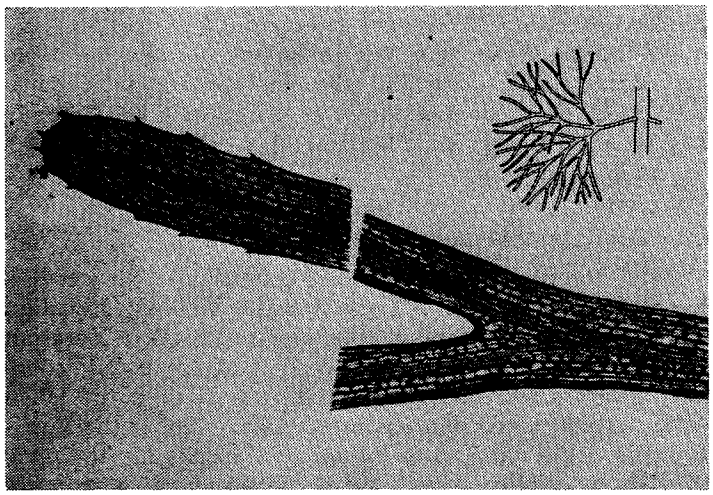

Figure 1. Example of ingested fanwort removed from the alimentary tract of grass carp. Distinguishing characters are: the leaf margins have spines on both sides in regular succession; leaf palmately dissected with a prominent midrib; and the leaf-tip rounded with usually four spines spaced about the tip.

Eurasion watermilfoil. Leaf form is the discernible portion of this species. The submersed leaves are usually whorled and pinnately parted into capillary divisions. The divisions are long and narrow, and often flexous and slender. Unlike fanwort, the capillary-like leaf divisions of Eurasian watermilfoil did not have discernible spines, neither around the leaf apex nor along the leaf margin. These dissected segments on each side of the rachis of Eurasian watermilfoil have distinguishable parallel veins extending from the base of the leaf to the leaf apex as compared to fanwort which has a distinct midrib (Figure 2).

Pondweed. Leaf margin and venation patterns are the distinguishing characters of this species. Large fragments were observed and positive identification made using both photographs and preserved specimens of preingested material. The submersed leaves usually have at least seven veins, and may have as many as 19 with conspicuous interlocking branches. The leaf is acute and somewhat mucronate at the apex. The margins have fugacious 1-celled translucent denticulations. These are identifiable only under high power objective (430X).

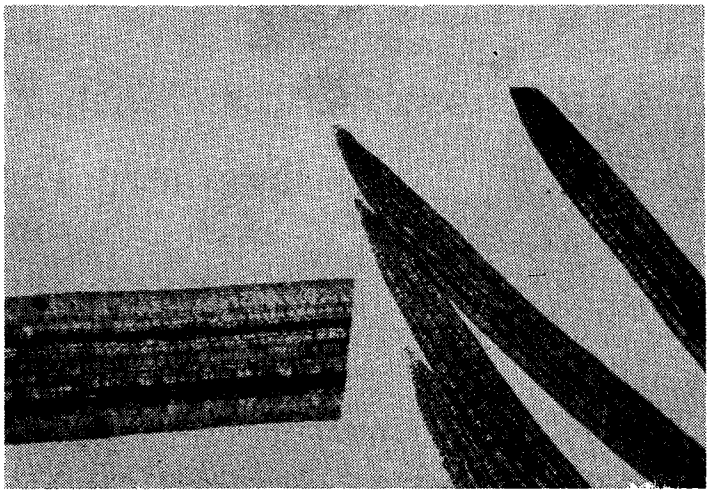

Figure 2. Example of masticated Eurasian watermilfoil fragments taken from the alimentary tract of grass carp. Distinguishing characters are: the leaf margins and tip are spineless; leaf pinnately dissected with distinct parallel venation; and apex of leaf is rounded to acuminate.

Southern naiad. The major discernible characters of this species were leaf-tip and spine formation. The leaves are narrow, ribbon-like in appearance, and enlarged at the base. The leaf tip is tapered to an acute to obtuse apex and usually tipped with 1 or 2 spines. There are generally minute spines along the leaf margin in irregular sequence. The linear leaves have a distinguishable midrib (Figure 3).

Common bladderwort. This species of bladderwort is characterized by discernible bladders and leaves which are capillarily dissected into filiform segments which are subtended by a spine-like cell with several spines along the margin (Figure 4). The fragments, however, in all samples were masticated beyond recognition. Segments of what appeared to be bladder walls were observed but identifiable only on high objective (430X), and could not be held as true identification for common use. Though carp (20-22 cm in length) did readily consume common bladderwort, it has been suggested that larger carp will not grind the plant fragments so

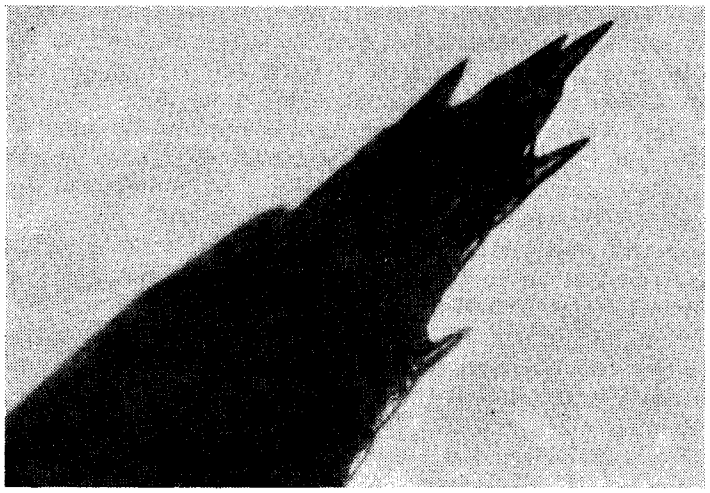

Figure 3. Example of masticated southern naiad fragments taken from grass carp alimentary tract. Distinguishing characters are: the leaf margins have irregularly spaced spines; and the leaf-tip is acute to obtuse with two spines.

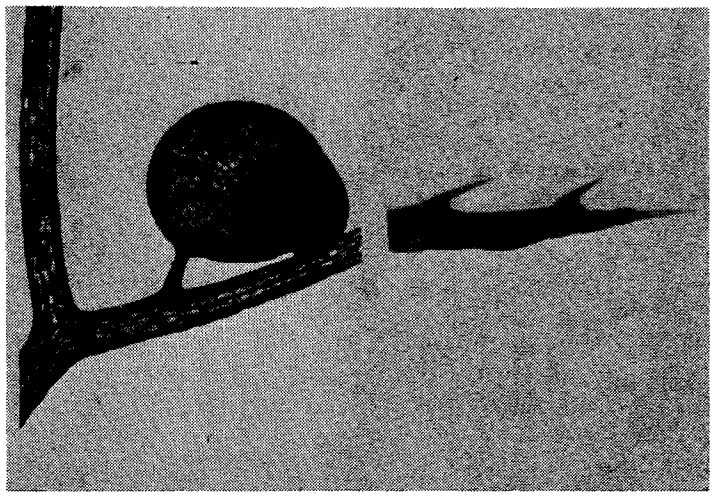

Figure 4. Example of preingested common bladderwort with bladder and filiform segment with subtended spine-like cell.

small and possibly the difficulty of identification would be alleviated[3].

Brazilian elodea and Hydrilla. Taxonomically these species are quite similar in many respects, but differ in several key characters. They are described jointly in order to express similarities and subtle character differences. The most discernible portions of the masticated plant material were the leaves. Even though carp 20-22 cm length were used, leaf fragments were large enough for analysis. Pre-ingested Brazilian elodea leaves are linear-elliptic to linear lanceolate, subobtuse to acuminate at the apex of the blade, serrate (having small marginal teeth pointing forward) with a characteristic spine at the tip. They exhibit a distinct smooth margin and surface texture, and venation displays a prominent discernible midrib. Hydrilla leaves are linear-elliptic or oblong, acute, minutely denticulate (bearing minute teeth directed outward) with a characteristic spine at the tip and along the lower midrib. They exhibit a distinct scabrous or harsh marginal and surface texture, and venation with a prominent discernible midrib.

When masticated fragments were analyzed and compared, however, no appreciable differentiation could be made between the two plants. Though whole leaf tips and sufficient marginal fragments were obtained from both species, leaf margins appeared the same as did spines and midribs. Serrate and denticulate spine differentiations were discernible on occasion but not frequent enough to differentiate between the species. Overall the general leaf form and leaf-tip characters were too similar to separate, and the single spine along the lower midrib of hydrilla was not observed (Figures 5 and 6).

Eelgrass. Leaf-tip, spine and ventation pattern characters are the discernible portions of this species. The leaves are linear in shape, flaccid, to about 6 dm long and 2 cm wide. The leaf blade is obtuse at the apex with several spines (3 to 4) about the tip and is often minutely denticulate (bearing minute teeth directed outward) along the margin (Figure 7). Venation patterns show nerved and netted veins. Though large fragments were observed, carp also characteristically

[3]Doug Colle, School of Forest Resources and Conservation, University of Florida—personal communication.

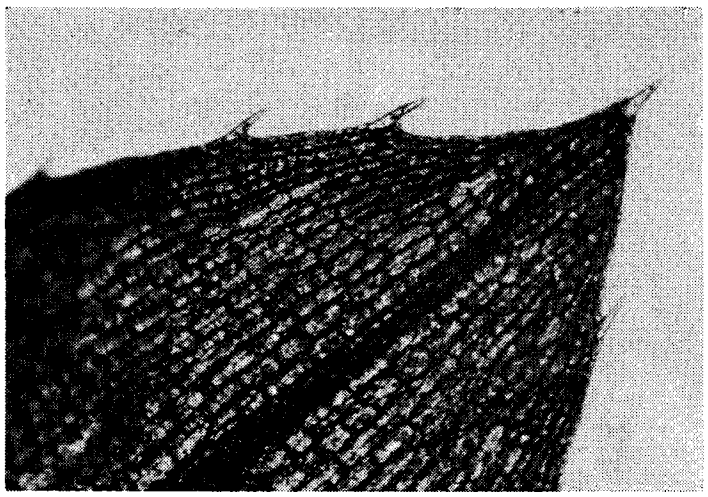

Figure 5. Example of ingested Brazilian elodea removed from the alimentary tract of grass carp. Distinguishing characters are: the leaf margins have spines on both sides in regular succession; blade apex nearly obtuse to acuminate with a single spine; margins serrate; and a single midrib prominent.

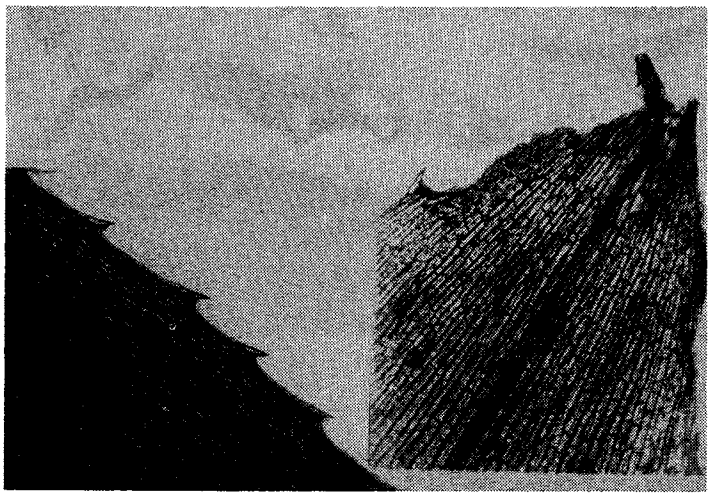

Figure 6. Example of masticated hydrilla fragments taken from the alimentary tract of grass carp. Distinguishing characters are: the leaf margins have spines on both sides in regular succession; blade apex acute with a single spine; margins denticulate; and a single midrib prominent.

shred the leaves in vertical segments from the margin inward, making identification complicated. This and the dwarf arrowhead were the only macrophytes investigated where shredding occurred in this manner. The leaves of eelgrass are apparently hard to tear off in bite-size chunks and are shredded instead in smaller carp.

Coontail. Leaf-tip and spines were the discernible characters of this species. The leaves are branched, brittle or somewhat cordlike and flexous, and form large masses; up to 12 finely dissected, capillary to linear-flattened serrate divisions appear in a verticle. The divisions are very variable as to the length, breadth and number of teeth. The length averages usually about 15 mm long. The divisions of the leaves have marginal teeth pointing forward and are located only on one margin. The leaf apex is rounded to truncate. Two spines are located an equal distance from apex producing a horned-like appearance. Entire leaves were observed and positive identification made using both photographs and

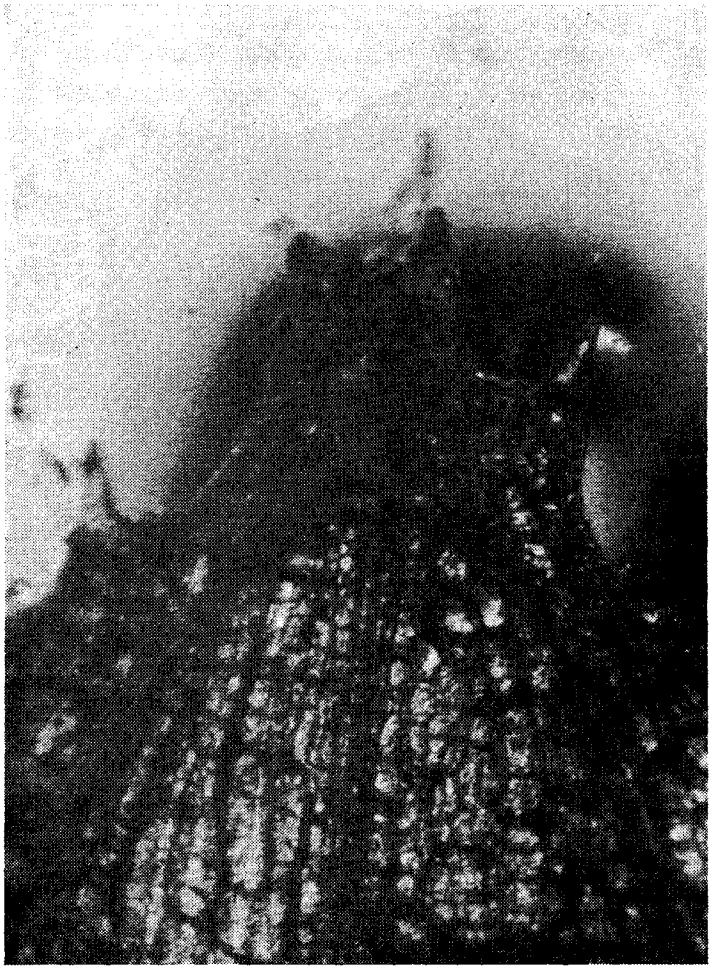

Figure 7. Example of eelgrass fragments taken from the alimentary tract of grass carp. Distinguishing characters are: the blade apex is obtuse with 3-4 spines; and margins denticulate.

preserved specimens of preingested leaf material. Because of its brittleness, leaves passed were almost completely intact as in fanwort and Eurasian watermilfoil. Stems were masticated beyond recognition (Figure 8).

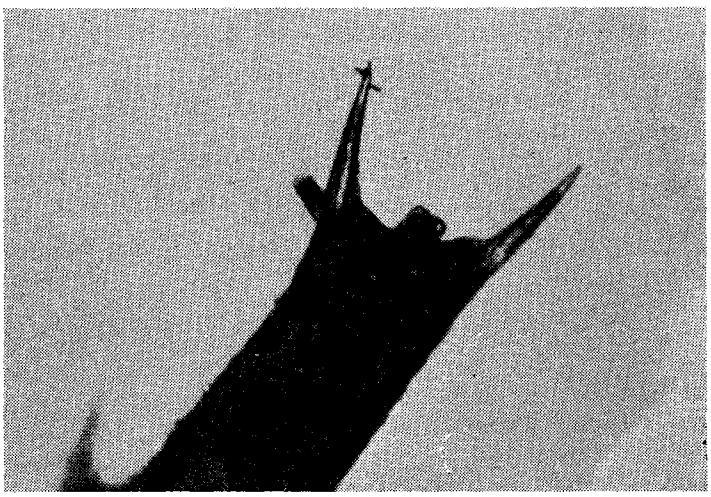

Figure 8. Example of ingested coontail removed from the alimentary tract of grass carp. Distinguishing characters are: the leaf margin has spines only on one side; and the apex is rounded to truncate with two spines equal distance from the tip, producing a horned-like appearance.

Dwarf arrowhead. Leaf shape and margins were the discernible portions of this species after ingestion. The submersed leaves are lanceolate to ovate in shape with a rounded apex. This species has leaves which are turgid in nature when compared to eelgrass which feels flat and hard. Unlike eelgrass the leaves did not have discernible spines around the leaf apex or along the leaf margin. The venation has a prominent midrib with a dominant lateral rib near each margin as compared to the net-like appearance of eelgrass. The basal portion of the leaf has characteristic horizontal bars extending for a distance of 0.5 to 0.8 mm from the base at regular intervals (Figure 9). This segment of the leaf constituted 85% of the masticated material. As with eelgrass the carp shredded the plant. The differences were (1) the shredded material was easier to discern in eelgrass suggesting greater palatability for easier consumption and mastication in dwarf arrowhead and (2) the lower basal segments of the leaves and root bundles of eelgrass were not eaten whereas they were in dwarf arrowhead and remained intact through digestion.

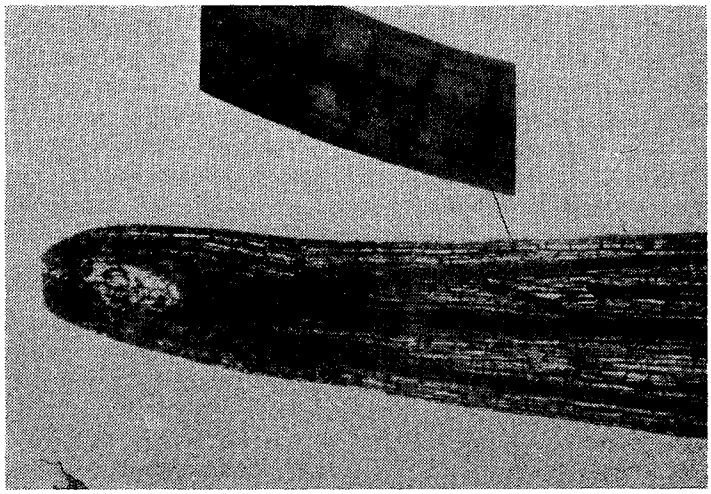

Figure 9. Example of masticated dwarf arrowhead fragments taken from the alimentary tract of grass carp. Distinguishing characters are: the leaf margins and tip are spineless; blade apex rounded with a distinct midrib and prominent lateral rib near each margin; and the basal portion of blades have several characteristic horizontal bars.

Muskgrass. It was thought that identification could be obtained through leaf-tip and spine formation as in the macrophytes. Even though each leaf in muskgrass is subtended by a discernible single or pair of spine-like cells, they were masticated beyond recognition. The internodal cells, however, were found quite frequently. The characteristic corticated vertical cells were easily observed as were the bracts at the nodes. Muskgrass, therefore, can be identified by the corticated cells of the erect axis of the thallus (Figure 10).

Larger grass carp (36 cm in length) were used for the pondweed and eelgrass studies. The larger grass carp were used for two reasons. Previous studies indicated that the carp should be larger than the 20-22 cm range to consume larger plants, and the difficulties in identifying the masticated fragments of bladderwort using the smaller carp. Actually the long and narrow thread-like capillary divisions of fanwort and Eurasian watermilfoil were easier to identify than pondweed, though larger fragments of pondweed were

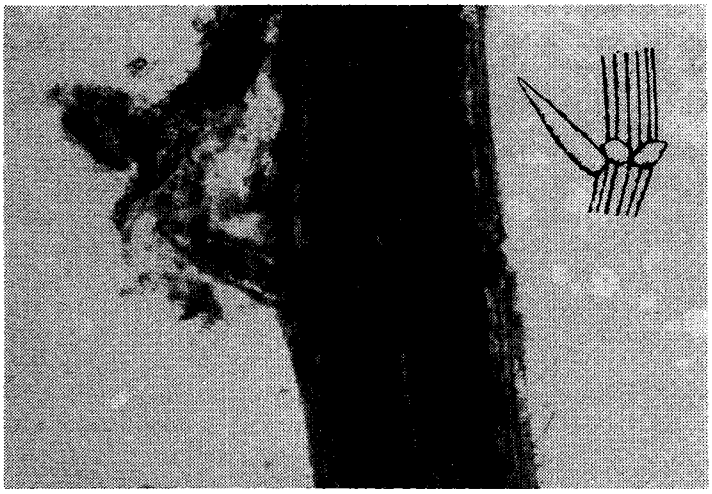

Figure 10. Example of the corticated vertical internodal cells of muskgrass taken from the alimentary tract of grass carp; with thorn-like cell (bract) at the node still intact.

obtained in the analysis. The blades of pondweed and eelgrass are measured in dm and cm, while those of fanwort and Eurasian watermilfoil are measured in mm. Though smaller in size, the thread-like divisions of fanwort and Eurasian watermilfoil are quite discernible and apparently pass through the mastication process more or less intact. Plants with longer, broader leaves such as pondweed and eelgrass, suffer more damage in the grinding process. Discernible fragment characters were found for all hydrophytes investigated except common bladderwort where fragments were ground beyond recognition. Minute subtle character differences were found between elodea and hydrilla. However, if the lower midrib spine of hydrilla cannot be discerned, the general overall leaf form and leaf-tip characters of these two plants are too similar to separate.

KEY TO THE IDENTIFICATION OF MASTICATED PLANTS REMOVED FROM THE ALIMENTARY TRACT OF GRASS CARP

1. Plants aquatic with finely dissected leaves.
   2. Leaf margins with spines; leaves palmately dissected or dichotomously forked, midrib distinguishable.
      3. Leaf margin with spines on both sides in regular succession; leaf palmately dissected, apex rounded with usually four spines equally spaced about the tip. ..... *Cabomba caroliniana*
      3. Leaf margin with spines on only one side; leaf dichotomously forked, rounded to truncate with two spines an equal distance from apex producing a horned-like appearance. ..... *Ceratophyllum demersum*
   2. Leaf margins without spines, leaf pinnately dissected, apex rounded to acuminate, no discernible spines were found, distinguishable parallel venation. ..... *Myriophyllum spicatum*
1. Plants aquatic, leaves not finely dissected.
   4. Leaf margin with spines.
      5. Margins with regularly spaced spines.
         6. Blade apex with single spine, midrib distinguishable.
            7. Blade apex nearly obtuse to acuminate; margins serrate. ..... *Egeria densa*
            7. Blade apex acute; margins denticulate, lower midrib spine. ..... *Hydrilla verticillata*
         6. Blade apex with 3-4 spines, obtuse; blade venation parallel with no distinct midrib; margins denticulate. ..... *Vallisneria americana*
      5. Margins with irregularly spaced spines (minute spinules), apex with two spines, acute to obtuse, midrib distinguishable. ..... *Najas quadalupensis*
   4. Leaf margin without spines.
      8. Blades usually with 7 nerves, rarely up to 19, with conspicuous interlocking veinlets; apex mucronate; margins with minute (observable only at 430X) translucent, 1-celled decidous teeth. ..... *Potamogeton illinoensis*
      8. Blades with prominent midrib and prominent lateral rib near each margin; apex rounded, basal portion of blade with characteristic horizontal bars. ..... *Sagittaria subulata*

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