APPENDIX 1: *Stella Code*

Program code for the baseline (oceanic scenario) model. The program was run using Stella ver 5.1.1 under the Macintosh Operating System. Parameter values that change between sites (see Chapter 7, Table 1) are highlighted. GRAPH functions are plotted from the coordinates (X,Y) given. Integration of non-linear functions uses the Runge-Kutta 4th order technique.

Environmental Forcing Functions

Seasonal_light = **350**+random(**-100,100**)+(**150***SIN(3*pi/2+(2*pi)*((TIME+30)/360)))
Seasonal_salinity = **33**+random(**-2,2**)+(**3***SIN(3*pi/2+(2*pi)*((TIME+120)/360)))
Seasonal_temp = **25**+(**7***SIN(**3***pi/2+(2*PI)*((TIME-45)/360)))
Water_Column_Nitrogen = **3.5**+random(**-1.5,1.5**)
Water_Column_Phosphorus = 0.01+random(-0.005,0.01)
Sediment_Nitrogen = 50+random(-30,100)
Sediment_Phosphorus = **1.0**+random(**-0.5,0.5**)

Drift Algae Sub-Model

Drift_algae(t) = Drift_algae(t - dt) + (drift_growth_rate - drift_death_rate) * dt
INIT Drift_algae = 40
drift_growth_rate = DELAY(((drift_max_growth*Drift_algae*(1-Drift_algae/Drift_K) *
    drift_light_dep*drift_temp_dep*drift_sal_dep*drift_nut_dep_gr) +
    Hydrdyn_Immigration), 60)
drift_death_rate = (natural_drift_death*Drift_algae) + Hydrdyn_Emigration
Drift_K = **10**
drift_max_growth = 0.1+random(-0.05,0.5)
natural_drift_death = 0.01+random(-0.005,0.005)
drift_light_dep = GRAPH(Seasonal_light)
    (0.00, 0.00), (125, 0.67), (250, 0.809), (375, 0.935), (500, 0.957), (625, 0.979), (750, 0.986), (875, 0.991), (1000, 0.993), (1125, 0.996), (1250, 0.998), (1375, 0.999), (1500, 1.00)
drift_temp_dep = GRAPH(Seasonal_temp)
    (10.0, 0.9), (12.0, 0.98), (14.0, 1.00), (16.0, 1.00), (18.0, 1.00), (20.0, 1.00), (22.0, 1.00), (24.0, 0.98), (26.0, 0.91), (28.0, 0.85), (30.0, 0.7), (32.0, 0.2), (34.0, 0.1), (36.0, 0.00)

drift_sal_dep = GRAPH(Seasonal_salinity_)
(0.00, 0.00), (5.00, 0.05), (10.0, 0.25), (15.0, 0.7), (20.0, 0.95), (25.0, 1.00), (30.0, 1.00), (35.0, 1.00), (40.0, 1.00)

drift_nut_dep_gr = min (drift_N_gr,drift_P_gr)

drift_N_gr = GRAPH(Water_Column_Nitrogen)
(0.00, 0.00), (5.00, 0.96), (10.0, 0.98), (15.0, 0.987), (20.0, 0.99), (25.0, 1.00), (30.0, 1.00), (35.0, 1.00), (40.0, 1.00), (45.0, 1.00), (50.0, 1.00), (55.0, 1.00), (60.0, 1.00), (65.0, 1.00), (70.0, 1.00), (75.0, 1.00), (80.0, 1.00), (85.0, 1.00), (90.0, 1.00), (95.0, 1.00), (100, 1.00)

drift_P_gr = GRAPH(Water_Column_Phosphorus)
(0.00, 0.00), (0.5, 0.9), (1.00, 0.95), (1.50, 1.00), (2.00, 1.00), (2.50, 1.00), (3.00, 1.00), (3.50, 1.00), (4.00, 1.00), (4.50, 1.00), (5.00, 1.00), (5.50, 1.00), (6.00, 1.00), (6.50, 1.00), (7.00, 1.00), (7.50, 1.00), (8.00, 1.00), (8.50, 1.00), (9.00, 1.00), (9.50, 1.00), (10.0, 1.00)

Hydrdyn_Emigration = MONTECARLO(**82**)*(random(0,Drift_algae))

Hydrdyn_Immigration = MONTECARLO(**18**)*(random(0,(Drift_K-Drift_algae)))

Seagrass Epiphyte Sub-Model

Epiphytic_algae(t) = Epiphytic_algae(t - dt) + (epi_growth - epi_death_rate) * dt

INIT Epiphytic_algae = 50

epi_growth = epi_Max_growth*Epiphytic_algae*(1-Epiphytic_algae/Epi_K) * epi_nut_dep_gr*ep_light_dep_gr*epi_temp_dep_gr*epi_sal_dep

epi_death_rate = (normal_epi_death*Epi_substrate_dep_dr)*Epiphytic_algae

Epi_K = **150**

epi_Max_growth = 0.15+random(-0.13,0.2)

normal_epi_death = 0.01+random(-0.005,0.005)

ep_light_dep_gr = GRAPH(Seasonal_light)
(0.00, 0.00), (125, 0.896), (250, 0.973), (375, 0.983), (500, 0.993), (625, 0.995), (750, 0.996), (875, 0.998), (1000, 0.999), (1125, 0.999), (1250, 1.00), (1375, 1.00), (1500, 1.00)

epi_temp_dep_gr = GRAPH(Seasonal_temp)
(10.0, 0.9), (12.0, 0.98), (14.0, 1.00), (16.0, 1.00), (18.0, 1.00), (20.0, 1.00), (22.0, 1.00), (24.0, 0.98), (26.0, 0.91), (28.0, 0.85), (30.0, 0.7), (32.0, 0.2), (34.0, 0.1), (36.0, 0.00)

epi_sal_dep = GRAPH(Seasonal_salinity_)
(0.00, 0.00), (5.00, 0.05), (10.0, 0.3), (15.0, 0.8), (20.0, 0.95), (25.0, 1.00), (30.0, 1.00), (35.0, 1.00), (40.0, 1.00)

Epi_nut_dep_gr = min (epi_N_gr+Epi_P_gr)

epi_N_gr = GRAPH(Water_Column_Nitrogen)
(0.00, 0.00), (5.00, 0.98), (10.0, 0.99), (15.0, 0.993), (20.0, 0.995), (25.0, 1.00), (30.0, 1.00), (35.0, 1.00), (40.0, 1.00), (45.0, 1.00), (50.0, 1.00), (55.0, 1.00), (60.0, 1.00), (65.0, 1.00), (70.0, 1.00), (75.0, 1.00), (80.0, 1.00), (85.0, 1.00), (90.0, 1.00), (95.0, 1.00), (100, 1.00)

Epi_P_gr = GRAPH(Water_Column_Phosphorus)
(0.00, 0.00), (0.5, 0.9), (1.00, 0.95), (1.50, 1.00), (2.00, 1.00), (2.50, 1.00), (3.00, 1.00), (3.50, 1.00), (4.00, 1.00), (4.50, 1.00), (5.00, 1.00), (5.50, 1.00), (6.00, 1.00), (6.50, 1.00), (7.00, 1.00), (7.50, 1.00), (8.00, 1.00), (8.50, 1.00), (9.00, 1.00), (9.50, 1.00), (10.0, 1.00)

Epi_substrate_dep_dr = GRAPH(Thalassia_Biomass+(Thalassia_Biomass*Turnover))
(0.00, 5.00), (50.0, 4.50), (100, 4.00), (150, 3.50), (200, 3.00), (250, 2.50), (300, 2.00), (350, 1.50), (400, 1.00), (450, 0.5), (500, 0.00)
Turnover = Tt_gr/Tt_dr

Rhizophytic Algae Sub-Model

Rhizophytic_algae(t) = Rhizophytic_algae(t - dt) + (rhizo_growth - rhizo_death) * dt

INIT Rhizophytic_algae = 20

rhizo_growth = DELAY((rhizo_max_gr*Rhizophytic_algae*(1-Rhizophytic_algae / Rhizo_K)*Rhizo_sal_dep*Rhizo_Light_dep_gr*Rhizo_nut_dep_gr *Rhizo_temp_dep_gr) ,90)

rhizo_death = (rhizo_nat_death+Random_dist_dr)*Rhizophytic_algae

Rhizo_K = **60**

rhizo_max_gr = 0.05+random(-0.03,0.04)

rhizo_nat_death = 0.01+random(-0.005,0.005)

Rhizo_Light_dep_gr = GRAPH(Seasonal_light)
(0.00, 0.00), (125, 0.692), (250, 0.807), (375, 0.926), (500, 0.953), (625, 0.981), (750, 0.988), (875, 0.993), (1000, 0.994), (1125, 0.995), (1250, 0.997), (1375, 0.998), (1500, 1.00)

Rhizo_temp_dep_gr = GRAPH(Seasonal_temp)
(10.0, 0.00), (12.0, 0.00), (14.0, 0.2), (16.0, 0.6), (18.0, 0.95), (20.0, 1.00), (22.0, 1.00), (24.0, 1.00), (26.0, 1.00), (28.0, 1.00), (30.0, 1.00), (32.0, 0.85), (34.0, 0.5), (36.0, 0.00)
Rhizo_sal_dep = GRAPH(Seasonal_salinity_)
(0.00, 0.00), (5.00, 0.00), (10.0, 0.00), (15.0, 0.3), (20.0, 0.79), (25.0, 1.00), (30.0, 1.00), (35.0, 1.00), (40.0, 1.00)
Rhizo_nut_dep_gr = min (Rhizo_N_gr,Rhizo_P_gr)
Rhizo_N_gr = GRAPH(Water_Column_Nitrogen+Sediment_Nitrogen)
(0.00, 0.00), (5.00, 0.93), (10.0, 0.96), (15.0, 0.97), (20.0, 0.98), (25.0, 1.00), (30.0, 1.00), (35.0, 1.00), (40.0, 1.00), (45.0, 1.00), (50.0, 1.00), (55.0, 1.00), (60.0, 1.00), (65.0, 1.00), (70.0, 1.00), (75.0, 1.00), (80.0, 1.00), (85.0, 1.00), (90.0, 1.00), (95.0, 1.00), (100, 1.00), (105, 1.00), (110, 1.00), (115, 1.00), (120, 1.00), (125, 1.00), (130, 1.00), (135, 1.00), (140, 1.00), (145, 1.00), (150, 1.00), (155, 1.00), (160, 1.00), (165, 1.00), (170, 1.00), (175, 1.00), (180, 1.00), (185, 1.00), (190, 1.00), (195, 1.00), (200, 1.00), (205, 1.00), (210, 1.00), (215, 1.00), (220, 1.00), (225, 1.00), (230, 1.00), (235, 1.00), (240, 1.00), (245, 1.00), (250, 1.00), (255, 1.00), (260, 1.00), (265, 1.00), (270, 1.00), (275, 1.00), (280, 1.00), (285, 1.00), (290, 1.00), (295, 1.00), (300, 1.00), (305, 1.00), (310, 1.00), (315, 1.00), (320, 1.00), (325, 1.00), (330, 1.00), (335, 1.00), (340, 1.00), (345, 1.00), (350, 1.00), (355, 1.00), (360, 1.00), (365, 1.00), (370, 1.00), (375, 1.00), (380, 1.00), (385, 1.00), (390, 1.00), (395, 1.00), (400, 1.00)
Rhizo_P_gr = GRAPH(Water_Column_Phosphorus+Sediment_Phosphorus)
(0.00, 0.00), (1.00, 0.9), (2.00, 0.95), (3.00, 1.00), (4.00, 1.00), (5.00, 1.00), (6.00, 1.00), (7.00, 1.00), (8.00, 1.00), (9.00, 1.00), (10.0, 1.00), (11.0, 1.00), (12.0, 1.00), (13.0, 1.00), (14.0, 1.00), (15.0, 1.00), (16.0, 1.00), (17.0, 1.00), (18.0, 1.00), (19.0, 1.00), (20.0, 1.00), (21.0, 1.00), (22.0, 1.00), (23.0, 1.00), (24.0, 1.00), (25.0, 1.00), (26.0, 1.00), (27.0, 1.00), (28.0, 1.00), (29.0, 1.00), (30.0, 1.00), (31.0, 1.00), (32.0, 1.00), (33.0, 1.00), (34.0, 1.00), (35.0, 1.00), (36.0, 1.00), (37.0, 1.00), (38.0, 1.00), (39.0, 1.00), (40.0, 1.00), (41.0, 1.00), (42.0, 1.00), (43.0, 1.00), (44.0, 1.00), (45.0, 1.00), (46.0, 1.00), (47.0, 1.00), (48.0, 1.00), (49.0, 1.00), (50.0, 1.00)

Thalassia Sub-Model

Thalassia_Biomass(t) = Thalassia_Biomass(t - dt) + (Tt_gr - Tt_dr) * dt

INIT Thalassia_Biomass = 300

Tt_gr = Tt_Max_growth*Thalassia_Biomass*(1-Thalassia_Biomass/Tt_K)*Tt_P_gr*
Tt_light_dep_gr*Tt_temp_dep_gr*Tt_sal_dep_gr

Tt_dr = Thalassia_Biomass*(Tt_senesence)

Tt_K = 470

Tt_Max_growth = 0.09

Tt_senesence = 0.02+random(-0.0,0.0)

Tt_light_dep_gr = GRAPH(Seasonal_light)
(0.00, 0.00), (125, 0.315), (250, 0.645), (375, 0.88), (500, 1.00), (625, 1.00), (750, 1.00), (875, 1.00), (1000, 1.00), (1125, 1.00), (1250, 1.00), (1375, 1.00), (1500, 1.00)

Tt_temp_dep_gr = GRAPH(Seasonal_temp)
(10.0, 0.00), (12.0, 0.05), (14.0, 0.1), (16.0, 0.235), (18.0, 0.405), (20.0, 0.6), (22.0, 0.74), (24.0, 0.91), (26.0, 0.96), (28.0, 1.00), (30.0, 1.00), (32.0, 0.875), (34.0, 0.755), (36.0, 0.585)

Tt_sal_dep_gr = GRAPH(Seasonal_salinity_)
(0.00, 0.00), (5.00, 0.001), (10.0, 0.21), (15.0, 0.74), (20.0, 0.99), (25.0, 1.00), (30.0, 1.00), (35.0, 1.00), (40.0, 1.00)

Tt_P_gr = GRAPH(Sediment_Phosphorus)
(0.00, 0.3), (1.25, 0.75), (2.50, 0.945), (3.75, 1.00), (5.00, 1.00), (6.25, 1.00), (7.50, 1.00), (8.75, 1.00), (10.0, 0.13), (11.2, 0.00), (12.5, 0.00), (13.8, 0.00), (15.0, 0.00)

Output to Seagrass Model

Avail_Light_Seagrass = Seasonal_light * ((fraction_light_reduction_drift
+fraction_light_reduction_epiphytes)/2)

fraction_light_reduction_drift = 1-(Drift_algae/Drift_K)

fraction_light_reduction_epiphytes = GRAPH(epiphyte_load)
(0.00, 1.00), (0.0833, 0.675), (0.167, 0.41), (0.25, 0.275), (0.333, 0.19), (0.417, 0.125), (0.5, 0.085), (0.583, 0.065), (0.667, 0.045), (0.75, 0.03), (0.833, 0.015), (0.917, 0.01), (1.00, 0.00)

epiphyte_load = Epiphytic_algae/Density_of_seagrass

Density_of_seagrass = 1000

APPENDIX 2: *Illustrations*

Drawings of representatives of the three functional groups of macroalgae found in seagrass habitats and investigated in this study. The figures were obtained from 'South Florida Benthic Marine Algae' by Woelkerling (1976) and 'Caribbean Reef Plants' by Littler and Littler (2000). Keys to the algae illustrated can be found in these two works, as well as species descriptions. Littler and Littler (2000) is recommended as it is the more recent work, and contains up-to-date taxonomic information. However, Woelkerling (1976) is specific to the South Florida region, and therefore a more concise taxonomic key.

In all figures a scale bar is provided to allow size comparisons. A general rule is that the rhizophytic algae had the largest thallus, drift algae were intermediate in size, and seagrass epiphytes tended to be smallest, often requiring the assistance of a microscope to aid in identification. Both drift algae and epiphytes were almost exclusively members of the Rhodophyta (red algae), while the rhizophytic algae were entirely comprised of chlorophytes (green algae) in the Order Bryopsidales.

The rhizophytic algae are unique in the macroalgae in possessing root-like rhizomes to anchor in soft sediments as well as allow nutrient uptake from porewaters, similar to seagrasses. In contrast the drift algae and seagrass epiphytes must rely on nutrients in the water column to supply their demand. A further difference is the calcification of the thallus of the rhizophytic algae (except the genus *Caulerpa*), while the drift algae and many of the epiphytes studied were not calcified.

Most individuals collected were not found in a reproductive phase. In the drift algae this may be a result of reversion to a juvenescent stage, while many of the epiphytes may not have been mature enough to be reproductive so soon after establishing on actively growing seagrass blades. Many of the rhizophytic algae die after reproduction, and the thallus quickly decays.

For further life-history and ecological information a recent phycology text is recommended, for instance Lobban and Harrison (1994) as well as the references there-in.

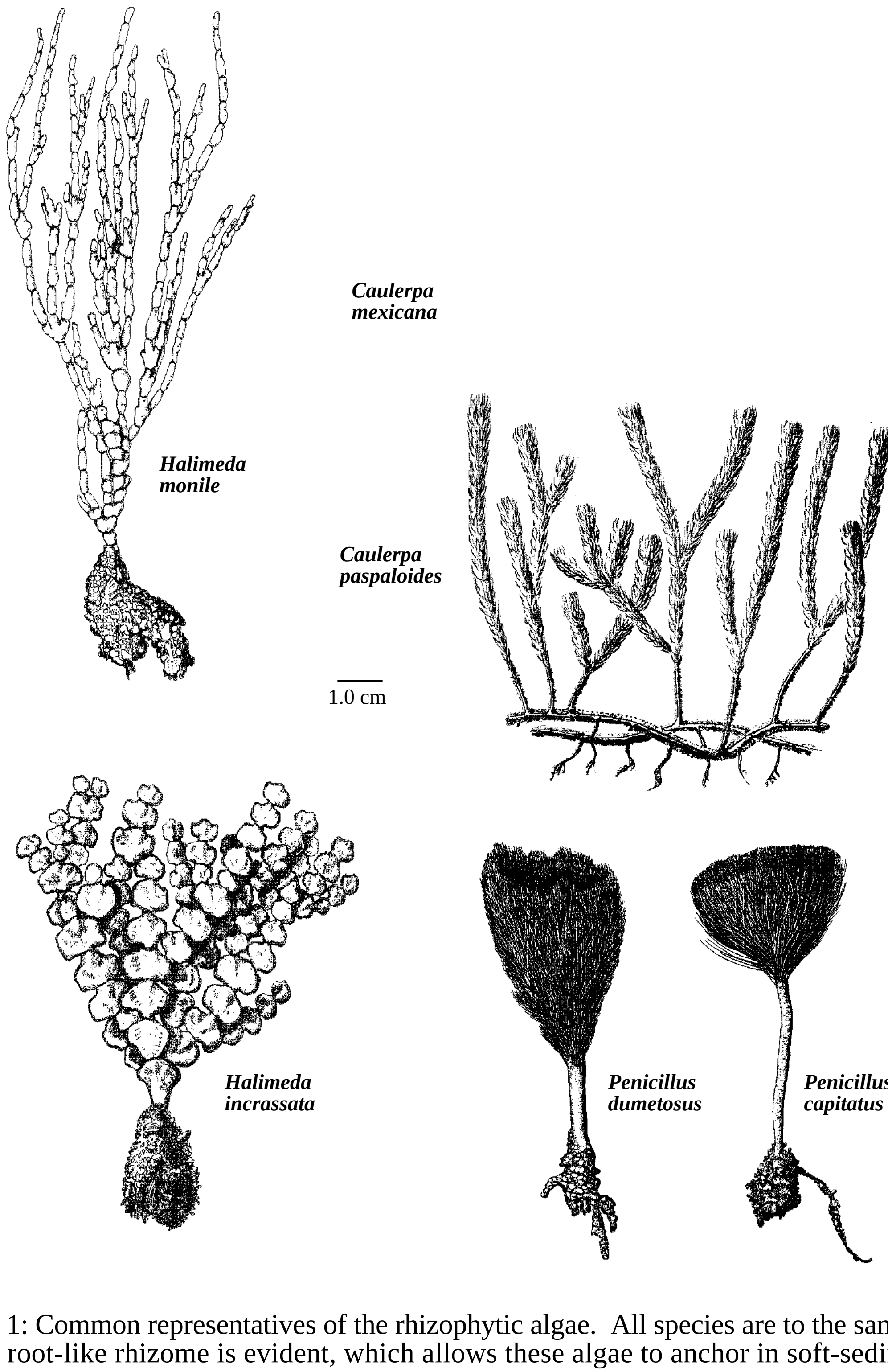

Fig. 1: Common representatives of the rhizophytic algae. All species are to the same scale. The root-like rhizome is evident, which allows these algae to anchor in soft-sedimentary environments.

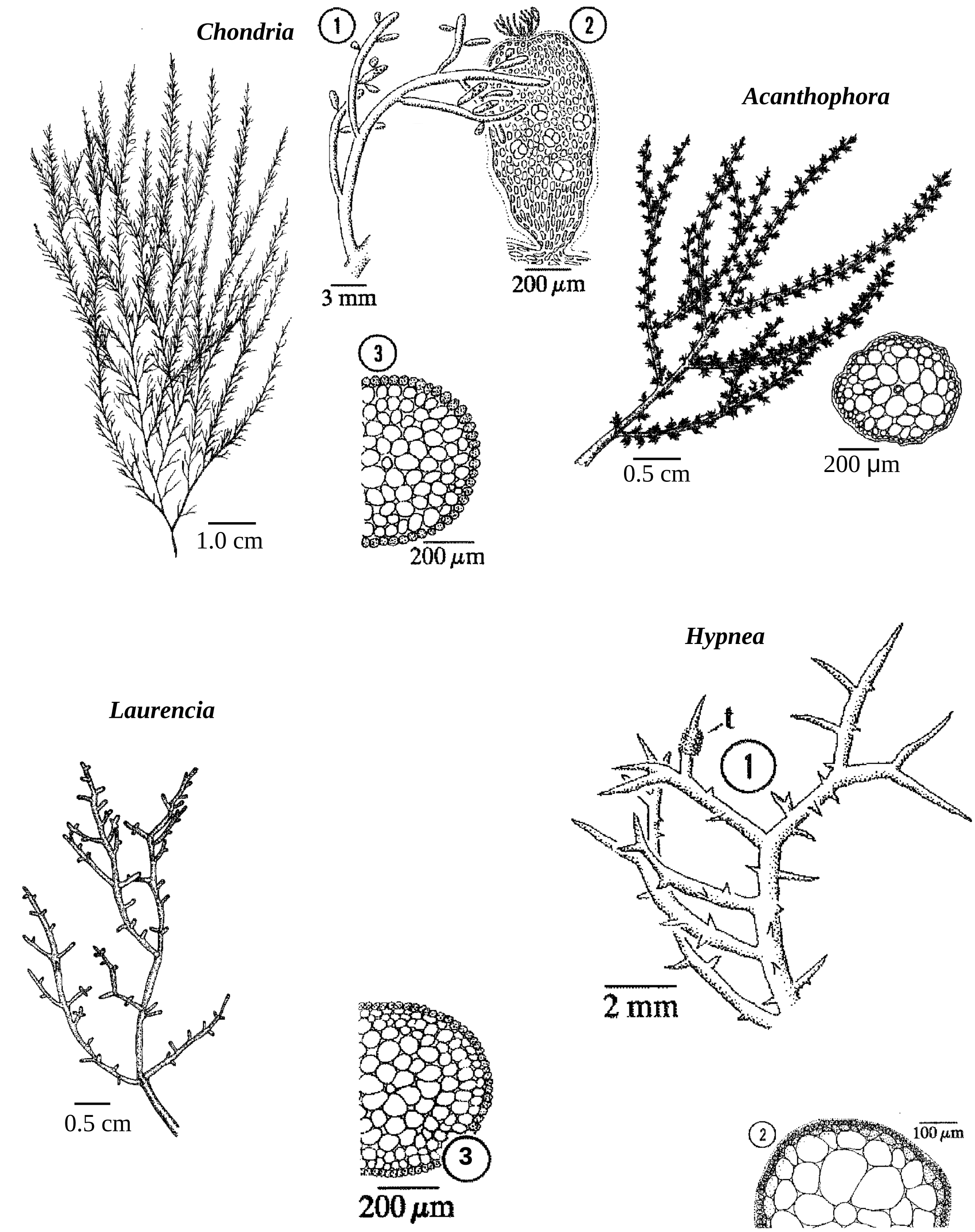

Fig. 2. Some representatives of the drift algae. Both *Chondria* and *Laurencia* were very common in Biscayne Bay. Scale bars indicate the relative sizes of the thallus and key morphological features used in the idenfication of these genera.

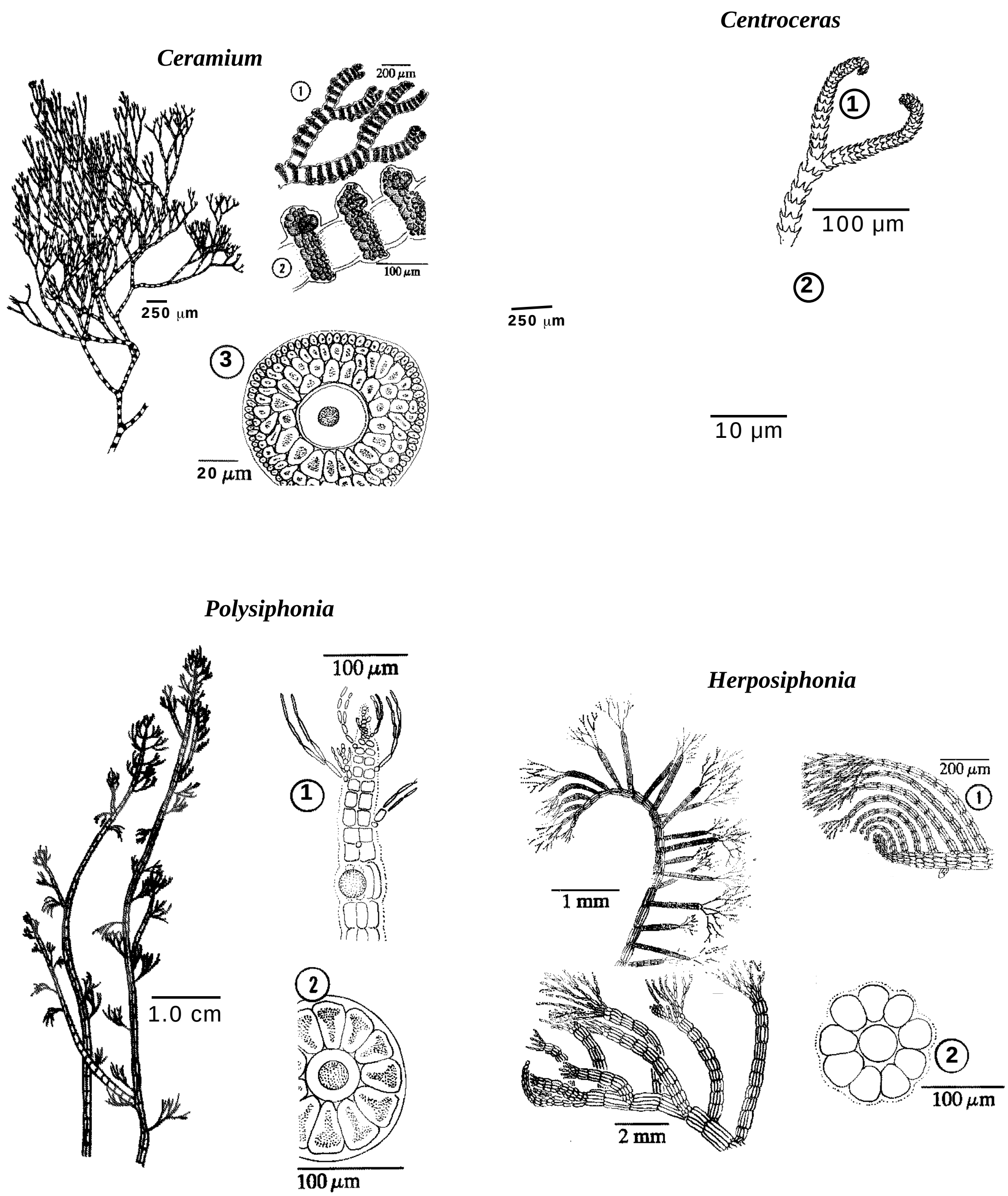

Fig. 3. Some representative of seagrass epiphytes. *Polysiphonia* was a common epiphyte, as well as a member of the drift community in Biscayne Bay. Scale bars indicate the relative sizes of the thallus and key morphological features used in the idenfication of these genera.