

A Q U A P H Y T E



UNIVERSITY OF
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Institute of Food and Agricultural Sciences

CENTER FOR AQUATIC PLANTS

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A "Natural" Sewage Treatment System

Problem: You produce a large recreational event that draws 100,000 people from all over the world for only four days out of the year. This many people produce more than 1 million gallons of waste during four days. Furthermore, your event is isolated from the city--and there are no toilet facilities nearby, not even a Kwik-Gyp store. There are environmental standards for disposing of this waste, and you cannot break the law.

What do you do?

One possible solution is to run wastewater trunk lines from your facility to a municipal treatment system. If you're lucky, then you're close enough so that this would not be too expensive. If you're unlucky, and the nearest connection point is several miles away, then the expense could be several million dollars.

Another solution is to set up a line of portable chemical toilets, which are universally unappealing and incur significant trucking and other disposal expenses.

And another solution is to build a sewage treatment plant on site. However, conventional sewage treatment plants are expensive to build and operate, and they must be continuously supplied with waste in order to "feed the bugs" that break down waste; these systems do not work well with only the occasional "batch loads" of waste produced during your infrequent events.

In real life, the National Hot Rod Association (NHRA) has experienced this dilemma: Every year 100,000 thrill-seekers attend Gatornationals, a four-day national drag racing event held in Gainesville, Florida. Until recently, the isolated race track was fully equipped, except for toilet facilities. Now it even has flushing toilets.

NHRA's solution, in close cooperation with the Gainesville Regional Utilities (GRU), was to design and build an innovative "constructed wetlands" for primary, secondary and tertiary sewage treatment. The system is unique because of its ability to accept sudden and heavy untreated waste loads after prolonged idle periods. And unlike the many acres of wetlands used in some places for tertiary wastewater treatment, this entire compact system occupies less than five acres.

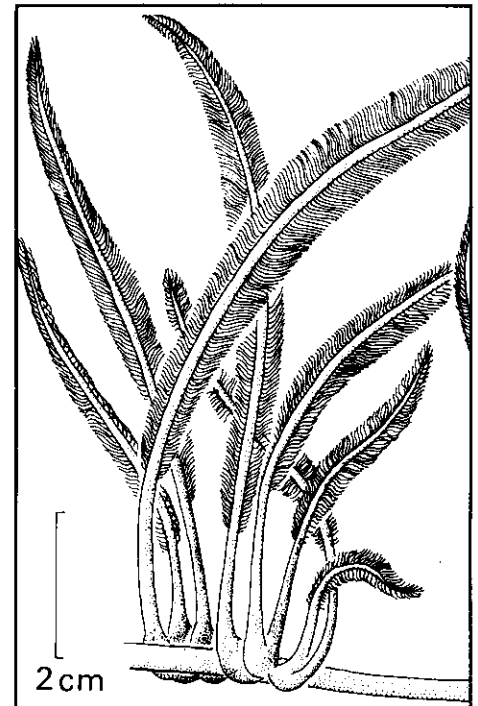
The NHRA/GRU system takes advantage of a new combination of aeration ponds, a gravel denitrification bed, and flow-through ponds filled with aquatic plants for final "polishing".

The resulting treated water meets required environmental standards, and is being used in two ways. Some is diverted for use in on-site fishponds; and some is sent to an automatic sprinkler system which irrigates an on-site pine-tree plantation.

During racing and other recreational events, the system acts as a wastewater treatment plant; during the rest of the year, it acts as an aquaculture farm, capable of supporting the commercial growth of fish, crayfish, shrimp and other freshwater creatures. The aquaculture products and the irrigated pulp-timber can be sold to help pay for the system's overall construction and operating costs.

After two years of operation, the NHRA raceway wastewater treatment system has been declared a success.

[See Waste on Page 4]



Vanroyenella plumosa. A new genus and new species of river-weed, Podostemaceae. (Used with permission from *Systematic Botany*)

River-weeds: A Fascinating Family of Aquatic Flowering Plants

by C. Thomas Philbrick¹ and Alejandro Novelo R.²

Although river-rapids and waterfalls are not typical habitats for angiosperms, this is where the largest family of strictly aquatic flowering plants abound--the Podostemaceae or "river-weeds". The

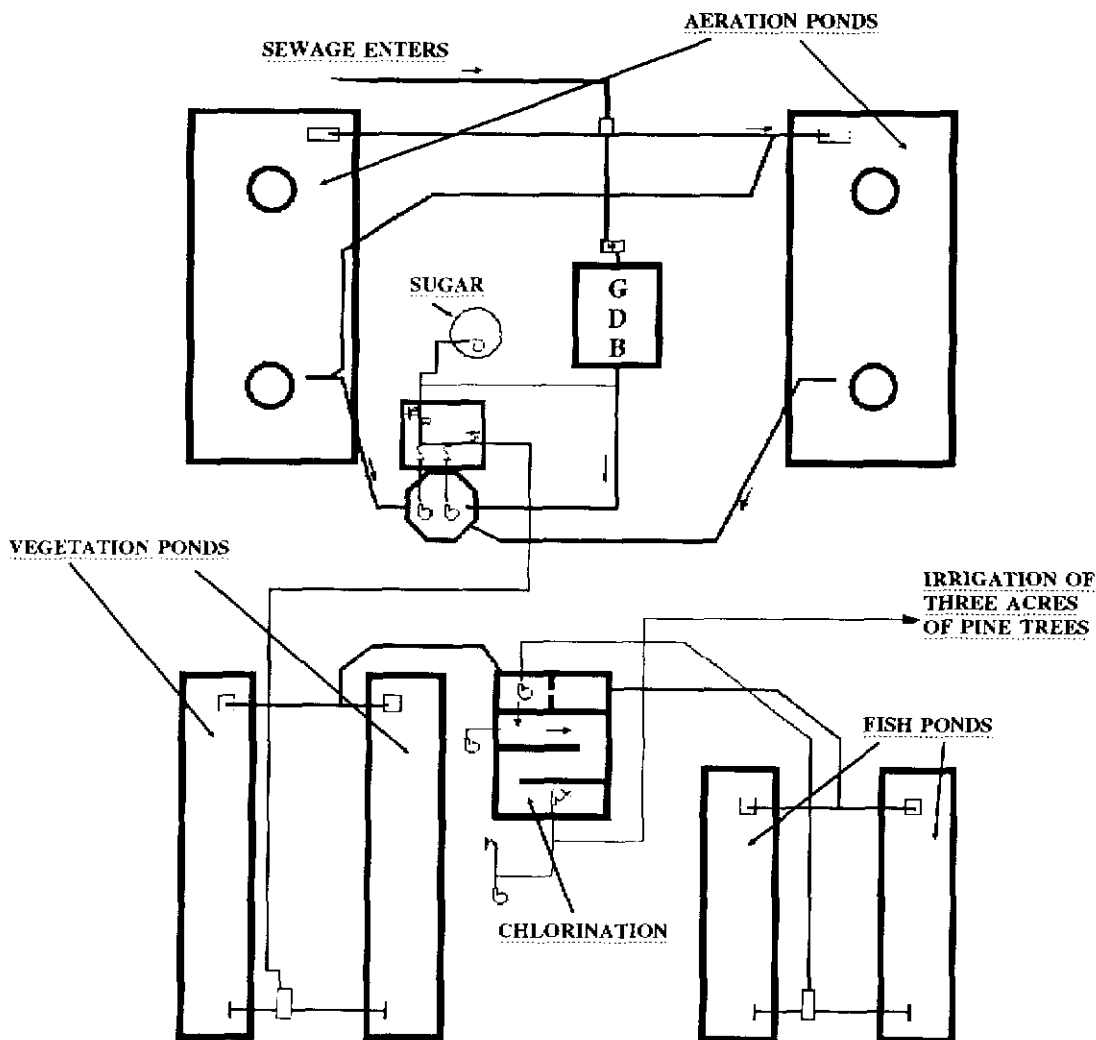
[See River-weeds on Page 6]

[From Waste on Page 1]

The aquaculture part of the system was designed and built under the guidance of researchers Dr. Jerome Shireman and Douglas Colle, and visiting Polish fisheries experts, husband and wife Drs. Karol and Wanda Opuszynski, all of the Department of Fisheries and Aquatic Sciences of the University of Florida.

The Site

The compact five acre treatment facility operates in four phases, and releases treated water on site.



Simplified schematic of the Gainesville Raceway Water Reclamation Facility. Raw wastewater is pumped from the restrooms to the aeration lagoons, to the gravel denitrification bed, and then to the aquatic plant filtration ponds. Polished water is then diverted to aquaculture fish ponds, or to an irrigation system being used to grow pine trees. Cultured fish and pine trees may be sold to offset overall wastewater treatment costs.

Phase 1 (Gatornationals phase)

During this phase, a primary objective is to minimize odors by supplying oxygen by aeration. During racing events, untreated wastewater flows from restrooms into the 1/2-acre lagoons, which are equipped with large floating aeration pumps. The aerators are turned on and allowed to run continuously. During this phase, much of the organic matter in the wastewater is metabolized by bacteria, but little nitrification is accomplished.

Phase 2 (Nitrification phase)

During this phase, ammonia in the wastewater is oxidized to nitrite and then to nitrate. Continuing aeration increases the population of and suspends waste-eating bacteria (*Nitrosomonas*), and helps remove total suspended solids (TSS) and reduce biological oxygen demand (BOD). (BOD is the amount of oxygen consumed by bacteria as they convert and use the organic waste materials.) During this phase, too, water alkalinity is reduced to levels safe enough for fish.

Phase 3 (Denitrification phase)

Denitrification is carried out in the gravel denitrification bed (GDB). During this phase nitrite and nitrate in the water are converted to nitrogen gas, which disappears into the atmosphere. Sugar is injected into the wastewater to establish and maintain high bacterial populations for the denitrification reactions.

The GDB is a plastic-lined pit filled to a five foot depth with 1-inch diameter gravel. In the GDB, water is fed to the bottom of the bed, and is distributed throughout the bottom by a network of pipes. The water percolates upward through the rocks and drains at the top. The water is circulated between the GDB and the aeration lagoons until bacterial action has reduced the ammonia nitrogen to below 1.0 mg/l and the total nitrogen to less than 10 mg/l.

A T T H E C E N T E R

Videophile

Two more video programs have been released by the Center for Aquatic Plants, bringing the total number to some 15 productions relating to aquatic plants and their management. They are:

Maintenance Control Of Aquatic Weeds--What It Is Not!

1993, 12 minutes.

This program presents the concept of maintenance control, "the most environmentally sound and economical method of aquatic plant management." Joe Joyce, Ph.D., explains how it reduces management costs, herbicide use and overall impacts of aquatic weeds and their management.

Florida Lakewatch--Join The Team!

1993, 10 minutes.

This program describes Florida LAKEWATCH, a program wherein citizen volunteers regularly take water and algae samples, and Secchi disc readings in an effort to track the water quality changes of lakes and rivers. The samples are analyzed at the University of Florida Department of Fisheries and Aquatic Sciences, and the resulting data are made available to volunteers and state resource management agencies.

Other video programs from the Center

Florida's Aquatic Plant Story

What Makes a Quality Lake?

Istokpoga--Lake of Legends

Calibration--A Field Approach

How to Determine Areas and Amount of Aquatic Herbicide to Use

AQUATIC AND WETLAND PLANT IDENTIFICATION SERIES:

Floating and Floating-Leaved Plants

Emerged Plants - Part I

Emerged Plants - Part II

Submersed Plants - Part I

Submersed Plants - Part II

Grasses, Sedges and Rushes - Part I

Grasses, Sedges and Rushes - Part II

Programs may be borrowed from the Information Office (904/392-1799). Or they may be purchased from IFAS Publications, Building 664, Gainesville, FL 32611 (904/392-1764) for \$15.00 (plus .90 tax for Florida residents), payable to the University of Florida. Checks or purchase orders are accepted. Specify VHS or European PAL format.

Welcome Back!

We are pleased to announce that *AQUAPHYTE* once again is available to subscribers overseas. We look forward to sharing information with our more than 1,000 friends in other countries. Please keep us advised of address corrections or of colleagues who may wish to receive the newsletter.

Remember to share your work with the readers of *AQUAPHYTE* by contributing reprints to the *APIRS* database. See *FROM THE DATABASE*, page 8-11.

APIRS Update

From approximately 5,000 records ten years ago, the Aquatic Plant Information Retrieval System (*APIRS*) has grown to a collection of more than 34,000 records. They include books, articles, abstracts, proceedings, management plans, and now, videos.

APIRS spans all types of research including plant physiology, taxonomy, weed control methods, utilization as animal feed or pollution control, restoration of freshwater ecosystems, constructing wetlands for wastewater treatment, aquascaping, value as wildlife habitat, and more.

Last year, more than 700 searches of the database were performed for a yield of almost 51,000 citations. Hard copies of 95% of all records are on file in the *APIRS* library.

Searches of the *APIRS* database continue to be provided free of charge, but with the expectation that reprints and publications lists will be contributed in exchange.

We encourage researchers throughout the world to contribute reprints or photocopies of their work for inclusion in the *APIRS* collection.

Aquatic Plant Drawings

Do you need line drawings of aquatic plants to enhance a report, book or journal article or to illustrate a pamphlet, sign or display? Line drawings of over 60 aquatic plants are available from the *APIRS* Office of the Center for Aquatic Plants. A set of the entire collection of illustrations can be provided, or drawings of specific plants may be requested. The botanical illustrations may be used for educational or scientific purposes only. (Commercial use is prohibited.) The drawings are provided free of charge. However, in exchange, users are requested to submit any publications in which the drawings are used. Full acknowledgement is required.

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Dr. Joseph Joyce, Director

Phase 4 (Polishing phase)

In this phase, treated wastewater is drained from the aeration lagoons into two long, narrow, flow-through aquatic vegetation ponds. One pond is filled with the submersed plant, hydrilla (*Hydrilla verticillata*), the other is covered over with the floating plant, duckweed (*Lemna spp.*).

In these ponds, the already treated wastewater is "polished" for use as "make-up water" in the adjacent aquaculture ponds and for ultimate release into the raceway's spray irrigation system.

One purpose of the vegetation ponds is to further reduce the suspended solids (TSS) of the wastewater. This is accomplished mainly by the hydrilla, where the large leaf surface area of the submersed plants act as a natural filter and provides much more substrate for the beneficial wastewater cleansing bacteria.

Another purpose of the vegetation ponds is to reduce the nitrogen and phosphorus in the wastewater. The constantly growing aquatic plants utilize nutrients, and greatly reduce nutrient availability to algae. Reducing algal density makes the water much clearer.

Aquaculture Ponds

For thousands of years, Oriental cultures have been using human and animal wastewater to culture fish and other food animals. Shireman and his researchers say their system is simply a more modern version of this age-old, completely safe and efficient way of growing food.

While finishing the wastewater to required standards, the aquatic plants are regularly harvested and fed to the plant-eating fish being grown in the aquaculture ponds. Harvesting the plants promotes their biomass production, thus further increasing their efficiency for cleansing wastewater, and making more plants available for aquaculture production.

In the present case, the fish being grown are grass carp (*Ctenopharyngodon idella*), which in Florida are used for aquatic weed control, and which elsewhere are used for food. Hydrilla is a favorite food of grass carp, and duckweed is a perfect size for growing fingerlings. In addition, blue tilapia and bighead carp have also been raised in these ponds.

However, there is no reason to limit aquaculture to these kinds of fish--other fish may be grown for food or re-stocking programs, or other freshwater animals such as shrimp or crayfish may be cultured.

Results

Costs

The construction cost of the present facility, approximately \$340,000, was less than one-third that of a conventional system of the same size. In addition, there are no high on-going costs for continuous operational preparedness or for full-time personnel. Operating costs have been estimated at approximately \$12,000 per year.

Water Quality Standards

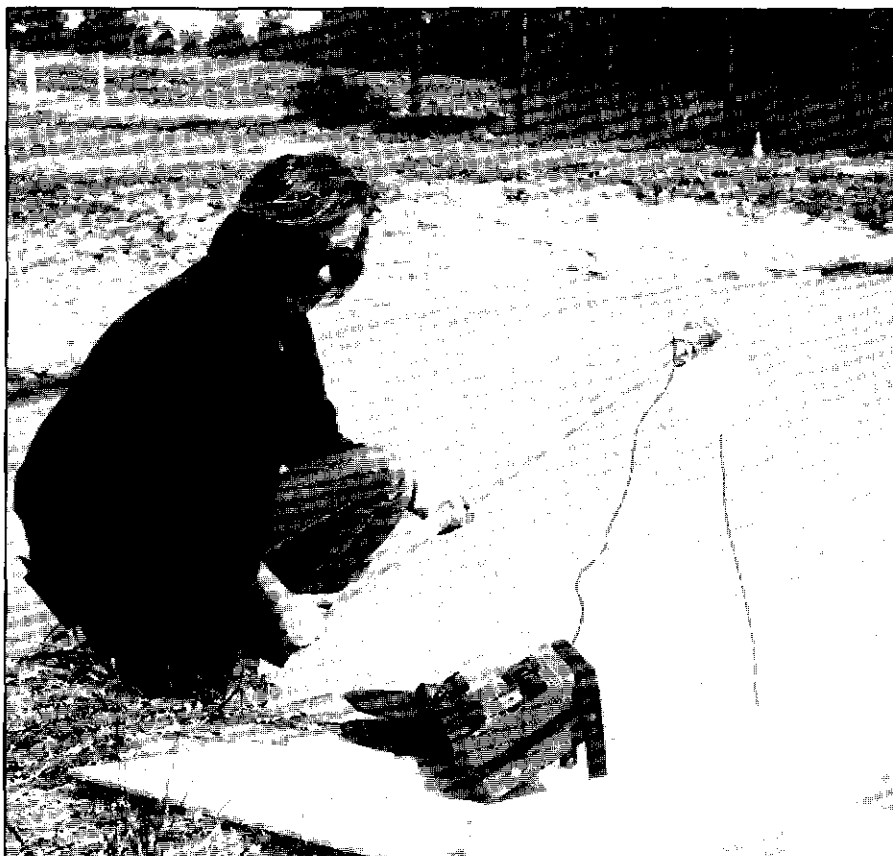
The finally polished water which is disposed of on-site to grow a pine plantation exceeds the standards required by the Florida Department of Environmental Regulation (FDER). These requirements are 20 ppm BOD, 20 ppm TSS, or 90% removal, whichever is greater; and 12 ppm ammonia nitrogen. Chlorine is applied before release to reduce the fecal coliform to less than 100/mL.

Aquaculture Value

The grass carp grown in the fish ponds may be sold in Florida for aquatic weed control. At the common sales price of \$6 for a (10-inch fish), the value of the fish grown in these ponds has been estimated at \$24,000 per hectare.

The system has worked well during two Gatormational events, each of which produced "batch loads" of more than 1 million gallons of wastewater during the four days of races. By all measures, this unique and compact "natural" wastewater treatment system must be judged a success.

For more information on this "constructed wetlands" system, contact Dr. Jerome Shireman, Department of Fisheries and Aquatic Sciences, 7922 NW 71st Street, Gainesville, Florida 32607, (904) 392-9617.

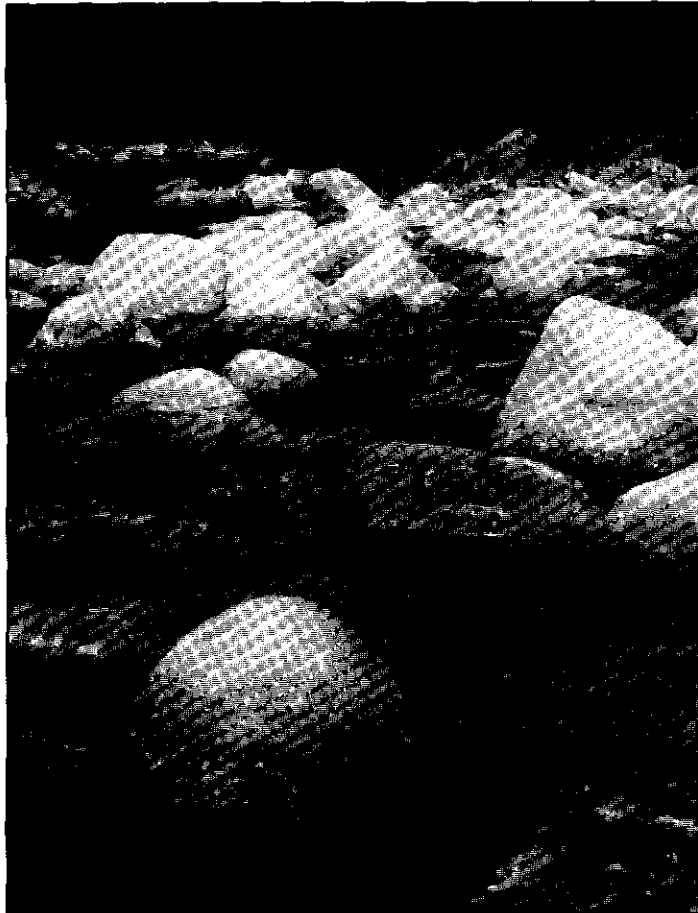


Chemist Dr. Wanda Opuszynska, takes one of her last water samples at the raceway before returning to her native Poland.

[River-weeds, From Page 1]

ecology of river-weeds stimulates the imagination. Plants grow tenaciously attached to rocks and other solid substrata in rushing torrents of tropical river-rapids and plummeting waterfalls. However, although a few general accounts of their seemingly bizarre morphology, anatomy, and modes of reproduction are available, virtually nothing is known in way of detail for any of the species. In fact, understanding of basic biology of these fascinating plants could provide valuable insight into the evolution of aquatic plants in general and man's impact on the aquatic environment.

In contrast to most other families of strictly aquatic flowering plants that possess at most 17 genera and seldom more than 30 species, the river-weed family contains 48 genera and 268 species. River-weeds have adapted well to, and flourish within, this extreme aquatic habitat.



General habitat of river-weeds during low water period (dry season), Horcones River in Jalisco, Mexico. Plants occur on these large granitic boulders.

mucilaginous layer of the seed coat. When hydrated, these cells expand, and upon drying adhere the seed firmly to the substratum. Successful attachment of the seed seems most likely when the rock is dry (low water period). Secondly, the seedling must become established. The seed germination and seedling attachment phases occur when the water level is high, i.e., in rushing current. Immediately after germination the projecting seedling bends toward the rock and the apex flattens against it. Elongate extensions of the epidermal cells of the seedling radical secrete a substance ("podosto-grip") that affixes the seedling.

Inadequate collections in herbaria are a central problem in dealing with the taxonomy of river-weeds. Species are generally represented by few, or often only one, collection from large geographic areas, and those specimens that are available are often incomplete. It seems that the life cycle of these plants has been a major hindrance to developing adequate collections. An additional factor seems to be the general lack of inclination of botanists to visit river-rapids in search of plants. Clearly a concerted effort is needed to collect complete specimens. Maximum vegetative growth of river-weeds is when the plants are submersed, thus the largest leaves are collected prior to flowering. However, when plants are exposed, and flower, the mature leaves are often shed. Smaller secondary leaves may be produced subsequently, often with a markedly different appearance. Finally at the time of mature capsule formation the leaves have long since died back. Thus it is necessary to visit a population repeatedly or for a duration of several weeks to collect all phases of the life cycle. All phases are needed for the most meaningful taxonomic work.

Numerous authors have noted the high level of endemism in the river-weeds, i.e., species that occur in only a single set of river-rapids or a single river. The species in the new world illustrates this nicely. From P. Van Royen's early 1950s treatment, it is evident that 14 of the 19 genera contain endemic species. About 48% of all new world species are endemic. However, because of

Podostemaceae are pantropical. Few species occur in temperate regions. *Podostemum ceratophyllum* occurs in eastern United States and Canada and is the only temperate New World species. Thus, it is not surprising that aquatic biologists in North America typically know little of the family.

General life history features of river-weeds reflect the nature of the seasonal habitat in which they occur. River-weeds primarily occur in rivers that have a distinct seasonality; high water levels followed by a low flow period. Vegetative growth takes place during the period of high water when the plants are submersed. River-weeds occur in areas of direct sunlight and well aerated water. Plants grow attached directly to solid substrata (typically rocks) by means of adhering roothair-like rhizoids and fleshy expanded holdfasts termed "haptera". Mature plants are submersed in the swiftly moving water, from which they derive nutrients and dissolved gasses. Podostemaceae do not fit the classical root-shoot model typical of most flowering plants. More akin to the seaweeds, the prostrate axis (the "root") serves primarily as an anchoring organ and seems to play no role in nutrient or water uptake.

Only after the water level drops does flowering take place. Flowering is distinctly aerial and both wind and insect pollination have been reported. The capsular fruit of river-weeds requires desiccation to dehisce. Seeds are initially shed passively onto the rock. Water dispersal is a likely mode of subsequent transport of seed, although dispersal between river systems has also been attributed to birds.

The seed and seedling attachment stages seem especially vulnerable periods in the life cycle of river-weeds. A protective covering of soil or leaf litter that is directly linked to the seed biology of most angiosperms is lacking. For a river-weed plant to become established from seed, two critical attachment phases must occur. First, a seed must attach to, and germinate upon, the surface of a rock. This is accomplished via the outer rather

the need for taxonomic work it is unclear what proportion of the endemism is real versus taxonomic artifact. Here too, the inadequate collections of specimens is a hindrance to interpreting the significance of the purported levels of endemism. Are endemics actually more widespread, or perhaps environmental forms of other species? These questions cannot currently be addressed.

Moreover, a range of intriguing evolutionary questions must wait to be addressed until the taxonomic framework is better established. For example, how has the unidirectional flow of the medium in which river-weeds grow affected gene flow? How is gene flow affected upstream, or between drainage basins? What role has habitat versus biological factors played in speciation? The river-weed family also provides an opportunity to test evolutionary theory, i.e., the overall paradigm that predicts slow evolutionary rates, and thus small taxonomic size, of aquatic angiosperm groups. Why are there so many species of river-weeds? What role does the strong attachment of the plant to the substratum play? The high degree of flowering of most river-weeds also contrasts markedly with the low incidence of flowering of many aquatic plants. What significance is this to the evolution of the group? We must know what the bounds are between species in order to address these questions.

From a conservation perspective it is most prudent to assume that the high level of endemism in river-weeds is real until additional evidence suggests otherwise. Given that high levels of endemism and conservation typically go hand in hand what are the current and projected conservation concerns for river-weeds? This is unclear. Rivers are utilized heavily by people and represent the most heavily polluted of tropical aquatic habitats (Sioli 1986). As human populations increase and development continues in tropical regions so will utilization of rivers for domestic, industrial and agricultural needs. These activities are likely to have detrimental impacts on river-weeds via pollution, water level manipulation, and siltation from construction and agriculture.

Even though little ecological work has been done on river-weeds it is evident that they are sensitive to water pollution. For instance, populations of *Podostemum ceratophyllum* in New Hampshire were decimated after apparent industrial water disposal in the early 1970s (Philbrick & Crow, 1983). Pollution associated with coffee plantations may have led to the extirpation of *Podostemum riciforme* at the type locality for the species in Veracruz, Mexico. Domestic sewage is a likely cause for the demise of two species of river-weeds in the Mexican state of Morelos. Herbarium records indicate that species of *Marathrum* and *Tristicha* occurred in rivers in Morelos as recently as the mid 1970s, although recent field work in these now polluted rivers suggests both have been extirpated.

Siltation is a particular concern. Siltation increases turbidity, decreasing available light for submersed plants. A layer of silt deposited upon the rocks will likely be detrimental to the initial attachment of the seed and subsequently the seedling. Grubert (1974) has shown that seedlings of Venezuelan species are most apt to be washed from the rock by the current during the initial seedling attachment. Studies of Mexican river-weeds have led us to the same conclusion.

It may be possible for aquatic resource managers in tropical regions to use river-weeds as biological indicators of water quality. However, comparing scanty historical records against current distribution patterns can only suggest their potential in this regard. We are hopeful that comprehensive records compiled from ongoing studies can contribute to a database to help assess changes in water quality in the future. Of course, detailed physiological studies would be needed to define sensitivities of particular species. Biological indicators of this sort could serve as a valuable low-cost means of quickly assessing water quality in tropical rivers.

The Podostemaceae are a fascinating group of aquatic plants that begs the attention of aquatic plant biologists. From an evolutionary perspective, the family remains enigmatic. Issues ranging from the ancestral origin of the family within terrestrial groups, to the ecological and biological factors resulting in the remarkable radiation in such an extreme aquatic environment, remain unexplored. From a conservation or wetland management perspective, river-weeds may hold special promise as biological indicators. Indeed, the habitats that river-weeds occupy, river-rapids and waterfalls, should be viewed as a unique form of tropical wetland with an unique flora (and fauna) and concomitant conservation issues. However, an appreciation of this unique habitat can only be attained after we achieve some degree of understanding of the biota that occur there. This is currently lacking.



Close-up of *Vandroeyella plumosa* plant attached to a granitic boulder. (Swift current running over the plant makes difficult the photography of the plant.) The leaves of this species are long and feather-like.

¹ Rancho Santa Ana Botanic Garden, 1500 N. College Avenue, Claremont, California 91711.

² Departamento de Botanica, Instituto de Biologia, Universidad Nacional Autonoma de Mexico, D.F. 04510.

FROM THE DATABASE

Here is a sampling of the research articles, books and reports which have been entered into the aquatic plant database since November, 1992.

The database has almost 35,000 items. To receive free bibliographies on specific plants and/or subjects, contact APIRS at the address shown on the mail label on page 16.

To obtain articles, contact your nearest state or university library.

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