Barr Report

Barr Report

with Tom Barr, Greg Watson, and the Plant Guru Team

The Freshwater Red algae: Rhodophyta

Special points of interest:

- Red algae are often commonly called Black Brush Algae and Staghorn Algae
- Only through verification and testing can we draw clear evidence
- PO4 is an ineffective method to control algae
- Red Algae appear to be very capable of withstanding low light, thus blackouts are ineffective.

Inside this issue:

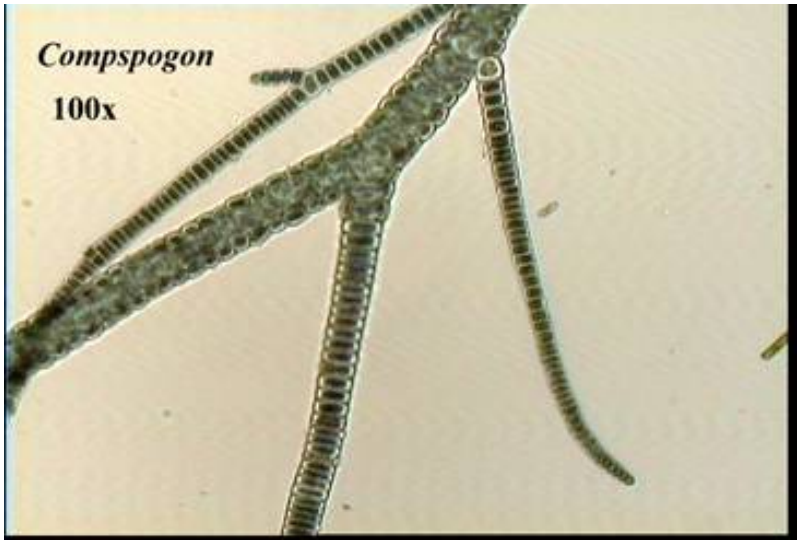


Figure 1. *Compsopogon* was not identified until the author identified it in 2002 as the main species labeled as "Staghorn Algae" in planted aquariums. It is a "red alga" even though it is generally a dull grey in color. Other pigments generally mask the character color of many species of algae. When decaying or dying, it will show the red pigment. Photo: University of Wisconsin, dept of Botany.

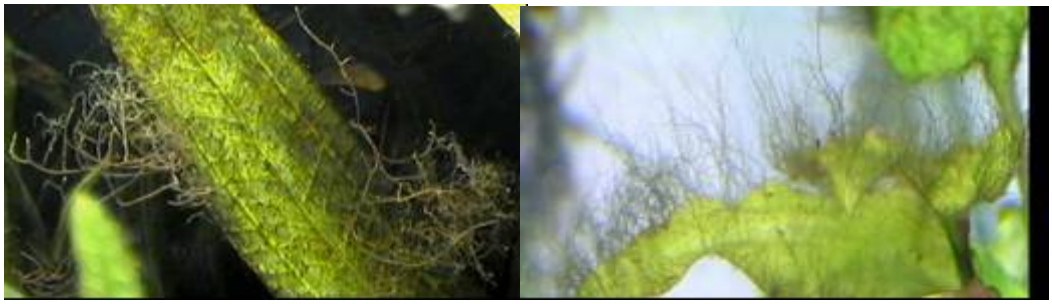
"… Red algae tend to be poorly identified. The key should help future aquarists better identify the pest algae they encounter …"

Red algae are typically a multicellular marine group but several species and genera are present in freshwater systems. Primarily the genera *Audouinella* and *Compsopogon* are the main two freshwater algae present in planted aquariums and often the bane of many aquarist. However, many aquarist enjoy *Audouinella* alga on their rocks and driftwood for adding a more "natural feel" to their decor. Some more common names for these are Black brush algae (generally shortened to the acronym: BBA) for *Audouinella* and for staghorn algae for *Compsopogon coeruleus*. Generally, red algae are considered "weeds" in freshwater aquariums and are frequently discussed perhaps more than any other topic on web forums. A "weed" is simply an alga or a plant that is somewhere you do not want it, thus the term is

Continued on page 2

The Freshwater Red algae: Rhodophyta

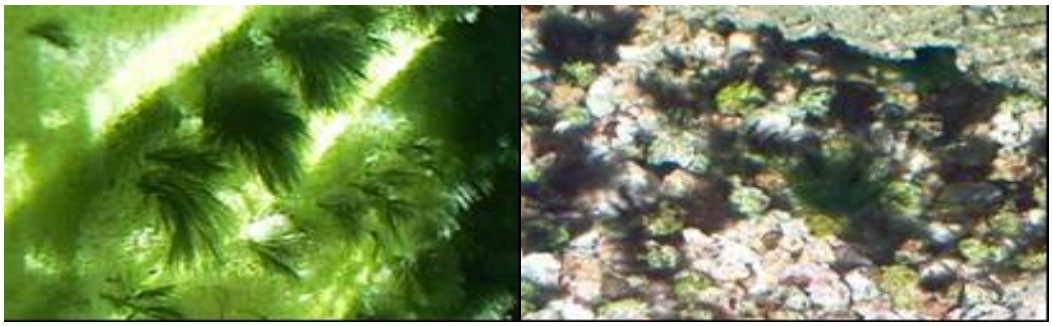
... there is a great deal of advice and folklore surrounding algae in general, its cure, its causes, and how to manage it ....



Larger scaled up version of staghorn algae

arbitrary, being defined the person viewing the plant or algae. There is a great deal of advice and folklore surrounding algae in general: its cure, its causes and how to manage it. While there are an infinite number of web sites and hobby levels books on algae, few, if any have done any significant research for methods for the identification and their physiology in the aquarium context. Most repeat the same hobby level advice without looking into the topic deeper and considering the underlying mechanisms of ecology and physiology of algae.

"Red algae are very frustrating for aquarists, desperation causes many to try all sort of methods and not think things through with careful step approaches ..."



Many aquarists feel that if everyone else agrees on something, that it must be correct, this is not true. When we make assumptions, try and find a cause, we need to make sure and test as well as confirm to see if these explanations are indeed correct. Poor test methods complicate results and correlations rather than causations are generally used to justify advice without virtually any confirmation. In order to gain a better understanding about algae, some background research and approaches to methods are critical in providing a more detailed understanding of algae's role and management. Observations alone are of limited use and often are not a powerful tool in understanding ecology and natural systems, thus when possible, testing and manipulation of the aquarium may be done. This allows the aquarists and researcher to isolate the environmental abiotic and biotic interactions surrounding algal ecology. Such tools and test methods are available for aquarists as well; one does not need to be at a research institution nor a professional Phycologist. Many such test are rather simple. Aquarists can learn a great deal about how to set up basic test, and the test need not prove something has a cause per se, it may prove what something is **not**. After ruling out various explanations, the aquarists may be better able to

... Good stable CO2 levels, 10 hour light times, good maintenance and cleaning will generally stop all red algae.

Continued on page 3

The Freshwater Red algae: Rhodophyta

ascribe cause to a limited number of possible variables and test these on the system and then compare the test with other aquarists to see how well the model fits a wider variety of aquarium systems.

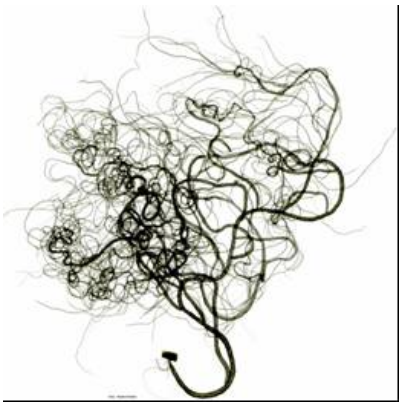
A practical test:
A simple test was done by a hobbyist to see if *Audouinella* was caused by excess levels of PO4 in the plant aquarium.

Hypothesis: *Audouinella* is caused by "excess" levels of PO4 in the plant aquarium
Test method:
Add KH2PO4 in an otherwise stable algae free planted aquarium(1ppm PO4 inorganic)
Observed and repeated the experiment 10 times.
Result:
No algae appeared and robust plant growth was also noted.
Noticeable dramatic increases in pearling occurred after 40 minutes of additions of PO4.
Conclusion
BBA cannot be induced by PO4 alone (or any other species of observable algae)

Table 1

Only through verification and the having good examples to draw from can the aquarists be assured that the test was correctly done. ...

While not showing what causes a BBA algae bloom, it showed that it could not be caused by excess PO4, therefore there must be some other reason for the algae bloom. Thus aquarists *can* make a hypothesis, then manipulate and test it to see if their hypothesis was correct or not by isolating the system. Aquarists need not wait for a definitive research paper to investigate freshwater algal ecology in planted aquarium systems. Researchers also rule out the most obvious possible answers by doing many test until they find one of a few that hypothesis that might be the correct answer. A hypothesis must be testable and falsifiable.

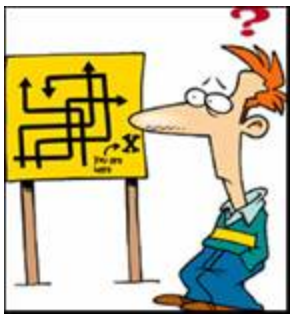


A key point to such test: good control of the environmental variables, this is critical to ensure other confounding factors are not influencing the results. Many new aquarists and older experienced aquarists can often be misled and be unconvinced if they do not have the ability to start with am good system that is algae free and non limiting. This is problematic and can cause conflict when

Continued on page 4

The Freshwater Red algae: Rhodophyta

debates as to causes are discussed. Only through verification and the having good examples to draw from can the aquarists be assured that the test was correctly done. A non bloom result example when the addition and treatment was done is a clear evidence that something else is maintaining the stability and that an algae bloom cannot be due to the treatment alone. While many have control issues with aquariums, many others do not and have shown this. Until the aquarists gains such control, they are general not sure how everyone else is doing it and are so certain.



How many feel with algae problems

"... repeat the experiment on the same tank several times ..."

The key parts: repeat the experiment on the same tank several times and go back and forth; using presence/absence hypothesis for blooms (if X causes algae blooms, then adding X should produce a bloom), defining what is "excess"- use some defined amount rather than some useless generalization that offers no quantitative measurement. These are methods and test aquarist can do and achieve. The use of a standard solution to verify test kit calibration are part of the method. Making a standard solution requires a volumetric flask or an accurate graduated cylinder, pipette and a decent gram scale for weighing the nutrients. Make a concentrated amount of reference solution and then dilute with DI water to make reduced concentrations for the range of interested being tested. This will greatly increase the confidence for the test. In doing this procedure, being able to state definitively that 2.0 ppm of PO4 does not induce black brush algae gives then aquarists far for confidence and precision than those that guess and say things like "Excess nutrients cause algae". That statement is so general and does not give any range of mention of what "excess is", thus has little meaning to help anyone solve their algae related issue.

Figure 2. Solar salt works using red algae to purify brine that is then eaten by brine shrimp (yes, this is San Francisco bay and that is the same brine shrimp you feed to your fish which was introduced to the hobby by the San Francisco Aquarium Society many decades ago) and removes the waste and impurities via fecal pellets before the pure brine is sent to the evaporation ponds. The higher the purity, the better the salt quality, reduced water content, better color and less transport and post harvest cost. These systems use about 10% of the total cost for electrical and fossil fuels as salt "mining". These are the main source of salt for the world's production (210 millions tones, 2006).

Continued on page 5

The Freshwater Red algae: Rhodophyta

Another aspect to this same test was to investigate if BBA could be potentially limited and die off with severe PO4 limitation.

Hypothesis:
Audouinella maybe eradicated using limiting PO4 levels from planted aquariums
Test method:
Aquarist added K, NO3, trace elements and all the other required nutrients at relatively high non limiting levels to drive PO4 to limiting levels using two planted aquariums.
Using PO4 make up water, did successive water changes and allowed aquarium to stabilize (3 weeks).
Treatments:
1# Added *Audouinella* from 3 substrates: a rock, driftwood and *Anubias* to one control tank test and limited PO4
2# Induce new *Audouinella* growth in #2 test tank using low CO2, attempted PO4 limitation
3# Raised the CO2 back up after colony had formed and subjected to PO4 limitation
4# Added CO2 and PO4
Results:
1# No change, even after 6 months
2# Increased growth
3# No new net growth
4# Slow decline in biomass, no new growth
Conclusions:
PO4 limitation is an ineffective method to control algae. Plant growth also slowed significantly but was not harmed over the long term and was able to return to non PO4 limited state growth rates rapidly afterwards.

Table 2.

The tap water was PO4 free and verified and tested as well. This aquarists was unable to stop the BBA bloom through PO4 limitation. The plant's growth rates decreased notably. Lamotte and Hach PO4 test kit methods where used and calibrated. The method of inducement was removal of the CO2 enrichment. Past aquarists had been relying solely upon observations and non calibrated hobby grade test kits alone, which where seldom if ever referenced against known concentrations of PO4, NO3 or CO2. If the planted aquarium had lower levels of CO2 for a few days, then an increasingly higher concentration of NO3 and PO4 might appear in the aquarium, as

Continued on page 6

The Freshwater Red algae: Rhodophyta

the limiting supply of CO2 would greatly reduce the plant uptake of PO4 and NO3. This is classic example of how correlation of higher NO3 and PO4 are not a cause of BBA; rather, they are artifacts from poor CO2. While poor CO2 is discussed as a cause, it should be suggested that varying high and low CO2 levels in the same day or within a relatively brief time frame of a few days, can also induce BBA blooms. This is due to plants adapting to a stable set of environmental conditions. Non CO2 enriched systems (not including Sachem "Excel" based dosing) maintain low stable CO2 to which the plants adapt and change their enzymes to account for, when high levels of CO2 are pulsed, the plants respond by reducing the enzymes responsible for CO2 uptake as there is much more available. Plants try to use signals from the environment make the most of their metabolism. When the levels are varied greatly, this can cause sub optimal to severe limitations of Carbon supplies for the plants. BBA appears to take advantage of these changes and their spores bloom. In natural systems, increases and decreases in CO2 in flowing logic waters tends to be marked by higher nutrients and seasonal changes, this provides a good environmental cue to bloom and have a high probability to complete their life cycle (Ensminger *et al*, 2000). While this does not prove causation form all cases, it has been shown for many years to address new growth of BBA over the long term and is better at addressing BBA than any other proposed models. Further support through inducing BBA in an otherwise stable aquarium by reducing/removing CO2 supply or varying it over a wide range and waiting to see what occurs leads to BBA in most cases. This suggests at least one cause. There maybe more but no one has shown what those might be to date. Many aquarists argued that this was not the case for *their aquariums*, but such aquarists had existing algae issues already and thus lacked the control to isolate their original problem with *Audouinella* bloom, poor CO2. This confounded their results. NH4 and CO2 are both very ephemeral and can vary over short time frames. As these are suspects for a variety of algae blooms, they can be manipulated to investigate algae blooms. This requires control and also the desire to induce algae in their aquariums, something few aquarists actively try to do. The advantages to purposeful blooms are being ready to measure and investigate the potential causes for algae. In doing so, we can gain a better understanding and prevent and predict future algae blooms, as well as offer methods to address cures.

I had BBA for about 3 years, it was very frustrating. I started applying better CO2 dosing and it went away. I've only had it return when the CO2 dosing has been poor, sometimes coming on later in the day a couple of hours after the lights had come on due to multiple tanks and long CO2 gas lines. These tanks consistently had issues and they all where traces to CO2 supply. I have not had any BBA related issues since I have had this understanding and model to control for BBA after over a decade. I've also been able to help countless hobbyists cure their tank over the long term using this model. Due to hobbyist's assumptions, over looking some issues, variability in giving advice over the web, there are few that have still had troubles. But for the most part, the results have been successful in pin pointing this alga's cause and solution for control.

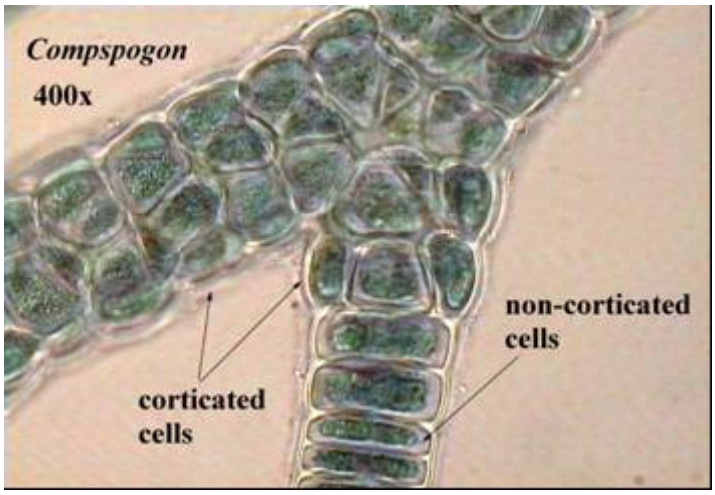


Photo credit: University of Wisconsin, Dept of Botany.

While many planted aquarist passionately believe that they are doing everything correctly, we are human. There is a social and economic side to this hobby.

Continued on page 7

The Freshwater Red algae: Rhodophyta

Thus we must confirm and double check things to make sure our assumptions are indeed correct. In order to keep ourselves honest, we must address such methods carefully and not be fooled by correlations alone. By adding a suspected nutrient that may cause algae to an otherwise stable planted aquarium, we should be able to rule out whether it does cause algae. It is surprising to read proposed hypothesis about various algae issues from commercial vendors and books suggesting casual relationships between algae and nutrients in this hobby, yet these same references have not even fairly tested their own proposed hypothesis and reasons for algae blooms in aquariums. There is little research in the scientific literature about mechanism of algae blooms in planted aquariums. Therefore aquarists are often left with doing the research themselves (if they want any answers anytime soon). The test are generally simple and relatively cheap to perform. The goal of this article as well as others on algae and aquatic plants is to leave the aquarists with some methods and approaches so that they might take the next step, test and manipulate their algae in effort to better understand the dynamics and ecology. The first part in that process is identification.

Rhodophyta Background and Identification:

There are about a total of 600 genera with 5500 morphological species of Rhodophyta. About 10% of the species are freshwater and 90% are marine. The Rhodophyta are a distinct eukaryotic lineage characterized by the accessory photosynthetic pigments phycoerythrin, phycocyanin and allophycocyanins arranged in phycobilisomes, and the absence of flagella and centrioles (Woelkerling, 1990). Their storage product is called Floridian starch with alpha 1,4 linked glucans. This starch lacks the amylose unbranched portion of "starch". The pigment, phycoerythrin, reflects red light and absorbs blue light. Because blue light penetrates water to a greater depth than light of longer wavelengths, these pigments allow red algae to photosynthesize and live at somewhat greater depths than most other "algae" (up to 800ft in some parts of the Caribbean). Some rhodophytes have very little phycoerythrin, and may appear green or bluish from the chlorophyll and other pigments present in them. Their chloroplast have thylakoids that do not stack; thus they form no “grana”. Their chloroplast is enclosed by double unit membrane. A few species are unicells but show no sexual reproduction. Unicells lack flagella; they can not swim. There are multicellular complex thalli; the majority of them grow via apical cell division. These macrophtyes typically have non-swimming unicells as life-history components (gametes or spores). They have been around a very long time. The oldest red alga fossil is *Bangiomorpha pubescens*, occurring in rocks dating to 1.2 Billion years old. *Bangiomorpha pubescens* is multicellular fossil that resembles the modern red alga *Bangia.*there are at least three species of *Audouinella* present in planted aquariums (*pygmaea*, *hermannii*(syn. *A. violacea*) and *eugenea* note: there maybe 1-2 other species in this genus) and staghorn algae is *Compsopogon coeruleus* most likely based on the samples shown. See Algae Key at the end as well as micrographs.

Water current:

Red algae often prefer fast flowing streams in natural systems. This provides more PO4, removes other epiphytes that might attach, enhances many aspects of metabolism, respiration rate and growth(Whitford, 1960, Schumacher and Whitford, 1965, Whitton 1975).

Continued on page 8

The Freshwater Red algae: Rhodophyta

Chemical factors:

As noted, CO2 concentration and variability has shown to be at least one cause and hypothesis aquarium red algae, DIC (Dissolved inorganic carbon) is critical in the influence the productivity and distribution of these two genera of red algae in natural systems (Sheath and Hambrook, 1990). Most occur in mildly acidic waters, pH 6 to 7 however staghorn is often found in alkaline waters (Sheath, 1987). They are often typically found at below the detection limits for P-PO4 less than 100 ug/l (Sheath and Hambrook,1990). The occurrence is likely due to flow replenishment at very low levels, note: this can be from plant leachates in a smaller semi closed aquarium. This is also the case from many aquatic macrophytes as well and a reason why they can grow at very low levels in flowing water with a large source that is constantly replenished. O2 ranges from 0.2 to 21 ppm have been observed and generally these algae are not found in stagnate, low O2, high organic waters. In general, red algae are found in unpolluted waters and in streams and rivers (Sheath and Hambrook,1990). *Compsopogon* is typically induced with two main methods: overloading the fish and or shrimp biomass, or by disturbing the sediment and not performing a water changes soon there after. Both mechanisms suggest NH4 and likely urea as potential causal factor.

Biotic factors:

Crossocheilus siamensis has proven to be highly effective at attacking and eradicating BBA. In lotic flowing systems, macrophytes are often washed out yearly/seasonally, thus the systems where red algae are present, tend to be in a non equilibrium state consisting mostly of successional stages(Sheath and Hambrook,1990). Nerite snails have been suggested at good herbivores for red algae as well. Few other organisms appear to control these red algae. Various shrimp species may prevent new young growth, but tend to be less effective against established blooms.

Other non Biotic remedies:

Chlorox (bleach)

Removing plant and treating with 5% Clorox (2-3 minutes with a 19 part water: 1 part bleach solution). Removing inanimate objects and treating with > 5%, can be longer time.

Copper

Treating tank (after removing fish) with 0.4 to 0.5 ppm Cu for 10 days

SeaChem's Excel

Addressed two issues, one it kills many algae species and adds a source of carbon which is the root cause for most red algae issues. Use as label describes and do daily water changes and full dose until results are noted. Much milder on plants that the other methods listed.

Continued on page 9

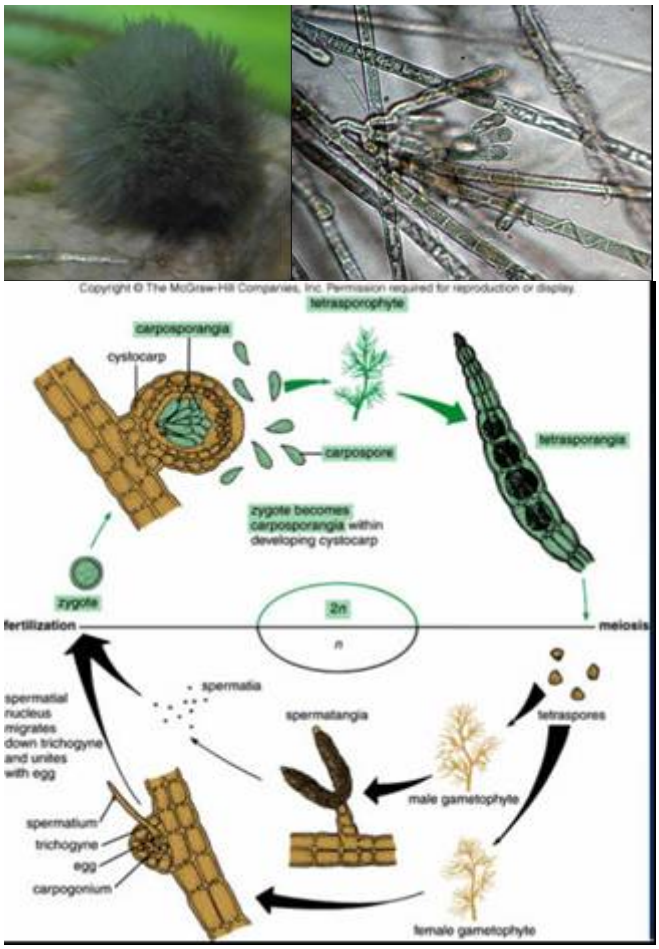
The Freshwater Red algae: Rhodophyta

Hydrogen peroxide

Generally used for whole tank treatments, however, as stated with Excel, may be used with a spray bottle and misted on plants. Copper may also be used with this method as well and allows more dose to the targeted area , less side effects to fish and livestock (plant leaves, equipment) without removal from the aquarium(much less labor involved).

Pruning infected leaves, add more CO2, add SAE's, add Excel

These are the preferred methods as they address the root causes, remove an ugly leaf that's of little use to the plant overall and is unattractive. This method is integrative, it uses several approaches in combination to control present and future outbreaks and is very mild to plants and acts to help them grow, unlike peroxide, copper, bleach, all of which inhibit plant growth. If the level of infestation is very high, then removal in stages and as new growth fills in that's algae free, successive leaves maybe pruned away. However, many times is easier to simple purchase new plants and trim aggressively and remove the filler plants as the new growth fills back in.



Taxonomic flux:

Rhodophytes are just about the only eukaryotes to possess phycobilins, a class of water-soluble pigments; the only other eukaryotes to have them are the Cryptomonads. This and their lack of accessory chlorophylls, such as those found in most other photosynthetic eukaryotes, suggest that the plastids of rhodophytes were gained independently from these other groups. Rhodophytes also lack the eukaryotic flagella, or undulipodia which characterize most other eukaryotes. This has led some experts (e.g. Tappan, 1980) to regard red algae as extremely primitive eukaryotes, a position which is sometimes challenged today. The taxonomic state is in flux at the present time with several groups proposing various schemes. This will surely change in the coming years with better molecular and morphological data.

Figure 4: Typical life cycle for a Red alga. Note the various life stages that occur here and compare this to the vegetative "cuttings only method" with the plants that is most common amongst aquarist. This gives a temporal advantage to the algae under harsh conditions, allow the spores and gametes to survive until preferable conditions occur again.

Continued on page 10

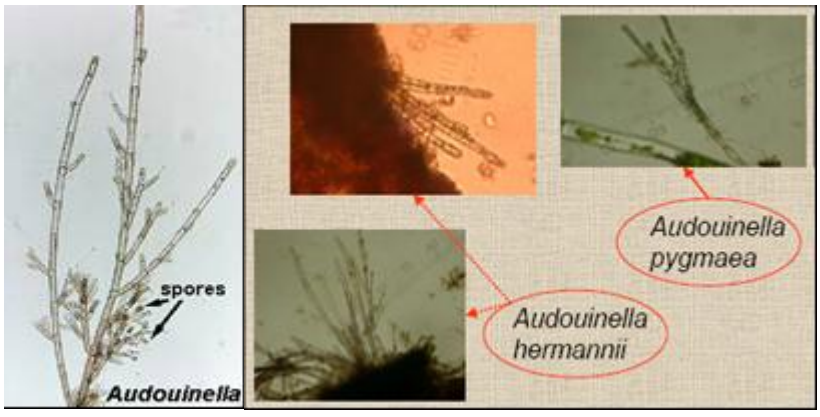
The Freshwater Red algae: Rhodophyta

Classification system according to Hwan Su Yoon et al. 2006

- Subkingdom Biliphyta Wettstein
  - Phylum Rhodophyta Wettstein
    - Subphylum Cyanidiophytina *subphylum novus*
      - Class Cyanidiophyceae Merola et al
    - Subphylum Rhodophytina *subphylum novus*
      - Class Bangiophyceae Wettstein
      - Class Compsopogonophyceae Saunders et Hommersand
      - Class Florideophyceae Cronquist
      - Class Porphyridiophyceae *classis nova*
      - Class Rhodellophyceae Cavalier-Smith
      - Class Stylonematophyceae *classis nova*

Classification system according to Saunders and Hommersand 2004

- Subkingdom Rhodoplantae
  - Phylum Cyanidiophyta
    - Class Cyanidiophyceae Merola et al
  - Phylum Rhodophyta Wettstein
    - Subphylum Rhodellophytina
      - Class Rhodellophyceae Cavalier-Smith
    - Subphylum Metarhodophytina
      - Class Compsopogonophyceae Saunders et Hommersand
    - Subphylum Eurhodophytina
      - Class Bangiophyceae Wettstein
      - Class Florideophyceae Cronquist
        - Subclass Hildenbrandiophycidae
        - Subclass Nemaliophycidae
        - Subclass Ahnfeltiophycidae
        - Subclass Rhodymeniophycidae



Audouinella pygmea and hermannii

Key for species:

Main axis filamentous and **uniseriate** (comprised of only single cells attached end on end) Main axis multicellular: consisting of a core of large axial cells covered by a layer of much smaller, **cortical** (surface) cells. **Uniseriate** (single celled) branches tapering. Swift flowing waters~ Order COMPSOPOGONALES

Continued on page 11

The Freshwater Red algae: Rhodophyta

Compsopogon coeruleus
Compsopogon sp.

Color bluish. Monosporangia obovoidal or elliptical, 12.5-17.5 um long and 9.0 - 12.0 um diameter. Having an irregular prostrate basal system, narrow branch angles and small monosporangia.

Audouinella pygmaea (Kutzing) Weber-van Bosse

Color reddish. Monosporangia >15.0 um long and >12.0 um in diameter. *A. eugenea*, is characterized by macroscopic thalli, the erect system consisting of filaments with cylindrical cells, undifferentiated into proximal and distal parts, and relatively large monosporangia ([gt-or-equal, slanted] 12·0 [mu]m long).

Audouinella. *hermannii* cells are 10-25 um long. Most common species.

1 Lateral branches produced more or less evenly throughout the tuft; branch angle frequently between 20–30° to main axis; monosporangia on several times branched short lateral (fasciculated) systems with central axis ..... **A. hermannii**

1* Lateral branches most frequent in upper parts of tuft; branch angle frequently 15° or less; monosporangia not as above ..... 2.

2 Rhizoidal system unspecialised; monosporangia large (c. 15 µm in diameter) and spherical on well developed, sometimes palmate, short laterals ..... **A. eugenea**

2* Rhizoidal system ropey and plait-like; monosporangia ellipsoid, c. 10 µm in diameter, on one-celled pedicel or sessile ..... **A. scopulata**

Audouinella hermannii (Roth) Duby in DC., *Bot. Gal.* 2: 972 (1830).

Conferva hermannii Roth, *Cat. Bot.* 3: 180 (1806).

Plants macroscopic, to 15 mm high, and composed of numerous uniseriate filaments, reddish. *Basal system* a prostrate open system on host or rock; *erect system* much-branched filaments with laterals forming at angles of 20–30° to the main axis; branching by laterals of indeterminate length throughout the tuft, so whole having a dendroid appearance; *rhizoidal filaments* little different from erect axes, except cells more undulate and slightly thicker walled; *vegetative cells* of erect filaments cylindrical, thick walled, (18–)30–55(–80) µm long, (6–)9–10(–15) µm diam., terminal cell domed, parietal plastid a reticulate system of irregular discoid fragments; *hairs*, when present, one-celled, terminal on lateral branches, narrow, 60–120 µm long, 2–2.5 µm wide. *Monosporangia* carried on short, oppositely branching laterals, in which the main axis may have 4 or 5 cells, the lower 2 often without laterals, and the side axes developing on upper 1 or 2 cells; monosporangia develop in groups of two or three, fresh spores developing inside old sporangium wall; ovoid to ellipsoid, 9–12(–14) µm long, 6–10(–11)µm diam. Sexual structures not seen in New South Wales collections. (Fig. 1d).

Distribution & habitat: Found as coatings on rocks, and occasionally bryophytes (when the mass of tufts look like bunches of currants), or the blades of submerged aquatic macrophytes, in fast flowing, cold, clear mountain streams. Apparently

The Freshwater Red algae: Rhodophyta

Audouinella eugenea (Skuja) Jao

Audouinella eugenea (Skuja) Jao, *Sinensia* 10: 362 (1940).

Chantransia eugenea Skuja, *Beih. Bot. Centralb.* 52: 177 (1934).

Plants macroscopic, pulvinate, 5–7 mm high, composed of numerous uniseriate branching filaments from a compact rhizoidal base, dark reddish, frequently on aquatic mosses. *Erect system* much branched throughout, laterals forming at angles of 15– 20(–25)° to the main axis but curving back to be more or less parallel; *rhizoidal filaments* thick walled and undulate; *vegetative cells* of erect axes cylindrical, thick walled, (20–)30–60 µm long and 10–12 µm diam., terminal cell long and domed, plastids parietal, densely reticulate; *hairs* absent in specimens examined. *Monosporangia* carried on palmate short lateral branches of closely appressed subdeltoid cells, branching mostly away from the axis; monosporangia subglobose, 14–16 µm long, 14–15 µm diam., mother-cell wall persistent. (Fig. 1 a–c).

Notes: The main distinctions between this taxon and *A. hermannii* are in the form of the sporangial branches and the size of the monosporangia. The short laterals in *A. hermannii* have a distinct candelabra-like form, sometimes described as fasciculate, separate, cylindrical (at least in the lower parts) cells and ellipsoid spores, 9–12(–14) µm long, 6–10(–11)µm diam. *A. eugenea* has a close packed short lateral branch, subdeltoid cells and subspherical spores14–16 µm long, 14–15 µm diam. A less reliable distinction can be made by comparing the manner of the longer laterals: the angle with the main axis is generally narrower than for *A. hermannii*, (15–20° cf. 20–30°) and there is a tendency for the laterals to grow parallel with the main axis, giving some appearance of fasciculation, though not as marked as in the following species.

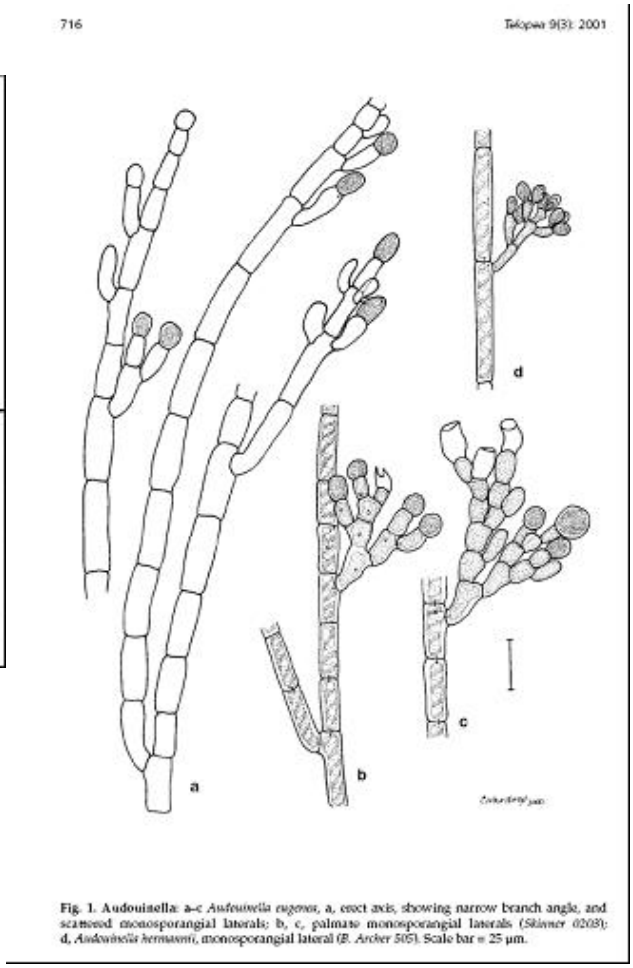


Fig. 1. Audouinella: a–c *Audouinella eugenea*, a, erect axis, showing narrow branch angle, and scattered monosporangial laterals; b, c, palmate monosporangial laterals (*Skinner 0203*); d, *Audouinella hermannii*, monosporangial lateral (*B. Archer 505*). Scale bar = 25 µm.

From: http://www.rbgsyd.nsw.gov.au/__data/assets/pdf_file/72794/Tel9Ski713.pdf

Both the gametophyte and tertasporophyte are isomorphic in *Audouinella.* They appear the same. The zygote divides into a microscopic diploid phase(Carposorophyte) and remains attached to the gametophyte until deterioration. The carpospores germinate into a diploid tetrasporotphyte which at maturity forms tetraspoangia at the branched tips, thus completing the lifecycle. It is likely at these stages that the transitions due to CO2 occur and are inducing blooms. These transitions occur rapidly in natural systems, Korch and Sheath, 1989). *A. hermannii* is the most common North American species and is typically a reddish color alga. Like most freshwater algae, these species tend to be world wide.

Study number 1:

"The responses of relative growth rate (% day ▪ [1]) and pigment content (chlorophyll a, phycocyanin and phycoerythrin) to temperature, irradiance and photoperiod were analyzed in culture in seven freshwater red algae: Audouinella hermannii (Roth) Duby, Audouinella pygmaea (Kützing) Weber-van Bosse, Batrachospermum ambiguum Montagne, Batrachospermum delicatulum (Skuja) Necchi et Entwisle, 'Chantransia' stages of B. delicatulum and Batrachospermum macrosporum Montagne and Compsopogon coeruleus (C. Agardh)

The Freshwater Red algae: Rhodophyta

Montagne. Experimental conditions included temperatures of 10, 15, 20 and 25°C and low and high irradiances (65 and 300 µmol photons m ▪ ^{2} s ▪ ^{1}, respectively). Long and short day lengths (16:8 and 8:16 LD cycles) were also applied at the two irradiances. Growth effects of temperature and irradiance were evident in most algae tested, and there were significant interactions among treatments. Most freshwater red algae had the best growth under low irradiance, confirming the preference of freshwater red algae for low light regimens. In general there was highest growth rate in long days and low irradiance. The highest total pigment contents were found in two species typical of shaded habitats: A. hermannii and C. coeruleus. "
http://www.blackwell-synergy.com/doi/abs/10.1046/j.1440-1835.2001.00230.x

One may conclude from this abstract that low light, warmer temperatures and long photoperiods are good for growth. If we added CO2 gas, the algae likely will grow much better, just like plants when we add higher light. However there is no such research that is available at the present time. As aquarists, we must try and develop our own methods as best as we can to determine such relationships.

Study number 2:

"Responses of net photosynthetic rates to temperature, irradiance, pH/inorganic carbon and diurnal rhythm were analyzed in 15 populations of eight freshwater red algal species in culture and natural conditions. Photosynthetic rates were determined by oxygen concentration using the light and dark bottles technique. Parameters derived from the photosynthesis–irradiance curves indicated adaptation to low irradiance for all freshwater red algae tested, confirming that they tend to occur under low light regimes. Some degree of photo-inhibition (β = -0.33–0.01 mg O_2 g $^{-1}$ DW h $^{-1}$ (µmol photons m $^{-2}$ s $^{-1}$) $^{-1}$) was found for all species/populations analyzed, whereas light compensation points (Ic) were very low (≤ 2 µmol photons m- photons s $^{-1}$) for most algae tested. Saturation points were low for all algae tested (Ik = 6–54 µmol photons m $^{-2}$ s $^{-1}$; Is = 20–170 umol photons m $^{-2}$ s $^{-1}$). Rates of net photosynthesis and dark respiration responded to the variation in temperature. Optimum temperature values for net photosynthesis were variable among species and populations so that best performances were observed under distinct temperature conditions (10, 15, 20 or 25°C). Rates of dark respiration exhibited an increasing trend with temperature, with highest values under 20–25°C. Results from pH experiments showed best photosynthetic performances under pH 8.5 or 6.5 for all but one species, indicating higher affinity for inorganic carbon as bicarbonate or indistinct use of bicarbonate and free carbon dioxide. Diurnal changes in photosynthetic rates revealed a general pattern for all algae tested, which was characterized by two relatively clear peaks, with some variations around it: a first (higher) during the morning (07.00–11.00 hours.) and a second (lower) in the afternoon (14.00–18.00 hours)."
http://www.blackwell-synergy.com/links/doi/10.1046/j.1440-1835.2001.00251.x/abs/

Again, they have not used enriched CO2 water, thus is it difficult to conclude much with respect to blooms and light. However the study does show more growth early in the day than late in the day, this is likely true for aquatic macrophytes as well.

Concluding remarks:

Red algae tend to be poorly identified. The key should help future aquarists better identify the pest algae they encounter and this will help target the research searches when looking for more information in the literature. They are generally not tested under CO2 enriched conditions and appear very capable of withstanding low light, thus blackouts are ineffective. Practical aquarists have learned this a decade or more ago. Some ba-

sic simple test, when other confounding factors are addressed and a good stable starting point is used can greatly enhance the understanding of algae growth and tentative causal mechanisms. Red algae are very frustrating for aquarists, desperation causes many to try all sort of methods and not think things through with careful step approaches. Good stable CO2 levels, 10 hour light times, good maintenance and cleaning will generally stop all red algae. While many aquarist may not believe this if they have a present issue with red algae, they should still focus on those aspects and try the other methods such as herbivores, Excel treatment, water changes and pruning. I would encourage aquarists to try and induce various algae species specifically, to confirm for themselves the possible causes for algae blooms.

References:

Note, reference listing is incomplete

Audouinella pygmaea
http://www.bio.ncue.edu.tw/teachers/research/wlwang/A25_Taiwania2004_49_209_217.pdf

John D. Wehr and Robert G. Sheath, 2003 'Freshwater Algae of North America. Ecology and Classification'

Ensminger I., Hagen C., Braune W. (2000) Strategies providing success in a variable habitat: I. Relationships of environmental factors and dominance of *Cladophora glomerata* Plant, Cell & Environment 23 (10), 1119–1128.

Yoon, Hwan Su, K. M. Müller, R. G. Sheath, F. D. Ott, and D. Bhattacharya. (2006). Defining the major lineages of red algae (Rhodophyta). *J. Phycol.* 42:482-492

Saunders, Gary W., Hommersand, Max H. (2004). Assessing red algal supraordinal diversity and taxonomy in the context of contemporary systematic data. *Am. J. Bot.* 91: 1494-1507