FINAL REPORT

CRYSTAL RIVER 316 STUDIES

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6.3 MACROPHYTES

6.3.1 Sampling and Laboratory Analysis

Three areas were selected to study the submergent macrophyte communities in Crystal Bay. The area between the CFBC and the intake spoil was defined as the thermally affected area. Two control areas were also sampled - one located off the Withlacoochee River and the CFBC and one off Crystal River. Fifty stations on 10 transects were established (Figure 6.3-1) for ground truthing. Of these stations, nine were designated as intensive monitoring (IM) stations and were subjected to a more extensive sampling program.

Quarterly overflights to shoot 1:18,000 (1 in. = 1,500 ft) scale vertical color aerial photographs were planned to map the distribution of the seagrass and macroalgae in the study area over the course of 15 months. However, conditions at the site prevented successful aerial photography as scheduled. Photographs which could be used for ground truthing were obtained only three times during the study (October 1983; February and April 1984). These photographs, along with others obtained from various sources were then groundtruthed each quarter by teams of divers.

Ground truthing was performed at each of the 50 stations using 10 randomly placed 1-m^2 quadrats. Quadrats were surveyed by divers who estimated percent cover for each species of seagrass and rhizophytic alga observed. An estimate of the percent bare bottom was also made during the latter part of the study. Estimates of percent coverage were facilitated by dividing each quadrat into 25 subunits (a 5 x 5 grid) and estimating percent cover in each subunit.

Of the nine stations selected (Figure 6.3-1) for intensive monitoring, three (A, D, and G) contained Halodule wrightii as the dominant seagrass; 3 (B, E, and H) contained Syringodium filiforme as the dominant seagrass; and 3 (C, F, and I) contained Thalassia testudinum as the dominant seagrass. These stations were sampled at 6 week intervals between June 1983 and July 1984, for a total of 10 sampling episodes. In addition to percent cover estimates, biomass and productivity samples were collected during each sampling episode.

Above-ground biomass of seagrass and algae was sampled using a plexiglass clip box sampler (25 x 25 cm). The box was inserted into the sediment and all plant material was clipped at the sediment surface. The clipped material was retained in the box. Six replicates were collected in this fashion at each IM station during each sampling episode. Samples were preserved in the field in 5-10 percent formalin in seawater. Five replicates were analyzed by sorting the plant material to species; drying to constant weight at 70°C; and weighing. The sixth replicate was saved, principally in case of loss or damage to one of the first five; however, the sixth replicates were examined to identify the algal epiphytes present.

Estimates of seagrass productivity (after Zieman, 1975) were based on quadrat sampling. Quadrats measuring 10 cm x 10 cm were employed at Halodule stations (A, D, and G); 10 cm x 20 cm quadrats were used at all other IM stations. Three quadrats were placed at the time the clip box samples were taken. After placement, all seagrass blades within the quadrats were clipped off level with the top of the quadrat and discarded. Two weeks later the uadrats were revisited and all new growth was harvested and preserved in

5-10 percent formalin/seawater. Samples were returned to the laboratory, sorted, dried to constant weight, and weighed. Shoot counts were made both at the time of quadrat placement and at harvesting using seven randomly placed 10 x 10 cm quadrats at Halodule stations and four 10 x 20 cm quadrats at Syringodium and Thalassia stations.

SAS was used to provide summary tables of percent cover, growth rates, total standing biomass, and total shoot density by time and station. The SAS GLM procedure was used to provide an analysis of covariance for the above four measures of macrophyte abundance. Tukey's HSD test was used to contrast means of main effect variables of station and time period. These analyses were also conducted by species to compare differences across stations for each species.

6.3.2 Results

Five species of seagrasses were observed in the Crystal Bay area during the course of this study: Ruppia maritima L., Halophila engelmannii Aschers; and Thalassia testudinum Banks ex Koenig, and Syringodium filiforme Kuetzing and Halodule wrightii Aschers.

Seagrass diversity (number of species) at the nine intensive monitoring stations over the course of this study is summarized, in Table 6.3-1. The three southern stations (A, B, and C, south of the intake canal) and the two central stations (E and F) usually contained the highest number of seagrass species, although in the last two sampling periods one or more of the three northern stations (G, H, or I) contained the greatest number of species. Station D (in Basin 1) routinely contained only one species of seagrass, Halodule wrightii.

Parameters of the seagrass communities which were measured were biomass (above ground standing crop), shoot density, productivity and percent cover. Table 6.3-2 summarizes the results of the ANOVA analyses on the seagrass data. Time (sampling date) and station were the two parameters which consistently had a significant effect on seagrass biomass, productivity, shoot density and percent cover. In most cases, the effect was highly significant (P less than 0.01, see Table 6.3-2). The other parameters tested showed no clear pattern. Temperature, salinity, pH, dissolved oxygen (DO), and the extinction coefficient (light penetration), all measured at the bottom, had a significant effect on the different species of seagrasses, but in a sporadic fashion, affecting various species differently (e.g., biomass in some cases, productivity in others, etc.). The environmental factors used in the ANOVA analyses are, of course, linked with the time of year and station location, and the relationship between these factors is examined in Section 6.1.

For all seagrasses combined, one or more of the three southern stations (A, B, and C) consistently had significantly higher biomass, shoot density and productivity than the other intensive monitoring stations. Appendix IV contains the results of the ANOVA analyses on the total seagrass data. There were some variations in this general pattern depending on the species of seagrass, i.e., Halodule stations tended to have higher shoot densities than Syringodium or Thalassia stations, since the former species is smaller, and thus has more shoots per unit area. Halodule stations had lower biomass and productivity compared to Thalassia and Syringodium stations, since the latter two species have larger blades than the former. Stations E and F typically

exhibited intermediate seagrass biomass, shoot densities, and productivities. Stations G, H, I, and D usually displayed significantly lower seagrass parameters than the other stations. Temperature, salinity, pH and DO were environmental factors which significantly influenced the measures of abundance of total seagrasses.

The following paragraphs discuss the analytical results for each species of seagrass separately.

Halodule wrightii

The ANOVA analyses performed on the Halodule percent cover, biomass, shoot density, and productivity data are presented in Appendix IV. Table 6.3-3 summarizes annual means for each of these items. Station A exhibited significantly higher biomass, shoot density and productivity than the other two Halodule intensive monitoring stations (D and G). Stations D and G did not differ significantly with respect to biomass or productivity, but Station G had a significantly greater shoot density (number per area) than Station D. All three Halodule stations were similar with respect to percent cover (areal coverage). This is contrary to the ANOVA results, which indicate that station differences do exist for percent cover, however the multiple comparison test used (Tukey's test) is very conservative. In addition, Zieman (personal communication) has questioned the value of percent cover data as an indicator of thermal effects of seagrasses.

Typically, productivity, biomass, shoot density and percent cover of Halodule were all significantly higher during the late spring -summer - early fall sampling periods. Salinity, pH, DO and light levels were environmental factors which significantly influenced one or more of the Halodule measures of abundance. Appendix IV contains summary tables on Halodule biomass, productivity and shoot density by sampling date and station.

Syringodium filiforme

The ANOVA analyses performed on Syringodium percent cover, biomass, shoot density, and productivity are presented in Appendix IV. Station B had significantly higher biomass, productivity, shoot density and percent cover than the other two Syringodium intensive monitoring stations. Station E had significantly higher biomass, shoot density and percent cover than Station H, but these two stations did not differ with respect to productivity. The summer months typically exhibited significantly higher Syringodium biomass, shoot density, productivity and percent cover. However, percent cover tended to be significantly higher during the winter months relative to the other three parameters examined. Temperature, light, salinity and DO were the environmental factors which significantly influenced Syringodium parameters. Syringodium biomass, productivity and shoot density by station and month are summarized in Appendix IV. Annual means by station and sampling date are shown in Table 6.3-4.

Thalassia testudinum

The ANOVA analyses performed on Thalassia percent cover, biomass, shoot density, and productivity data are presented in Appendix IV. Station C exhibited significantly higher Thalassia biomass, shoot density, and

productivity than Stations F and I, which did not differ for any of these parameters. Thalassia percent cover among stations was not tested, since in two cases (Stations E and F and Stations B and C), a Thalassia and a Syringodium station were located in the same grassbed and sampling results were for a mixed seagrass bed. For the four Thalassia parameters tested, significantly higher values were observed during the summer sampling periods, but the winter values for Thalassia tended to place relatively higher in the rank order, compared to the winter values of Syringodium and Halodule. Temperature, light and pH were environmental factors which significantly influenced the Thalassia measures of abundance. Thalassia biomass, productivity and shoot density by station and month are summarized in Appendix IV. Annual means by station and sampling data are shown in Table 6.3-5.

Macroalgae

Rhizophytic Algae

Table 6.3-6 lists the species of rhizophytic (attached) algae observed during the course of this study. More stations south of the power plant discharge (Stations 32 and higher) supported rhizophytic algae, compared to the northern stations, and the southern stations usually exhibited higher rhizophytic algal percent cover than the northern stations (see quarterly data tables). Percent cover was higher during the summer/fall period. Rhizophytic algal diversity is summarized in Table 6.3-7. More species of rhizophytic algae were found at the three southern intensive monitoring stations (A, B, and C) throughout the study period, compared to the other intensive monitoring stations.

Rhizophytic algal biomass was significantly correlated to time (sampling date), station and bottom DO. Results of the ANOVA analyses are found in Appendix IV. Station E had significantly higher biomass compared to the other stations. Other than for this station, however, no clear station trend was evident. Rhizophytic algal biomass was significantly higher during the summer/fall sampling periods.

Drift Algae

A number of species of drift algae were collected during the course of this study. These are listed in Table 6.3-6. Percent cover was the only drift algal parameter measured and statistically analyzed. Time, station, temperature and salinity at the bottom had significant effects. Station B had the significantly highest drift algal percent cover, but no other clear trends were evident. Drift algal percent cover tended to be significantly higher during winter and summer months.

Typically, a species of Gracilaria (G. tikvahiae or G. verrucosa) tended to dominate the drift algae throughout the year in the northern half of the study area (the discharge area and north), with Sargassum filipendula locally dominant in areas with rocky bottom. Gracilaria debilis and/or G. sjoestedii dominated the drift algae in the southern part of the study area in the winter. Drift algae appeared to form a lesser proportion of the total macrophyte cover during the summer months in the south part of the study area. Red algae, as a group, were the dominant component of the drift algae in the study area throughout the period of study.

Total Macrophyte Percent Cover

An estimate of the percent bare substratum was made when estimating percent cover of the different species of macrophytes, in order to obtain an estimtae of total macrophyte cover. Time, station, bottom temperature and DO had significant effects on total macrophyte cover (see Appendix IV). The southern intensive monitoring Stations A and 47 (B and C) had the significantly highest total macrophyte coverage. Stations 33 (E and F) and I were intermediate, and Stations D, H, and G had significantly lower total submergent macrophyte cover. Station D exhibited the lowest total macrophyte cover. Total macrophyte cover tended to be significantly higher during the summer months. Drift algal cover and occurrence in the thermal areas was lower during the summer than it was in other parts of the study area.

Macrophyte maps of the area show much higher total macrophyte cover in the south part of Crystal Bay (south of the intake canal and dike) compared to the northern region. Figures 6.3-2 to 6.3-10 show macrophyte distribution in Crystal Bay in February 1984.

Syringodium was not widely distributed at many of the stations in the northern half of the study area, but occurred frequently at many southern stations throughout the study period. This was not the case for the other species of seagrasses observed. These species typically occurred at similar numbers of southern and northern stations. Thalassia and Syringodium occurred at the fringes of Basins 1 and 3, but were not found within these basins at the hottest areas of the discharge. Halodule and Halophila engelmanni were the only species of seagrasses which occurred in the thermal area, occurring in Basin 3 and portions of Basin 1.

Seagrass or seagrass/rhizophytic algal assemblages dominated the macrophyte cover in the southern part of the study area. Thalassia and Syringodium were dominant offshore and Ruppia maritima and Halodule were dominant inshore. Dense patches of rhizophytic algae (generally Caulerpa sp.) were found locally in inshore areas of the southern part of the study area. Seagrasses formed a lesser proportion of the macrophyte cover in the northern half of the study area. Algae, particularly drift algae, were dominant there. Seagrasses and algae in the northern part of the area existed as small patches, while larger, more continuous areas of cover were found in the southern area.

An historical trend analysis of submergent macrophyte communities was compiled from seven sets of vertical aerial photography, dating back to October 1950. Trend analysis focused on the Basin 1 area. When available, data from past Crystal River monitoring reports were also used in compiling this summary.

Analysis of the early(1950 and 1960) photography indicated a general absence of strong signatures of submergent macrophyte communities in the Basin 1 area. Some seagrass and algae appear to be present; however, the quality of the black and white photography does not allow conclusive interpretation. Historically, the Basin 1 area appears to have been subjected to freshwater inundation from Rocky Creek, a tidal drainage creek of the type found throughout the study area. The flow of Rocky Creek was subsequently interrupted by construction of the Crystal River discharge canal. The obstruction of the freshwater flow may have permitted seagrasses to invade the

Basin 1 region, due to higher salinities. No field data are available to support the above, and thus it must be regarded as speculative. The 1972 aerial photography (color) shows the presence of photographic signatures consistent with relatively dense submergent macrophyte communities. FPC (1974) confirmed the presence of extensive beds of Halodule (= Diplanthera) wrightii in Basin 1. FPC (1978; 1979) also depicted extensive (> 50 percent coverage of the bottom) Halodule cover in Basin 1. The 1981 photography reveals a slight decrease in submergent macrophyte coverage, supported by percent cover data from FPC (1981). Current (1983-84) photography reveals further declines in macrophyte cover in Basin 1, a trend confirmed by the field verification and sampling program conducted in the present study. Although Halodule may be sparsely distributd throughout Basin 1 (as suggested by the aerial photography), field inspection indicated this was not so, Halodule being confined to the northeast portion of the basin. Other areas of Basin 1 were unvegetated mud bottom, sometimes associated with a blue-green algal mat. These mats, along with areas of benthic diatom concentrations, could be responsible for the "green mud" signatures visible in the recent photography of Basin 1.

6.3.3 Impact Assessment

Seagrasses

The effects of the effluent from the power plant discharge on seagrass received much attention in past studies (Van Tine 1977; FPC 1978; 1979; 1980; 1981) at Crystal River. It is known that the effluent from the plant results in a lower number of species of seagrasses in the area affected by the discharge. This was seen in the present study. Halodule wrightii, the most eurythermal of the seagrass species in the area (Phillips 1960; Zieman 1982), was the only species of seagrass found at Station D, the station most exposed to the power plant discharge. More seagrass species were observed at Stations E and F further offshore. These stations appeared to be only moderately impacted by the effluent plume. The greatest number of seagrass species throughout the period of study were seen at these two stations and at the three southern stations (A, B, and C). The three northern stations (G, H, and I) generally had a lower number of seagrass species throughout the study period.

The intensive monitoring stations (D, E, and F) located in the discharge area routinely exhibited significantly lower seagrass biomass, for all three species, compared to the three southern unimpacted stations (A, B, and C). Thalassia and Halodule biomass did not differ between thermal and northern stations (F and I; D and G, respectively), but Syringodium biomass was significantly higher at the impacted Station F than at the northern Station H. Previous monitoring studies at the Crystal River complex have not considered biomass of each species of seagrass separately (e.g., FPC 1978; 1979), or only considered biomass of Halodule, since it is the only species of seagrass found in the discharge area (FPC 1981). The past Crystal River monitoring reports, however, show the same general trends seen in this study: lower seagrass biomass in the discharge area compared to the southern area (the region south of the intake canal).

All three species of seagrass chosen for intensive monitoring displayed the same type of annual biomass trend: summer maxima and winter minima. The

thermal effects from the effluent plume are likely to be more pronounced during the summer when the organisms are normally exposed to natural water temperatures closer to their thermal tolerance limits.

Like biomass, seagrass productivity was significantly lower in the discharge area than in the southern area. All three species of seagrass showed highest productivity at the three southern stations. None of the thermal stations differed from any of the respective northern stations, suggesting that thermal effects alone are not entirely responsible for the depressed productivity. None of the previous monitoring studies conducted at Crystal River specifically examined seagrass productivity. Zieman and Wood (1975) showed that Thalassia productivity (gm/m 2 /day) decreased linearly with increasing temperatures above 32°C. Thalassia has a temperature optimum for productivity of 28-30°C (Zieman and Wetzel 1980). Seagrass productivities in the present study exhibited summer maxima and winter minima for all three species of seagrass. Productivities during the winter were more similar in the thermal area and in the northern and southern control areas suggesting that thermal effects of the plant discharge are more pronounced during the summer.

Shoot densities of all three seagrass species were significantly higher at the three southern intensive monitoring stations (A, B, and C). The northern Halodule Station G had a significantly higher shoot density than the thermal Station D. Shoot density of Syringodium at the thermal Station E was significantly higher than at the northern Station H, while Thalassia shoot densities at thermal and northern stations (F and I) did not differ. Shoot densities did not show as pronounced an annual trend as biomass and productivity.

Percent cover of Halodule did not differ among the three intensive monitoring stations (A, D and G), while cover of Syringodium was significantly higher at Station B than at Station E, which in turn was significantly higher than cover at H. Thalassia percent cover was not tested among stations. Previous monitoring reports at Crystal River have principally used percent cover estimates to monitor the seagrass and macroalgal communities in the area. These reports (FPC, 1978; 1979; 1980; 1981) indicate that Halodule cover is reduced in the area immediately adjacent to the mouth of the discharge canal, but that in general Halodule cover does not differ between impacted and control areas. Syringodium and Thalassia, however, were generally not found in the inner discharge area (van Tine 1977, "Basin 1") and typically exhibited higher cover south of the intake canal. Similar trends were seen in the present study.

The seagrass coverage depicted in the macrophyte maps generally support the quantitative data, seagrass cover being greater in the southern part of the Crystal Bay area. The area impacted by the thermal plume was devoid of macrophytes, along with the area around the mouth of the Cross Florida Barge Canal.

Seasonally, percent cover tended to be significantly higher during the summer months for the three species of seagrass. FPC (1980) reported winter cover maxima (December) in the southern control and discharge areas of the Crystal River Plant, while FPC (1981) reported fall (September) cover maxima in the southern area, with no appreciable seasonal cover changes of seagrasses in the discharge area.

Macroalgae

Algae may be better indicators of thermal stress than seagrasses, since the buried rhizomes of seagrasses may be protected from thermal efects by the sediment (Zieman and Wood 1975). In particular, Zieman (pers. comm.) has noted that the rhizophytic green algae (members of the orders Siphonales and Dasycladales) are especially susceptible to thermal stress.

In the present study, rhizophytic algal diversity (number of species) was lower at all the thermal stations (D, E, and F) compared to the southern stations (A, B, and C). However, the northern stations also supported few species of these algae, once again suggesting that other factors, in addition to thermal stress, are regulating submergent macrophyte communities in the area.

Rhizophytic algal biomass (g dry wt/m^2) at the nine intensive monitoring stations was tested statistically. Station E had significantly higher algal biomass than any other station. No other clear station trend was evident. Rhizophytic algal biomass was significantly higher during the summer/fall period. Van Tine (1977) noted that very few species of siphonaceous green algae (Caulerpa spp., Udotea spp.) were found in the discharge area of the Crystal River Plant. Other monitoring studies at this site did not consider rhizophytic algae (FPC 1978; 1979; 1980), but FPC (1981) reported that siphonaceous algae did not occur in the discharge area of the plant. Zieman and Wood (1975) noted at Turkey Point that, in areas most severely impacted by thermal addition, the seagrass/macroalgal community was replaced by a blue-green algal mat. This phenomenon was also seen at Crystal River in the Basin 1 section of the discharge canal.

Drift algal diversity and biomass were not measured in the present study. A general impression was that a greater number of species of drift algae were found south of the intake canal. Drift algal percent cover was highest in the southern part of the Crystal Bay study area (Station B), but no other clear percent cover trends were evident from the percent cover analyses. Steidinger and Van Breedveld (1971) showed that the discharge area of the Crystal River Plant supported fewer species of algae than the rest of the Crystal Bay area. Van Tine (1977) also showed that the thermally impacted area of Crystal Bay supported a lower number of species of all three divisions of algae: Rhodophyta (red algae); Chlorophyta (green algae) and Phaeophyta (brown algae). He also showed that algal biomass was lower in the impacted area. FPC (1981) showed that drift red and brown algae were excluded from the Crystal River Plant discharge area.

In summary, the data and observations collected in the present study suggest that the thermal effluent from Crystal River exerts a negative effect on the seagrass and macroalgal communities in the inner part of the discharge area (Basin 1). The thermal effects appear to be more moderate in the outer parts of the discharge area (Basin 3). However, other factors are influencing the submergent macrophyte communities in the study area and the data gathered in the present study cannot distinguish between these different factors. Thus, the observed trends in macrophyte biomass, percent cover, etc, cannot be attributed solely to the effects of thermal addition. Increased turbidity and sedimentation, some of which may be due to the outflow current from the discharge canal, may be exerting a negative effect on the macrophyte

communities in the discharge area. The selection of the three northern intensive monitoring stations (G, H, and I) in the region of the Cross Florida Barge Canal (CFBC) represented an attempt to distinguish between potential turbidity and sediment loading effects and any thermal effect, but the statistical analyses of the data failed to differentiate between stations located in the thermal and northern areas. Decreased light levels (associated with increased water turbidity) and increased sedimentation are suspected of causing declines in seagrass coverage (Zieman 1982). Other factors influencing the seagrass and macroalgal communities in the study area are nutrient concentrations in the water column, sediment type and depth and salinity changes associated with freshwater influx.