CONTINUOUS LIGHT MONITORING IN FLORIDA BAY:
Completion Report for the Period November 1998- June 2002

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INTRODUCTION

This project began in response to a need for light monitoring data to support seagrass modeling efforts. The first two years of light monitoring data were summarized and presented disks at the Florida Bay Science Conference, April 23-26, 2001. Data for the period November 1998 through February 2001 were distributed at that meeting. Attached to this report is a CD containing those data, data for the period January 2001 through June 2002, summary files and statistics for the entire project period.

At this time, we have collected four years of data (over 600,000 data records), and we can begin to see long-term as well as short-term temporal trends in the data. Furthermore, as the Comprehensive Everglades Restoration Plan (CERP) begins implementation, we see the utility of continuous light monitoring data to evaluate impacts of changed water management on Florida Bay, and we will work more closely with Everglades National Park staff to better meet their needs to monitor CERP impacts. As this project continues under different funding, we hope to install a fluorometer and transmissometer at Rankin Lake to enable us to distinguish sediment resuspension events from phytoplankton blooms in the north central Bay.

OBJECTIVES

We have made significant progress on the following objectives:

1. Provide four years of continuous light data to be used to calibrate seagrass productivity models.

2. Develop an optical water quality model for Florida Bay to determine the influence of resuspended sediment, phytoplankton chlorophyll, colored dissolved organic matter (CDOM), and epiphytes on the light field in the Florida Bay water column.

3. Use continuous light monitoring to assess the intensity and persistence of storm impacts on optical water quality in Florida Bay.

4. Establish a baseline dataset of optical water quality in Florida Bay that can be used to measure changes resulting from restoration activities in the Everglades watershed.

5. Continue light monitoring in Florida Bay to assess impacts of Everglades restoration activities.

6. Install a fluorometer and turbidimeter at the Rankin Lake platform to determine factors associated with the initiation and maintenance of phytoplankton blooms in north-central Florida Bay.

METHODS

Continuous light data have been collected at seven stations: Johnson Key, Rabbit Key, Rankin Lake, Little Madeira Bay, Long Sound, Butternut Key, and Peterson Key. Data collection began in December 1998 and continues at present. At each of these seven stations, we have installed Licor LI-1400 data loggers connected to two spherical, underwater light probes. The probes are PAR (photosynthetically-active radiation) sensors which measure light with wavelengths from 400 nm to 700 nm. Their spherical shape integrates downwelling light and some bottom reflectance in much the same way that seagrass blades receive light from all directions. The probes are mounted on PVC staffs, one near the water surface and one near the bottom. In addition to measuring the amount of light available to seagrass and phytoplankton at the surface and at the bottom, the two probes enable us to calculate the diffuse attenuation coefficient for light in the water column. Data from each probe are recorded by the logger every 15 minutes from 0530 hrs to 2100 EST hrs each day. Probes are cleaned, and data are downloaded twice monthly.

Fouling of sensors by resuspended sediment, algae, and other organisms has required us to clean probes every two weeks. To reduce fouling and to ease cleaning, sensors have been covered with Saran Wrap which is replaced every two weeks when the probes are cleaned. Instantaneous light measurements are made before and after Saran Wrap replacement, and a fouling correction is calculated from the difference of the “before cleaning” and “after cleaning” measurements. The fouling rate is assumed to be linear over the two-week period between probe cleanings, and the fouling correction is applied incrementally to data over the entire period. Fouling corrections are typically between 1% and 15%, but values as high as 50% have occurred after large storms.

The resulting data files are reasonably complete, but data gaps do occur as the result of several processes. Several shallow PAR sensors have been broken by boat strikes over the course of this study. Bottom sensors at Rankin Lake have been broken by a large stingray or nurse sharks who live under the platform. Licor submersible cables are used for all submerged probes, and the cables are protected by flexible plastic electrical conduit. However, cables typically last six to twelve months, even when protected by conduit. We have improved the longevity of Licor cables by applying silicone sealant to the cables before they are deployed. We are also looking for cables with superior resistance to salt water.

To prevent data gaps, we have changed our monitoring strategy over the past two years. When the project began, we installed two submersible probes at each site, one near the water surface and one near the bottom. However, several shallow sensors were lost to boat strikes and cable damage for either sensor could result in a data gap. In the last two years, we have eliminated shallow sensors at all sites. Each site now has a deck PAR sensor and two bottom sensors. Two bottom sensors provide redundancy if one cable or sensor fails, and water column transparency is calculated from an empirical relationship between deck sensor values, water level variations, and bottom sensor values. Each bottom sensor remains onsite for one year unless the sensor or its

cable fails prematurely. However, the installation and removal of bottom sensors at each site are staggered by six months so that the maximum age of the newer sensor at each site at any given time is six months.

In addition to the continuous bottom light data files distributed to modelers, we have summarized data by calculating several key parameters. Daily total PAR flux and peak mid-day PAR values, measured between 1100h and 1300h, have been calculated for each site using SAS (SAS Institute, 1988). We have also calculated the number of hours in each day when PAR values have exceeded 200 and 500 uE, respectively called Hsat 200 and Hsat 500. These parameters are based on the work of Dennison and Alberte (1985) who found that Zostera survival and growth were positively correlated with the number of hours each day when light exceeds the saturating light intensity for eelgrass, and they called the parameter Hsat. Our choice of two Hsat values, one based on 200 uE and the other on 500 uE, reflect the range of Hsat values which might be applied to seagrasses. Monthly averages have been calculated for all parameters, and monthly summaries have also been included on the distributed CD-ROMs. One significant qualification of the data presented is that some sites, notably Peterson Key and Butternut Key, are close enough to keys that tree shadows affect the data. At Peterson Key, probes are shaded until approximately 1000 h each day. Butternut Key data are only affected by tree shadows very late in the evening.

In addition to light data, we have collected discrete water samples monthly at each monitoring site and 12 other sites scattered across Florida Bay for analysis of total suspended solids, turbidity, color, and chlorophyll. Total suspended solids have been determined by filtering 500 to 1000 ml water through tared, combusted GF/C filters. Filters were dried, weighed, combusted, and weighed again to calculate seston weight and organic content. Filters were then rinsed with 1 N HCl, rinsed with deionized water, dried, and weighed again to determine seston carbonate content. Turbidity was determined in a Hach turbidimeter using formazin standards, and data were expressed in nephelometric turbidity units (NTUs). Samples were filtered through 25 mm GF/F filters, and color was determined spectrophotometrically and expressed in platinum-cobalt units (APHA, 1985). Chlorophyll samples were filtered in the field and frozen. Samples were extracted with methanol overnight at 4° C, and chlorophyll was determined fluorometrically using the procedure of Weltschmeyer (1994). Epiphyte loads were measured during the first two years of this study, and , because epiphyte loads might respond to increased nutrient loading, we will probably resume measurements in the future.

RESULTS AND DISCUSSION

CONTINUOUS LIGHT MEASUREMENTS: All four measures of PAR - daily sum PAR, Hsat 200, Hsat500, and mean mid-day PAR- varied significantly seasonally and among sites (Figures 1-4). Mean daily photon flux was generally higher at Butternut and Madeira than at Long Sound, Peterson Key or Rabbit Key. However, as noted above, Peterson values were not corrected for significant morning shading. Lowest photon fluxes occurred at Johnson Key Basin and Rankin Lake.

The seasonal pattern of daily photon flux was similar for all sites. Highest bottom light values occurred in the months of March, April and May of both 1999 and 2000. Lowest

values occurred in the months of November, December, and January for both years. Low values coincided with seasonal insolation minima, but the maxium values in spring probably resulted from a combination of cool water (low phytoplankton growth rates), low rainfall, and low cloud cover.

In fall 1999, Tropical Storm Harvey (19-21 September 1999) and Hurricane Irene (13-15 October 1999) had severe impacts on water clarity, especially at the Rankin Lake and Johnson Key Basin sites. In October, 1999, mean daily photon flux values at those two sites dropped to less than 10 E and remained at low levels through February 2000. It is likely that persistent low light levels in fall 1999 caused seagrass loss in western Florida Bay. Durako et al. (2001) reported seagrass losses in the western Bay that probably resulted from the persistent, poor light conditions during fall 1999.

Seasonal and spatial patterns of Hsat200 were similar to patterns for mean daily photon flux. However, the effects of Tropical Storm Harvey and Hurricane Irene were even more pronounced for Hsat 200. The number of hours when PAR values exceeded 200 uE at Rankin Lake declined to zero in October 1999 and slowly recovered to normal seasonal levels in February 2000, five months later.

Low values of Hsat 200 can have considerable impacts on Florida Bay seagrass communities. Dennison and Alberte (1985) found that Zostera survival and growth were positively correlated with the number of hours each day when light exceeds the saturating light intensity for eelgrass, and he called the parameter Hsat. There is considerable variability in literature estimates of saturating light intensity for Thalassia, and much of the variability depends on the conditions used to measure productivity. Small pieces of leaf tissue have a much lower respiratory oxygen demand than whole plants, because up to 90% of a whole Thalassia plant is non-photosynthetic tissue- roots, rhizomes, and shoots. For this reason, we consider 200 uE to be the absolute minimum saturating light intensity for Thalassia, and our benthic flux chamber experiments, which measure whole community oxygen balance, put the community compensation point closer to 500 uE.

The spatial and seasonal pattern of Hsat 500 was similar to that of Hsat 200. However, the depression of Hsat 500 values caused by Tropical Storm Harvey and Hurricane Irene was more severe and persistent than the pattern observed for Hsat 200 (Figure 3). The effects were most severe at Rankin Lake and Johnson Key Basin, although Johnson Key Basin values rebounded more quickly than values for Rankin Lake. Rankin Lake values dropped below 2 hours/day in fall 2000, apparently in response to the fall-winter phytoplankton blooms which have occurred frequently over the past 10 years.

Seasonal peaks in mid-day bottom PAR values occurred in spring of both 1999 and 2000 (Figure 4), although the seasonal pattern is not as pronounced as the seasonal pattern of solar insolation. As noted earlier, spring peaks in water clarity can result from the combined effects of low phytoplankton production, low rainfall, and low cloud cover.

The concept of daily oxygen balance and its influence on seagrass survival and growth is worthy of additional study and modeling. Because seagrass respiratory oxygen demand is tied to water temperature while photosynthetic oxygen production is dependent on light, Florida Bay seagrasses might also be affected by the number of hours when light

levels exceed the compensation point- the point where photosynthetic oxygen production and respiratory consumption are balanced. Poor water clarity during warm months would therefore cause greater hypoxic stress than in cold months. Hcomp- if it were modeled- would be dependent on both light and temperature.

Data collected in Johnson Key Basin illustrate the decoupling of seasonal cycles of temperature and light availability for seagrasses (Figure 5). Mean daily photon flux reached its peak in May 2000 and then declined, while water temperature increased through June and then remained high in July, August, and September. The disparity between the two seasonal cycles was even greater during 1999, when photon flux peaked in April, declined through September, and then plunged farther in October. The combination of decreased productivity and high water temperatures from May through October might have led to hypoxic stress and/or sulfide toxicity for Thalassia in Rankin Lake and Johnson Key Basin.

STATISTICAL ANALYSIS OF 1999 AND 2000 DATA

Analyses of variance indicate that season was the most important independent variable affecting all measures of light availability for seagrasses (Table 1). Site was the second most important variable, and year followed in third place. All interaction terms were also significant. Highest values of mean daily photon flux, Hsat200, and mid-day peak PAR values occurred in spring, followed by winter or summer. Lowest values of all parameters occurred in fall.

Table 1: Analyses of variance for mean daily photon flux, Hsat200, and mid-day peak PAR values with site, year, season, and interaction terms.

Independent Variable	DF	Mean Daily Photon Flux	HSAT 200	Mean Mid-Day Peak PAR Value
SITE	6	249.50 <.0001	103.13 <.0001	208.61 <.0001
YR	3	32.48 <.0001	42.13 <.0001	56.75 <.0001
SEASON	3	1094.13 <.0001	764.67 <.0001	657.97 <.0001
SITE*YR	18	25.92 <.0001	7.77 <.0001	24.73 <.0001
SITE*SEASON	18	39.79 <.0001	18.09 <.0001	32.36 <.0001
YR*SEASON	3	44.31 <.0001	25.49 <.0001	44.11 <.0001
SITE*YR*SEASON	18	10.96 <.0001	7.38 <.0001	9.26 <.0001

Table 2: Seasonal means for Hsat200, mean daily photon flux, and mean maximum mid-day PAR values for 1999-2000. Values in each column with different subscripts are not significantly different according to Duncan's multiple range test, a=0.05.

Independent Variable		Hsat 200	Mean Daily Photon Flux	Mean Maximum Mid-day PAR	Obs
A. Season					
Winter		8.4 c	31.2 b	1237.9 b	1387
Spring		10.5 a	43.3 a	1510.4 a	1200
Summer		9.1 b	29.8 c	1082.8 c	1172
Fall		6.7 d	18.6 d	785.9 d	1394
B. Site					
Butternut		9.5 a	40.6 a	1520.0 a	789
Long Sound		9.2 b	34.9 c	1289.9 c	722
Little Madeira		9.5 a	37.9 b	1409.7 b	704
Peterson Key		8.2 c	32.0 d	1243.6 d	801
Rankin Lake		6.6 e	18.0 f	688.4 f	713
Rabbit Key		9.4 ab	29.7 e	1108.4 e	688
Johnson Key		7.6 d	17.9 f	708.4 f	736
C. Year					
	1999	8.3 b	30.9 a	1169.3 a	2307
	2000	8.9 a	30.2 a	1122.0 a	2370

With the exception of Rabbit Key Basin, a very shallow mudbank site, sites in the eastern Bay generally had higher mean values for Hsat 200, mean daily photon flux , and mean maximum mid-day PAR during the first two years of the study. Butternut Key had the highest values of any site, followed by Long Sound and Little Madeira and Peterson Key. Lowest values occurred at Rankin Lake and Johnson Key Basin. Annual means for daily photon flux and maximum mid-day PAR were not significantly different between 1999 and 2000. Mean Hsat values for all sites combined were slightly higher in 2000 than in 1999.

STATISTICAL ANALYSIS OF 2001-2002 DATA

These analyses are qualified by the fact that 2002 data are incomplete, representing only the first six months of the year. As noted earlier for the 1999-2000 data, season is the independent variable with the greatest effect on light availability for seagrasses in Florida Bay. Site is the second most important independent variable, followed by year, and then by interaction terms.

Table 3. Analyses of variance for mean daily photon flux, Hsat200, and mean mid-day peak PAR values for 2001 and 2002. Data are Type III Sum-of-Squares F-ratios for site, year, season, and interaction terms.

Independent Variable	DF	Mean Daily Photon Flux		HSAT 200		Mean Mid-Day Peak PAR Value	
Site	6	239.30	<.0001	84.55	<.0001	184.85	<.0001
Year	1	63.80	<.0001	7.85	<.0001	60.60	<.0001
Season	3	463.70	<.0001	392.73	<.0001	269.31	<.0001
Site*Year	6	10.93	<.0001	5.20	<.0001	17.29	<.0001
Site*Season	18	19.07	<.0001	6.13	<.0001	20.69	<.0001
Year*Season	2	12.91	<.0001	4.96	<.0001	22.84	<.0001
Site*Year*Season	7	10.47	<.0001	1.04	<.0001	8.48	<.0001

The seasonal pattern of 2001-2002 data is similar to that for 1999-2000 data. Highest values of all parameters occurred in spring, followed by winter and summer. Lowest values occurred consistently in fall, as seen in the 1999-2000 data. Spatial patterns observed in 2001 and 2002 are also similar to the earlier data: highest values occur at Rabbit Key and eastern Bay stations. Lowest values occur at Johnson Key Basin and Rankin Lake.

Table 4. Mean values for Hsat200, mean daily photon flux, and mean maximum mid-day PAR values. Values with the same letter subscript are not significantly different according to Duncan's multiple range test.

Independent Variable	Hsat 200	Mean Daily Photon Flux	Mean Maximum Mid-day PAR	Obs
A. Season				
Winter	8.73 c	30.41 b	1150.2 b	1226
Spring	10.15 a	37.30 a	1275.6 a	1183
Summer	9.10 b	31.24 b	1076.4 c	683
Fall	7.42 d	19.70 c	787.8 d	640
B. Site				
Butternut	9.79 a	40.88 a	1424.0 a	513
Long Sound	9.36 b	30.79 d	1096.9 d	554
Little Madeira	9.35 b	34.44 b	1258.0 b	514
Peterson Key	8.46 c	32.79 c	1156.6 c	537
Rankin Lake	8.40 c	23.78 e	877.6 e	520
Rabbit Key	9.77 a	35.63 b	1287.4 b	537
Johnson Key	8.11 d	18.84 f	727.1 f	557
C. Year				
2001	8.99 b	31.33 a	1127.1 a	2540
2002	9.11 a	30.00 b	1087.1 b	1192

CONCLUSIONS

Continuous light monitoring, water quality, and epiphyte assessment in Florida Bay provide the framework for modeling the responses of seagrass communities to historical and anticipated changes in water clarity associated with recent changes and future management, respectively.

Although Tropical Storm Harvey and Hurricane Irene did not physically disrupt or defoliate seagrass communities in fall 1999, the resultant drop in water clarity lasted for five months and had a significant impact on seagrass communities, especially in western Florida Bay.

With the collection of four years of baseline data, spatial and seasonal patterns are discernible. Eastern stations such as Butternut Key and Peterson Key typically have highest Hsat, photon flux, and mid-day PAR values. Rankin Lake and Johnson Key Basin typically have lowest values. The seasonal pattern of light availability has been the same for all four years sampled: highest photon flux, Hsat, and mid-day PAR values have occurred in spring between April and June. Lowest values in each year have occurred in fall (October through December). As noted in our previous report, the lag between declining water temperature and declining photoperiod in the fall is a potentially major factor contributing to historical and ongoing seagrass mortality.

With long-term data sets, subtle annual difference appear (Figure 6). Fall daily photon flux values fell between 1998 and 1999 and have shown successive increases in 2000, 2001, and 2002. In contrast, spring photon flux values declined each year since 1999, declining almost 30% over the three year period. With long-term datasets, the effect climatic factors such as El Nino and drought years on the seasonal balance of light parameters might emerge. Their combined effects on seagrasses in Florida Bay might be considerable.

It is our hope that light monitoring will be incorporated into any monitoring program assessing the impacts of Everglades restoration activities on Florida Bay. Continuous light monitoring provides information that discrete sampling cannot. Discrete sampling data are generally collected in good weather, but infrequent events like hurricanes and winter storms are extremely important determinants of seagrass survival and growth. Additional stations along the northern edge of Florida Bay may be necessary, and the addition of fluorometers and transmissometers to some northern Bay stations might be desireable.

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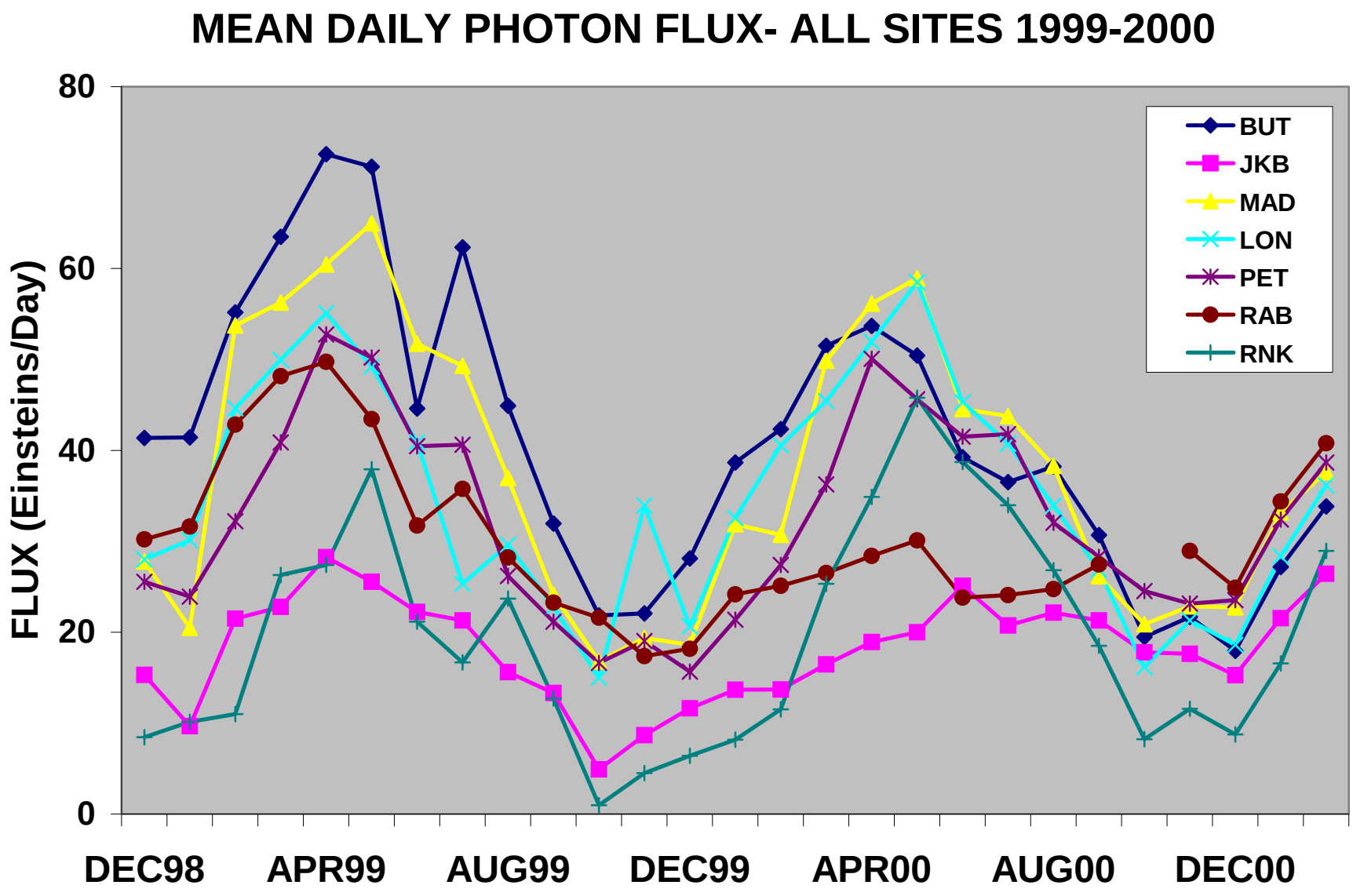

Figure 1: Mean Daily Photon Flux at Seven Sites in Florida Bay. Data are expressed in E/d for the period December 1998 through February 2000.

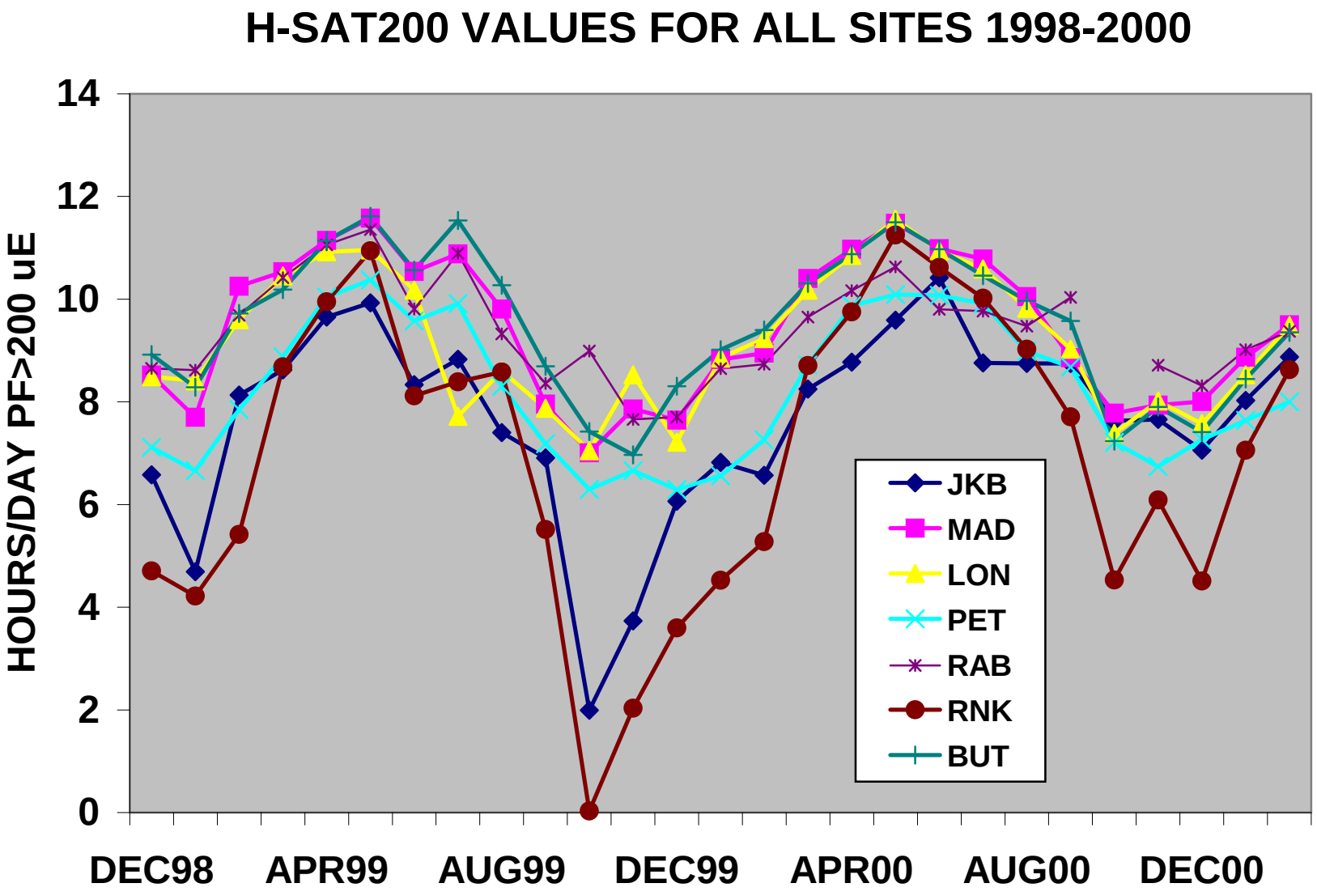

Figure 2: Hsat 200 Values for Florida Bay Light Monitoring Stations. Hsat 200 values represent the number of hours each day when bottom PAR values exceed 200 uE.

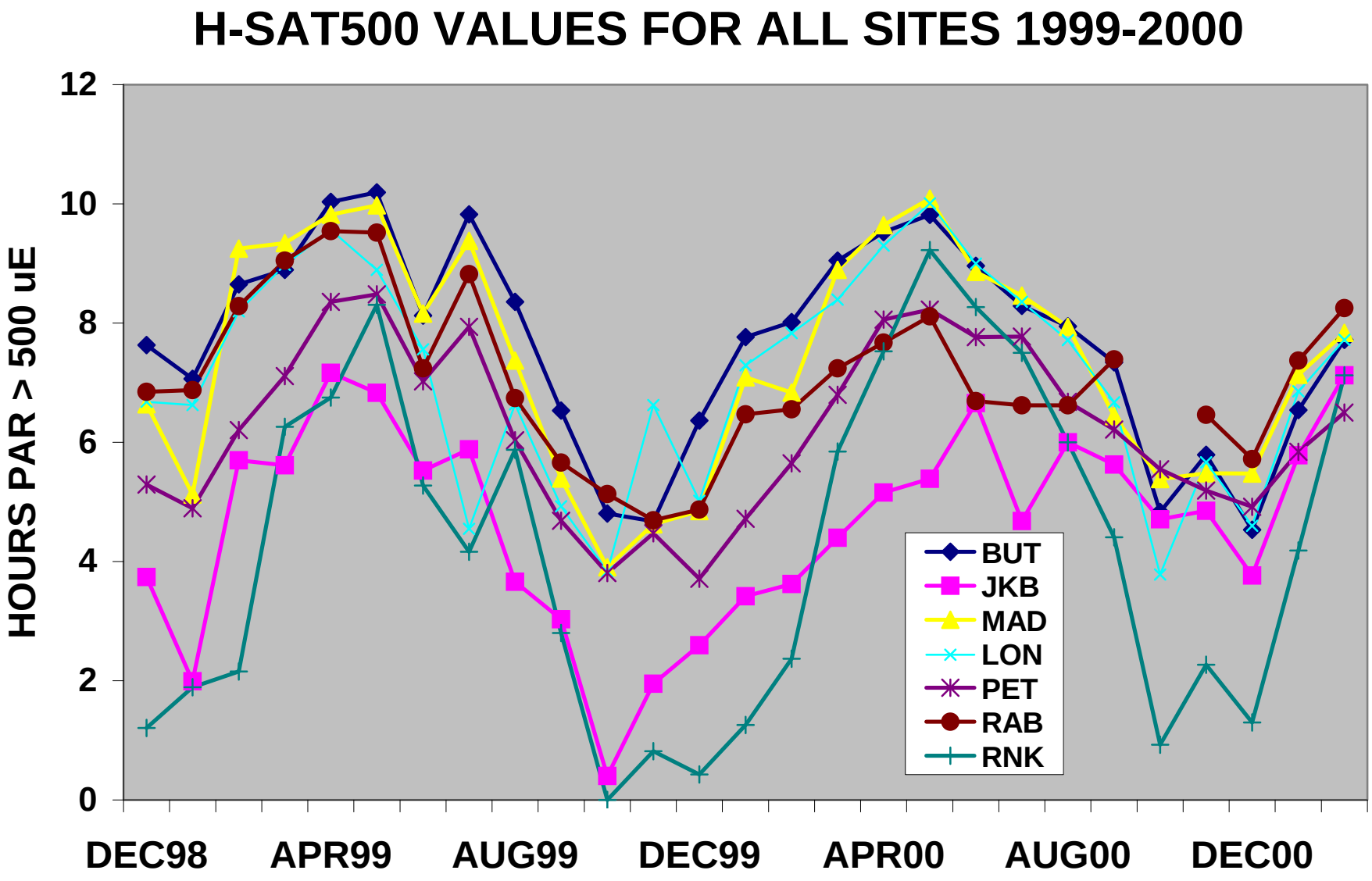

Figure 3: Hsat 500 Values for Light Monitoring Stations in Florida Bay.

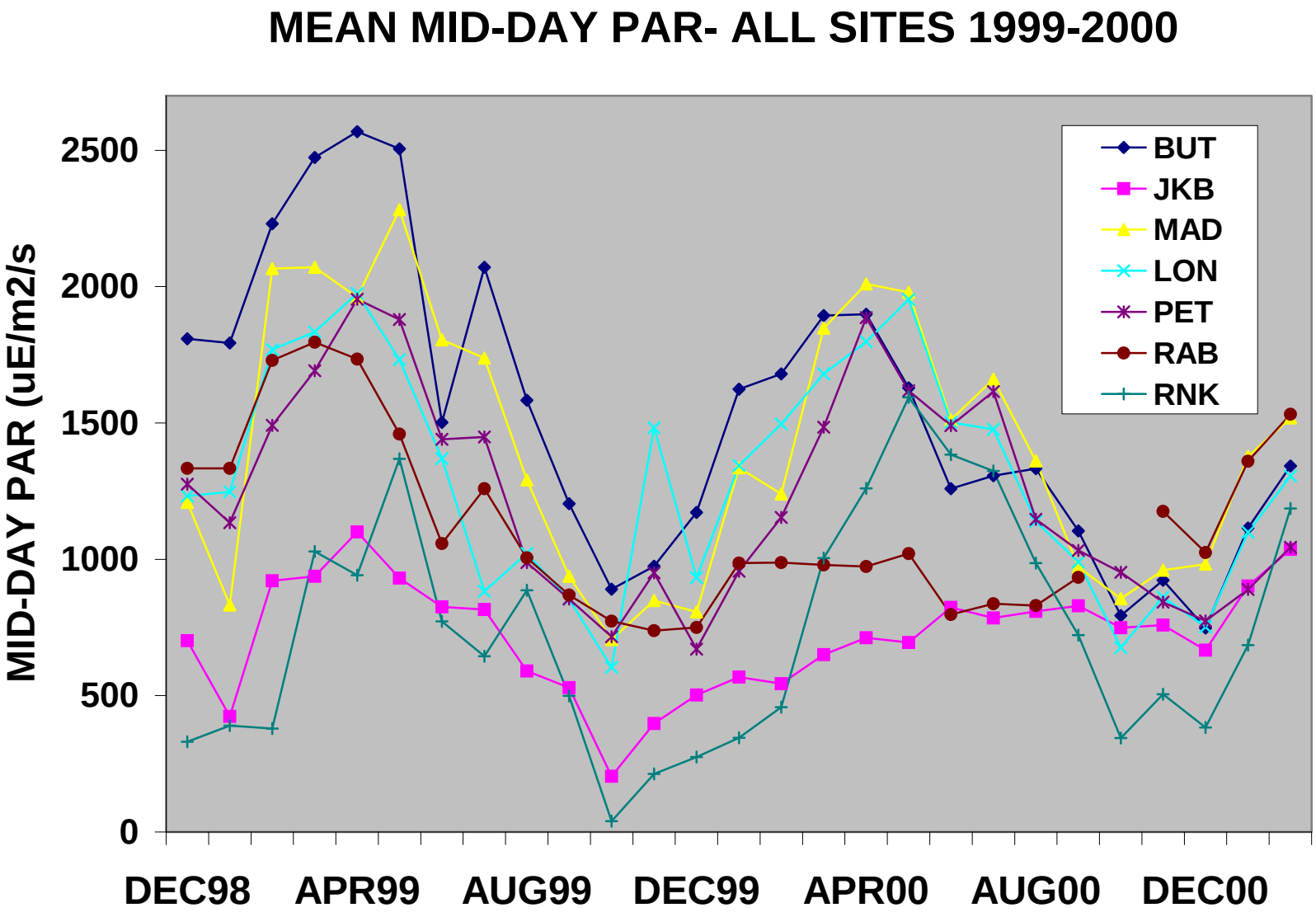

Figure 4: Mean Mid- Day PAR values for light monitoring stations in Florida Bay.

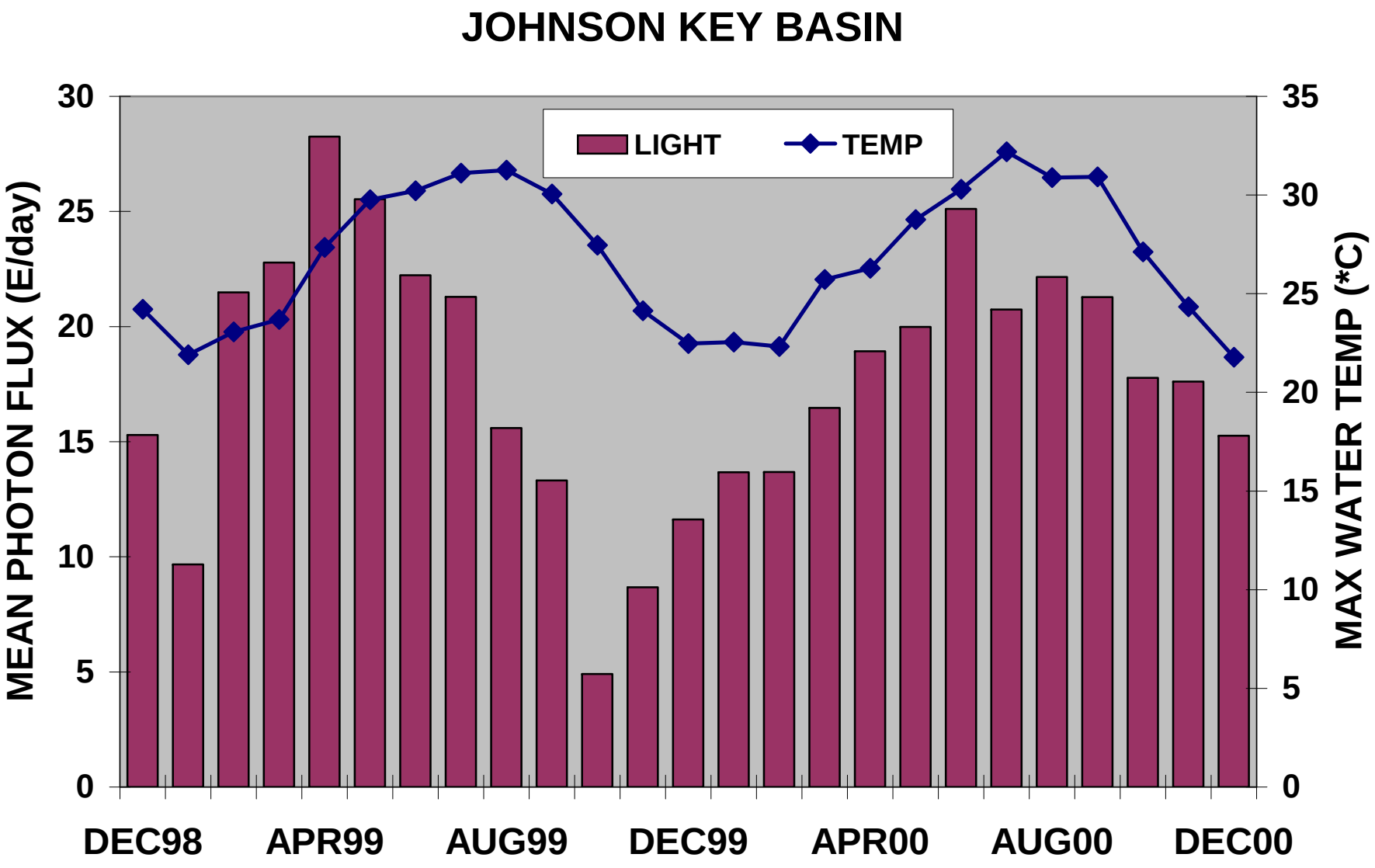

Figure 5: Disparity between seasonal cycles of bottom PAR values and water temperature for Johnson Key Basin.

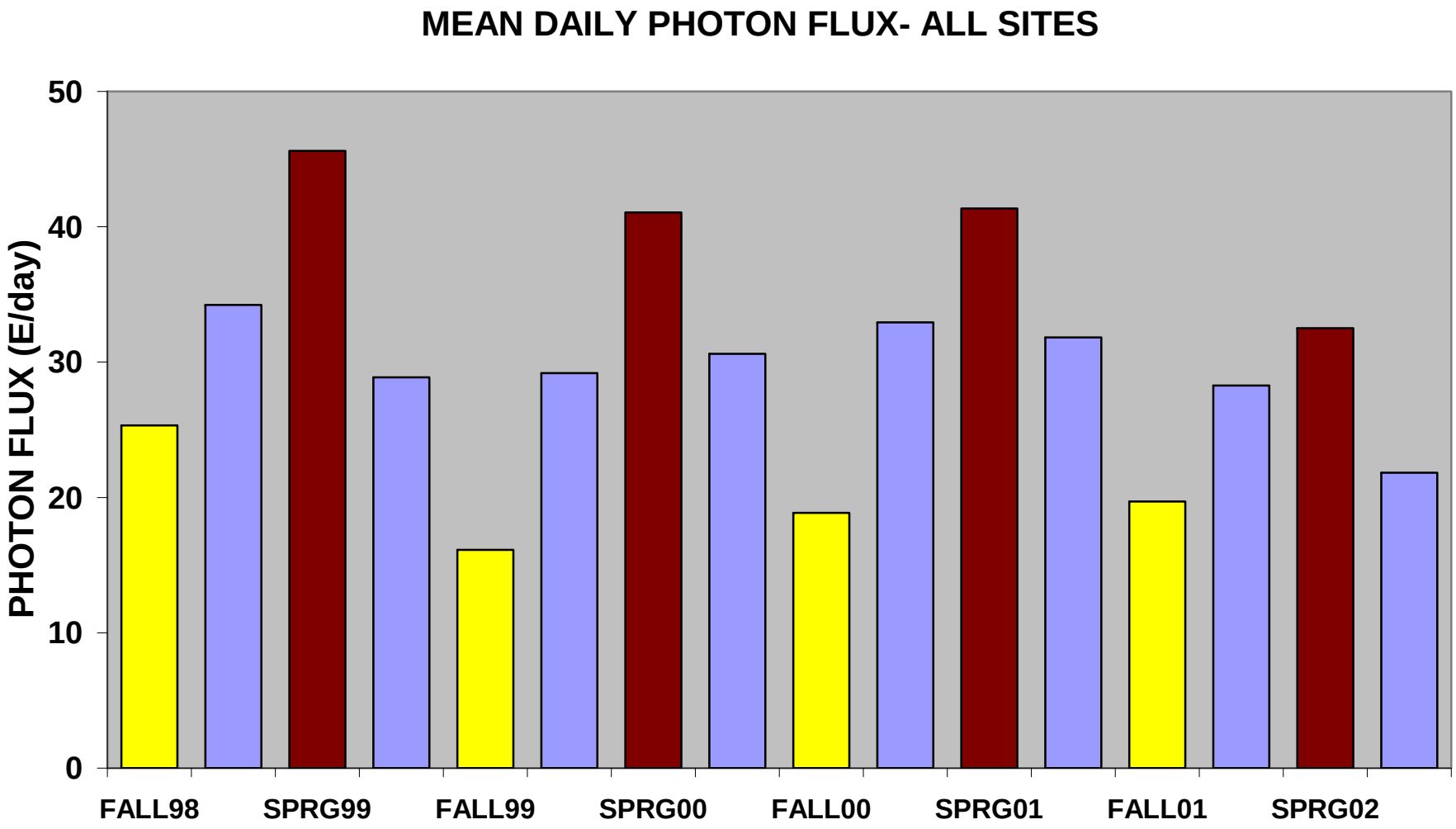

Figure 6: Seasonal changes in daily photon flux for all Florida Bay sites, fall 1998 through summer 2002.