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HYDROGRAPHIC CONDITIONS AND DISSOLVED OXYGEN STATUS OF THE TAMPA BAY ESTUARINE SYSTEM (SEPTEMBER-OCTOBER 1993-1996)

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ENVIRONMENTAL PROTECTION COMMISSION
OF HILLSBOROUGH COUNTY
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ENVIRONMENTAL PROTECTION COMMISSION OF HILLSBOROUGH COUNTY

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EXECUTIVE SUMMARY

Surveys of the dissolved oxygen status of the Tampa Bay estuary are an integral element of the annual bay-wide benthic monitoring program, which has been on-going since 1993. These surveys include daytime monitoring of the water column as well as overnight monitoring at selected stations. The four-year period encompassing 1993-1996 has been designated as the "baseline" condition from which trends in the dissolved oxygen status of Tampa Bay will be identified and assessed.

The dissolved oxygen status of Tampa Bay is a concern because "marginal" dissolved oxygen concentrations (greater than 2 milligrams per liter and less than 4 milligrams per liter) can encourage the movement of fish, crabs, shrimp, and other invertebrates from their preferred habitat. "Subnominal" dissolved oxygen concentrations (less than 2 milligrams per liter= hypoxia) can, if they persist, contribute to the death of bottom-dwelling animals.

Extremely high concentrations of dissolved oxygen may also be an indicator of impairment from high amounts of nutrients (nitrogen and phosphorus). When surface waters are supersaturated with dissolved oxygen it is likely the result of production by microscopic algae (or seagrasses) during photosynthesis. In waters which are highly productive, the oxygen concentrations can undergo profound changes over a daily cycle, often leading to oxygen depletion at night. In addition, decomposition of algae "blooms" results in lowered DO, which can contribute to fish kills.

Over the 1993-1996 "baseline"period, 15%(60 square miles) of the Tampa Bay estuary was estimated to have "marginal"and "subnominal"dissolved oxygenconcentrations. More than 30%of both the Hillsborough Bay and Manatee River segments were so affected.

More than 3%(12 square miles) of Tampa Bay was hypoxic. The Hillsborough Bay and Manatee River segments were, again, most affected. There was no evidence of hypoxia in the Lower Tampa Bay, Boca Ciega Bay, and Terra Ceia Bay segments.

Between 19%and 29%of the Old Tampa Bay, Hillsborough Bay, Middle Tampa Bay, Lower Tampa Bay, and Boca Ciega Bay segment surface waters were supersaturated. Middle Tampa Bay had the greatest overall area of supersaturated surface waters (23 square miles).

A dissolved oxygen index showed that, baywide, nutrient enriched (eutrophic) conditions affected more than twice the area of low nutrient (oligotrophic) conditions. Average dissolved oxygen index scores indicated extensive nutrient enrichment in all but the Terra Ceia Bay and Manatee River segments of the bay. Index scores were highest in Boca Ciega Bay and Hillsborough Bay. Low nutrient conditions were most evident in the Manatee River segment (36.5% of the bay segment) and least in Lower Tampa Bay (8% of the bay segment).

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SECTION I
INTRODUCTION

Dissolved oxygen [DO] status has long been recognized as one of the critical environmental factors characterizing a water body. DO is included in Florida's numerical water quality standards (Florida Administrative Code Chapter 362) and the USEPA's EMAP Program has designated DO as one of the critical habitat factors to characterize the status of the nations estuaries (Holland 1990).

Two categories of substandard DO are defined: "marginal" (DO > 2 < 4 mg/l) and "subnominal" (hypoxia: DO < 2 mg/l) (Diaz *et al.* 1992; Summers & Engle 1993). Nutrient entrichment, typically anthropogenic in nature *(e. g.* ,wastewater treatment plant effluent) and the concomitant increase in standing crop of phytoplankton is a primary cause of substandard DO. Stratification of the water column, often subsequent to rain events, is also a factor in contributing to declines in DO near the bottom of the water column. Establishment of either a pycnocline or a thermocline effectively isolates bottom waters, where respiration predominates, from surficial waters, where photosynthesis is ongoing. Thermal effluents can also contribute to lowering of DO by reducing the amount of oxygen capable of being dissolved.

Hypoxia (DO < 2 mg/l; Diaz *et al.* 1992; Summers & Engle 1993) has been associated with emigration of nekton, epifauna, and infauna from affected areas (Steimle & Radosh 1979; Thoemke 1979; Pihl *et al.* 1991), vertical displacement of both infauna and demersal fishes (Rosenberg & Loo 1988; Pihl *et al.* 1991), and with mortality of benthic infauna (Steimle & Radosh 1979; Santos & Simon 1980; Harper *et al.* 1981; Gaston 1985). Anoxia (DO < O.2; Diaz *et al.* 1992) is invariably associated with defaunation (Harper *et al.* 1981; Rabalais 1992).

Supersaturation (> 100%) can also be indicative of an environment degraded by algal blooms and, by extension, nutrient enrichment (Rabalais 1992). However, supersaturation is evident in waters proximate to seagrass beds and, in surface waters, may be influenced by wind action (Kemp & Boynton 1980).

In the Tampa Bay estuary, impacts on the biota as a consequence of the DO regime have been documented since the 1970's (Thoemke 1979; Santos & Simon 1980). The responses reported have ranged from emigration of amphipod populations (Thoemke 1979) to complete defaunation of the habitat (Santos & Simon 1980).

There are criticisms of relying upon measurements recorded during daytime hours to ascertain the DO status of a water body. During the daytime, photosynthetic activity is maximal, respiration is at a minimum and DO concentrations typically attain their daily maximum. Generally, few routine measurements are taken during nightttime to early morning hours when aquatic plants and phytoplankton are respiring and DO values are decreasing.

In recent years, the case has been made that detection of the minimum daily DO concentration is especially desirable since this more accurately represents the status of the system in question (Diaz *et al*. 1992; Summers & Engle 1993). In addition, the duration of subnominal DO concentrations can also be determined by continuous monitoring. Diel patterns of DO concentrations are expected to be consistent and more pronounced in waters < 3m in depth, where biological processes (photosynthesis) predominate (Kemp & Boynton 1980). In deeper waters, diel DO is more variable and both biological and physical (e.g., winds and tides) processes are generally equally involved in regulating DO (Kemp & Boynton 1980).

This report summarizes up to four years of dissolved oxygen monitoring, including both daytime and diel measures, in each of the seven designated segments of Tampa Bay. Areal estimates of marginal and subnominal DO in bottom waters and supersaturation in near-surface waters are also reported.

SECTION II
MATERIALS AND METHODS

II.1 FIELD METHODS-SYNOPTIC SURVEY: Water column measures of DO were included as part of the annual benthic monitoring program initiated in 1993 for the Tampa Bay estuary *(cf.* Courtney *et al.* 1993; Grabe *et al.* 1996). The specifics of the study design have been described in detail elsewhere (Courtney *et al.* 1993). This is a random, probability-based approach which permits the computation of areal estimates for the various environmental parameters measured (Coastal Environmental, Inc. 1995). Sampling locations are shown in Figures 1-7.

DO concentrations were determined *in situ* with a Hydrolab Surveyor equipped with a battery-powered stirrer. Measurements were made at approximately 0.1-m below the surface, at 1-m intervals thereafter, and at 0.2 to 0.5-m above the bottom. In 1996, at sites where the water depth was > 10 m, measurements were made every meter to 5 m and at 5 m intervals thereafter. Field "replicates" were effected by taking readings while both lowering and retrieving the instrument. Temperature, salinity (or conductivity), and pH were measured as well.

Instruments were calibrated according to the manufacturer's specifications prior to deployment. Upon retrieval, instruments were checked against a Hydrolab Surveyor in a bucket of water if they were to be deployed again that same day. Otherwise the dataloggers were calibrated upon return to the laboratory.

II.2 FIELD METHODS-DIEL MONITORING: In order to determine the daily minimum DO concentration, instrumentation (either Hydrolab Dataloggers equipped with a low flow membrane or a YSI logger) was deployed at selected stations. The recorders were deployed approximately 0.2 to 0.5-m above the bottom. These would sample every 15 minutes, either over a 24-hr cycle or from late afternoon (starting at 1700 or 1800 hrs EDT) to early morning hours (0800 EDT). Water temperature, salinity (or conductivity), and depth were also recorded.

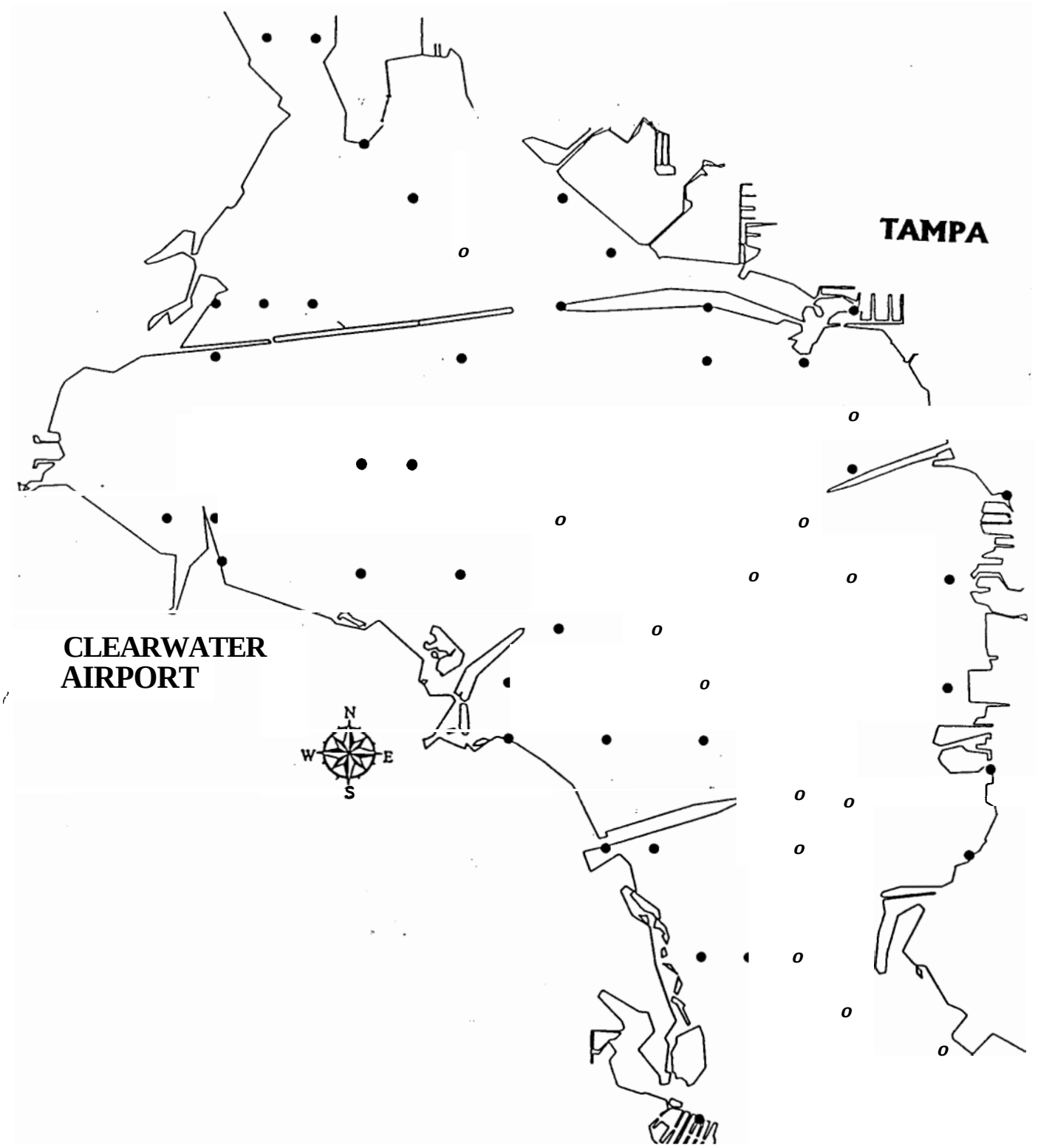

Figure 1. Location of sampling stations in the Old Tampa Bay segment of Tampa Bay, 1993-1996.

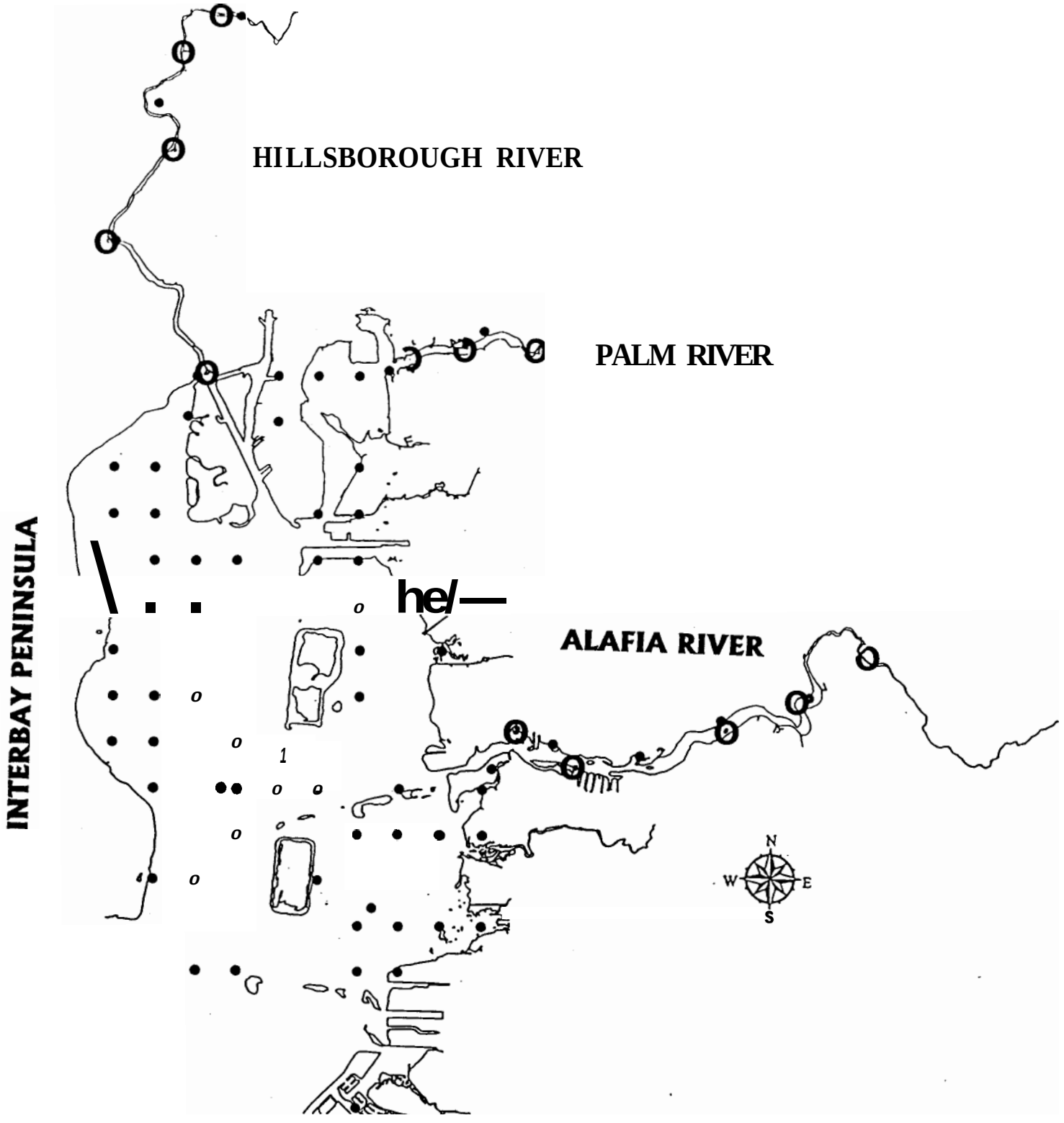

Figure 2. Location of sampling stations in the Hillsborough Bay segment of Tampa Bay, 1993-1996.

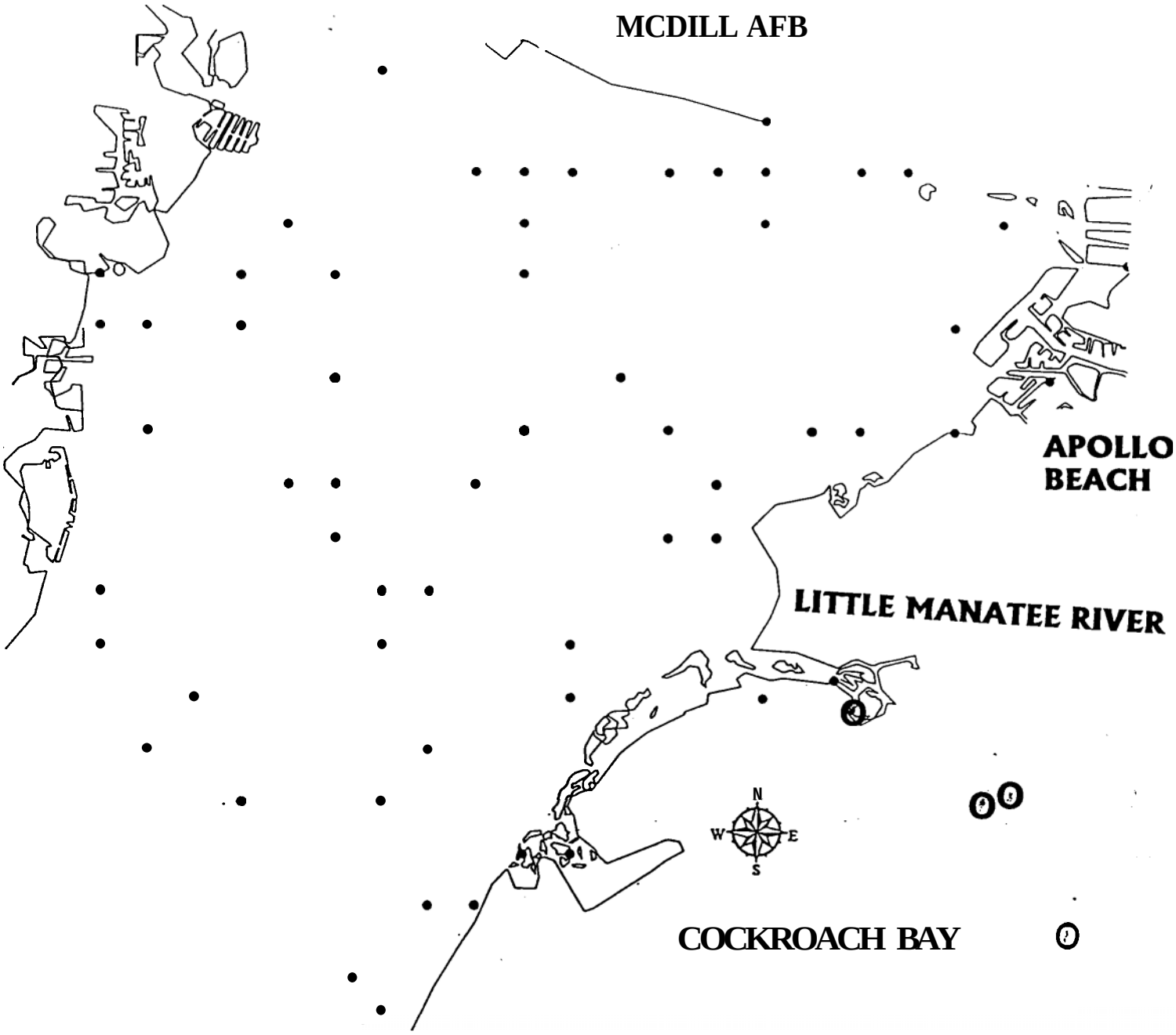

Figure 3. Location of sampling stations in the Middle Tampa Bay segment of Tampa Bay, 1993-1996.

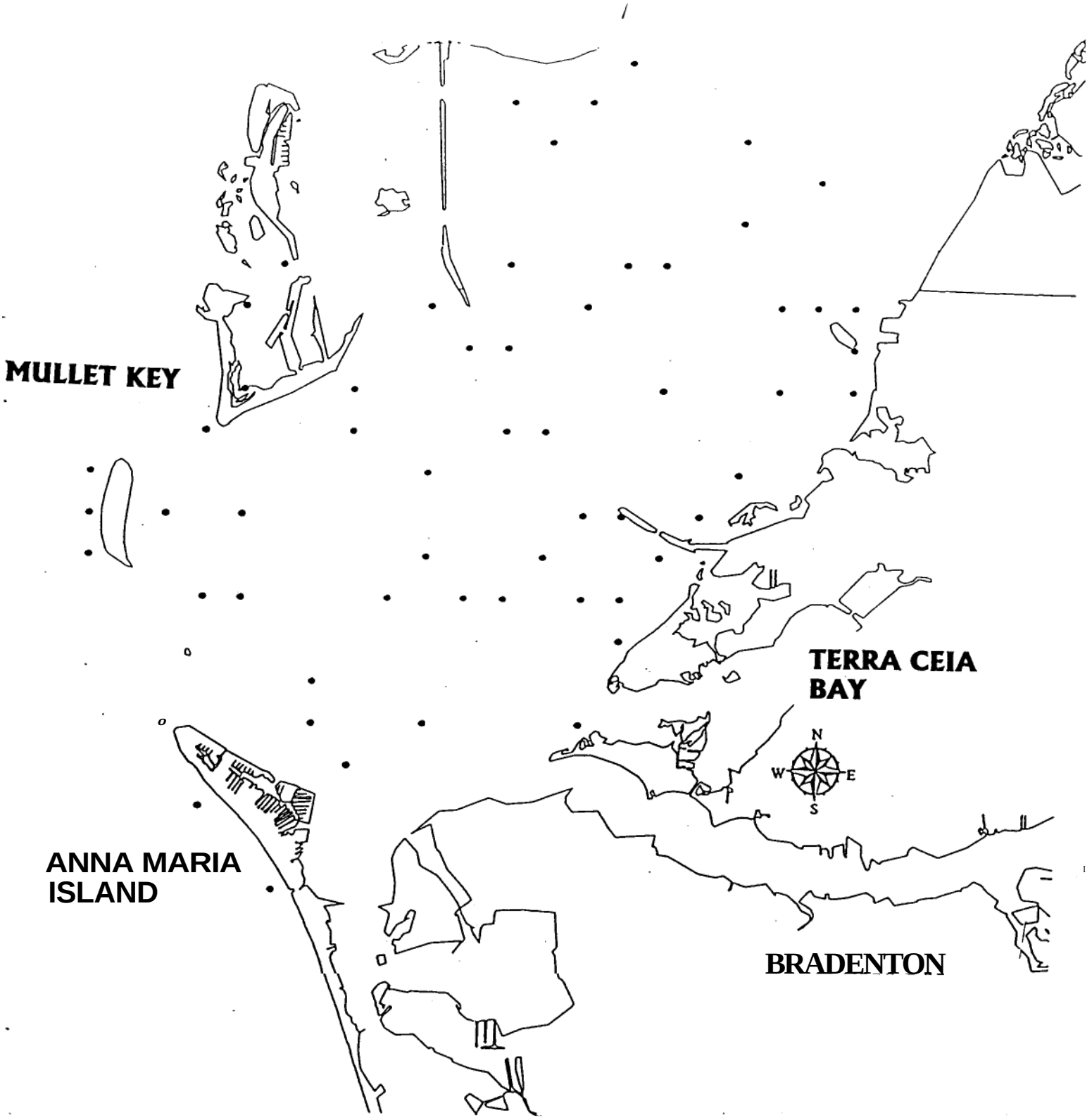

Figure 4. Location of sampling stations in the Lower Tampa Bay segment of Tampa Bay, 1993-1996.

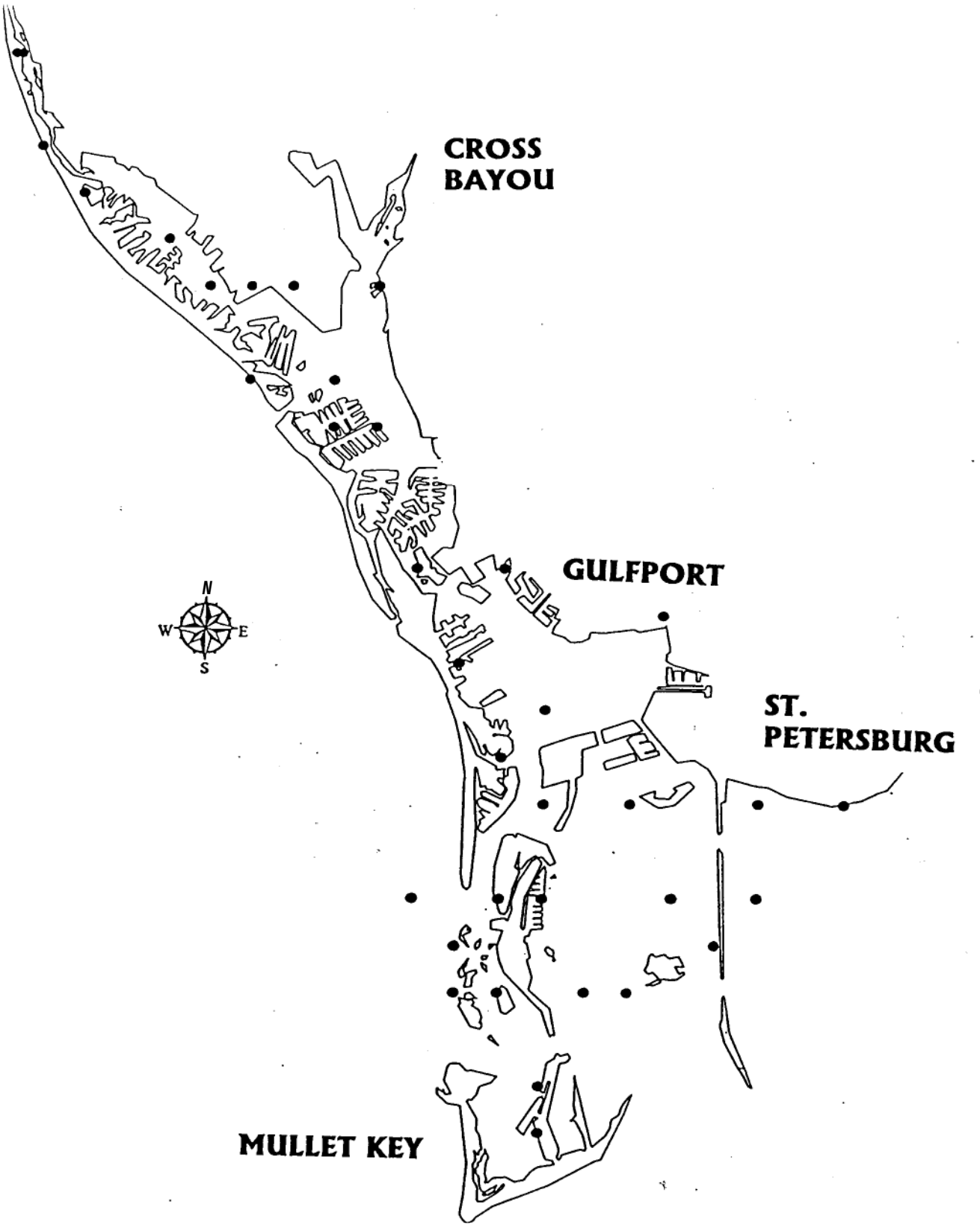

Figure 5. Location of sampling stations in the Boca Ciega Bay segment of Tampa Bay, 1995-1996.

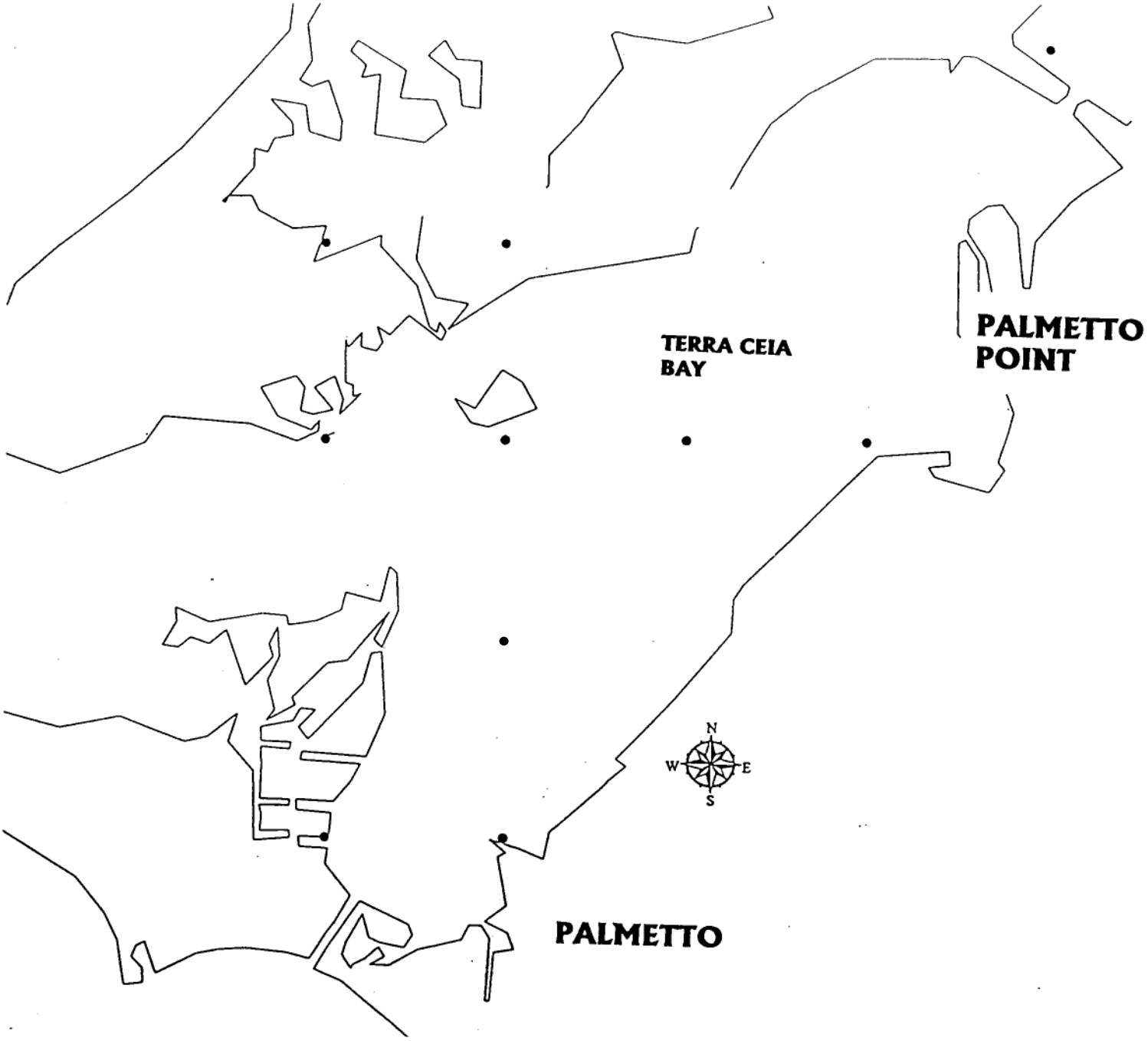

Figure 6. Location of sampling stations in the Terra Ceia Bay segment of Tampa Bay, 1993-1996.

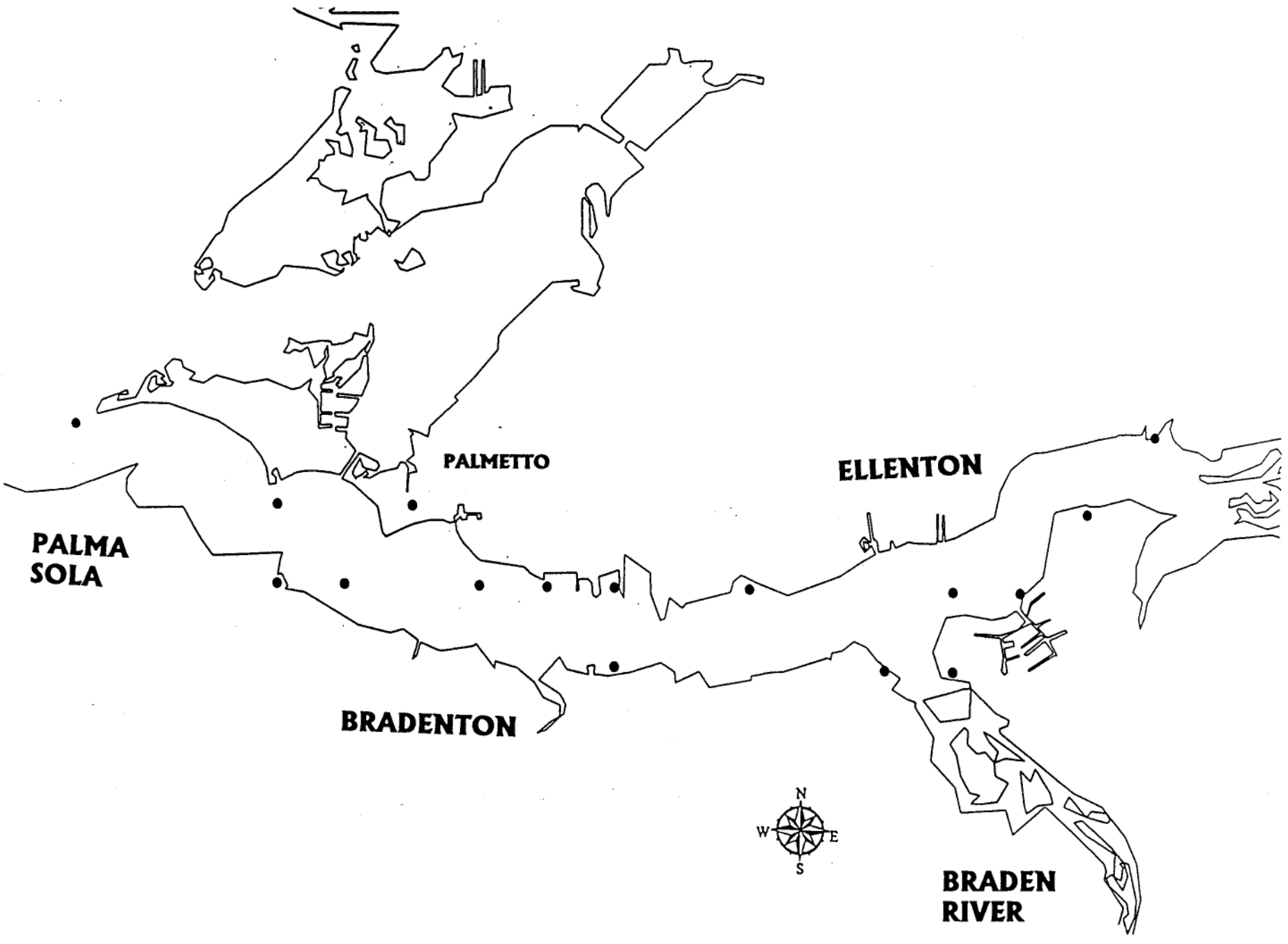

Figure 7. Location of sampling stations in the Manatee River segment of Tampa Bay, 1993-1996.

In practice, data loggers could be deployed at only a small subset of sites in the main stem of Tampa Bay because of a shortage of instruments. Sites were not randomly selected. For example, if near-bottom DO concentrations were < 2 mg/l, instruments were not deployed to avoid poisoning the DO probe. Dataloggers were not generally deployed at adjacent stations. Dataloggers were never deployed on Fridays (to preclude vandalism if left over weekends). In the Manatee River, Terra Ceia Bay, and Boca Ciega Bay segments (only sampled during 1995 and 1996), dataloggers were deployed at virtually all stations.

II.3 DATA ANALYSES: Data were analyzed by bay segment (Figures 1-7). Segment areas were after Lewis & Whitman (1985). Cumulative frequency distributions were plotted and areal extents of "subnominal" (hypoxia: DO < 2 mg/l) and "marginal" DO (> 2 < 4.0mg/l) in near-bottom waters and supersaturation of near-surface waters estimated. Since the effects of winds and tides on DO saturation can be considerable (> 40%; *cf* Kemp & Boynton 1980), and the purpose of presenting such data are to indicate trophic state, "supersaturation" is defined for this report as > 150%of saturation rather than just >100% *(cf.* Rabalais 1992).

Saturation of dissolved oxygen, as a function of temperature and salinity, was calculated by developing a multiple regression equation (Sokal & Rohlf 1982). The data were a subset (covering the ranges of water temperature and salinity in the study area) of those in the nomogram presented in Strickland & Parsons (1972). The resultant equation was:

$$100\%\ \text{Saturation} = 8.147 - 0.029(\text{Salinity}) - 0.094(\text{Temperature})$$

$$[F_{2,24}=572; p < .001; r^2=0.98]$$

Analysis of Variance (ANOVA) (Sokal & Rohlf 1982) was used to test for differences in mean DO by year, relative sample depth (surface [S] *vs.* bottom [B] only), and the interaction of year and relative depth. Multivariate analysis of variance (MANOVA) (Johnson & Wichern 1988) was used to test for differences in mean temperature and salinity (as indicators of water-mass characteristics). All variables were normalized as Ln (n+ 1) prior to ANOVA and MANOVA. Where effects were significant ($p < .05$), in either the

ANOVA or MANOVA, the Bonferroni test was used to determine which means were equal (Sokal & Rohlf 1982).

Justic's (1991) Oxygen Index was computed to assess the trophic state of each bay segment. The Oxygen Index (D) is defined as $(X_s^2 + X_b^2)^{0.5}$ where:

X_s = (saturation of surface waters)-1

X_b = 1-(saturation of bottom waters)

Essentially any deviation from 0 is indicative of eutrophication. In practical terms, oligotrophic marine waters are defined as $D < 0.2$ and eutrophy as $D > 0.4$ (Justic 1991). Examples of water column profiles demonstrating extreme high and low D values are shown in Figure 8.

Justic (pers. comm. 14 April 1997; Appendix A) has cautioned that D may not be appropriate in a shallow, unstratifed estuary such as Tampa Bay. This Index was developed from data collected in coastal waters 15 to 35-m deep, showing marked stratification. In practice it has been used to assess the trophic status of marine, estuarine, and limnetic systems. Justic also cautions that this Index may not be especially useful where DO stratification is absent. However, in this database four of the seven bay segments do show evidence of either temperature or salinity stratification (Table 3 below) and DO stratification was widely observed (Table 4 below). Therefore, Tampa Bay does meet some of the criteria required to apply this Index and it merits evaluation as an assessment tool.

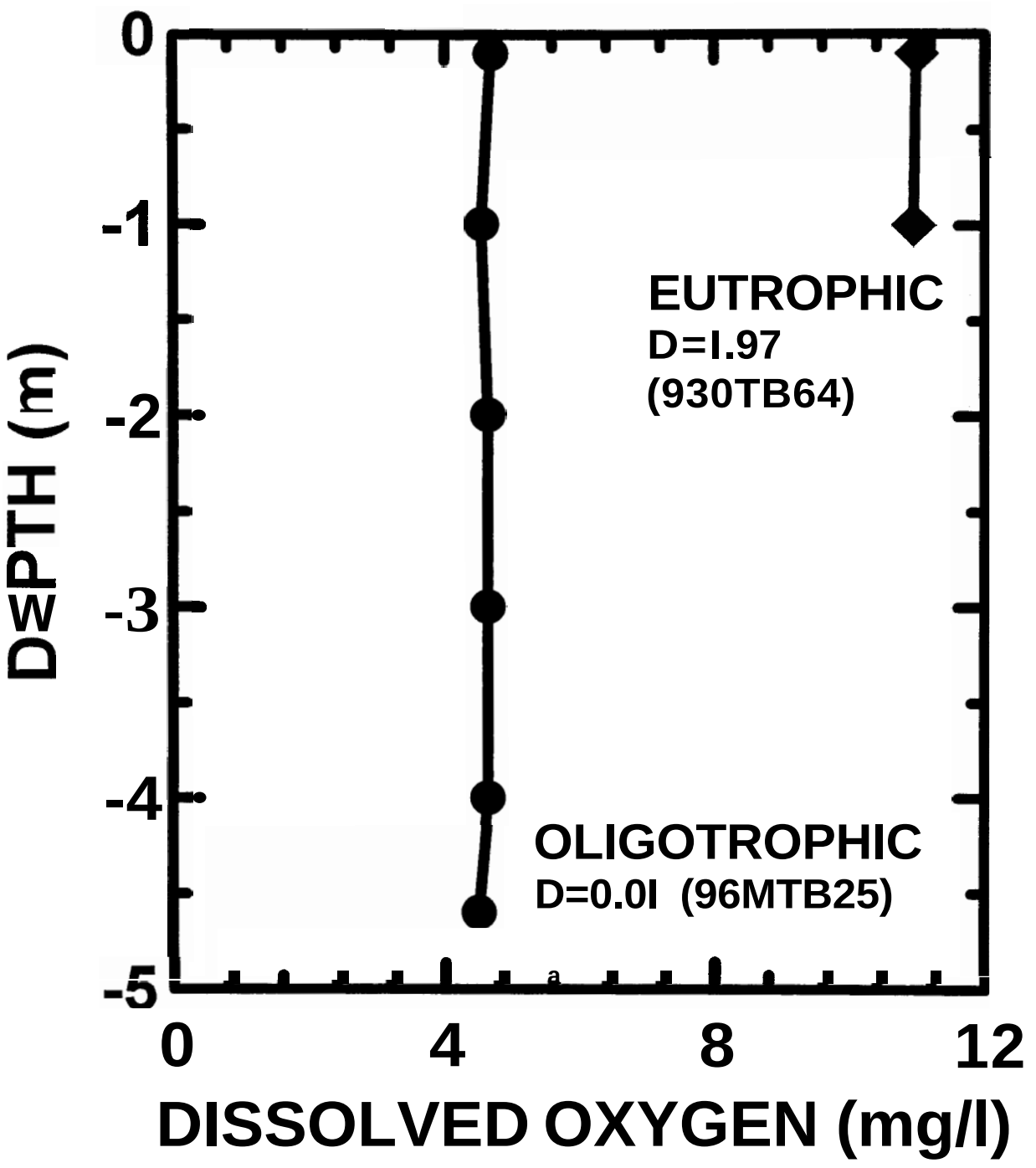

Figure 8. Examples of dissolved oxygen profiles at stations with high and low dissolved oxygen index (D) values. Stations noted in parentheses.

SECTION III
RESULTS

Hydrographic data are summarized, for each of the bay segments and by relative depth (surface and bottom) and year in Appendix B. Appendix C summarizes monthly rainfall amounts for the summer-fall months.

III.1. OLD TAMPA BAY: Mean surface water temperatures were greater than mean bottom temperatures (Table 1; Figure 9). Water-mass characteristics (based upon temperature and salinity) also differed between years (Table 2). Mean temperatures were different between each year and mean salinity was highest in 1993 and lowest in 1995 (Figure 10; Table 1).

Mean DO concentrations differed between years, with concentrations higher in 1993 and 1994 than in 1996 (Table 2). DO was also stratified (S > B). Marginal and subnominal DO concentrations were estimated to cover up to 80% (160 km^2) of this segment's bay bottom during the four year study period; the four-year composite estimate was 23% (46 km^2) (Figure 11). Approximately 4% (7.4 km^2) of this bay segment's bottom waters experienced hypoxia. Old Tampa Bay also showed some evidence of anoxia (DO < 0.2), with two readings of 0.2mg/l. Approximately 20% (43 km^2) of this segment's surface waters were supersaturated (Figure 12).

The mean oxygen index (D) ranged between 0.34 (1995) and 0.76 (1993) over the four year study period. 12% of Old Tampa Bay was considered oligotrophic (D < 0.2) and more than 50% was eutrophic (D > 0.4) (Figure 13).

Diel DO measurements were made at only eight sites over the four year period (Table 3). Only one of these sites had an overnight DO <2mg/l. However, four of these sites had DO minima <4mg/l, with one site experiencing marginal DO for more than nine hours.

Table 1. **MANOVA Summary: Temperature-Salinity by bay segment, year, and relative sample depth (surface *vs.* bottom). Summary of *p* values for univariate and multivariate tests (Wilks' Lambda and Pillai Trace).**

	OTB	HB	MTB	LTB	BCB	TCB	MR
A. Year							
Temperature	***	***	***	***	NS	***	***
Salinity	***	***	***	***	***	***	***
Wilks' Lambda	***	***	***	***	***	***	***
Pillai Trace	***	***	***	***	***	***	***
B. Relative Depth							
Temperature	*	NS	NS	NS	NS	NS	NS
Salinity	NS	*	NS	NS	*	*	*
Wilks' Lambda	**	*	NS	NS	NS	**	NS
Pillai Trace	**	*	NS	NS	NS	**	NS
C. Relative Depth x Year							
Temperature	NS	NS	NS	NS	NS	NS	NS
Salinity	NS	NS	NS	NS	NS	*	NS
Wilks' Lambda	NS	NS	NS	NS	NS	*	NS
Pillai Trace	NS	NS	NS	NS	NS	*	NS

***: p<.001 **: p<.01 *: p<.05 NS: p>.05

Bonferroni tests (underlined means are =)

Temperature: Year
OTB: 1996 > 1994 > 1993 > 1995
HB: 1993 1995 > 1996 1994
MTB: 1996 1993 1995 > 1994
LTB: 1993 1995 > 1994 1996
TCB: 1993 1995 1996 > 1994
MR: 1996 1995 > 1993 1994

Salinity: Year
OTB: 1993 > 1994 1996 > 1995
HB: 1996 1993 1994 > 1995
MTB: 1996 1993 > 1994 > 1995
LTB: 1993 > 1995 > 1996 > 1994
BCB: 1996 > 1995
MR: 1996 1993 1994 > 1995

Salinity: Relative Depth x Year
TCB: 96B 96S 93B 93S > 94B 94S > 95B 95S

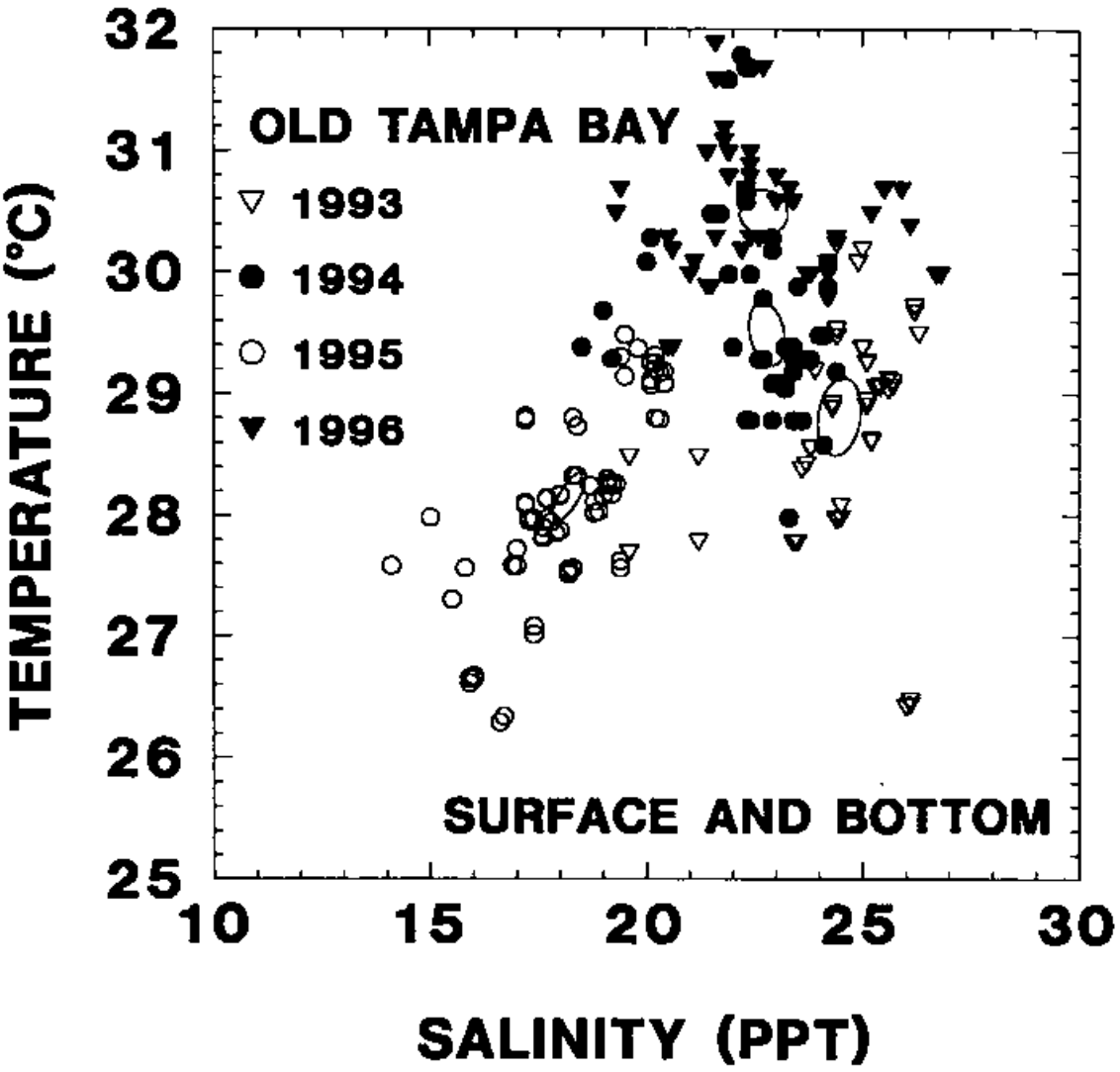

Figure 9. Relationship between temperature and salinity in the Old Tampa Bay segment of Tampa Bay, 1993-1996, by relative depth. Ellipses represent bivariate 95% confidence limits of mean temperature and salinity.

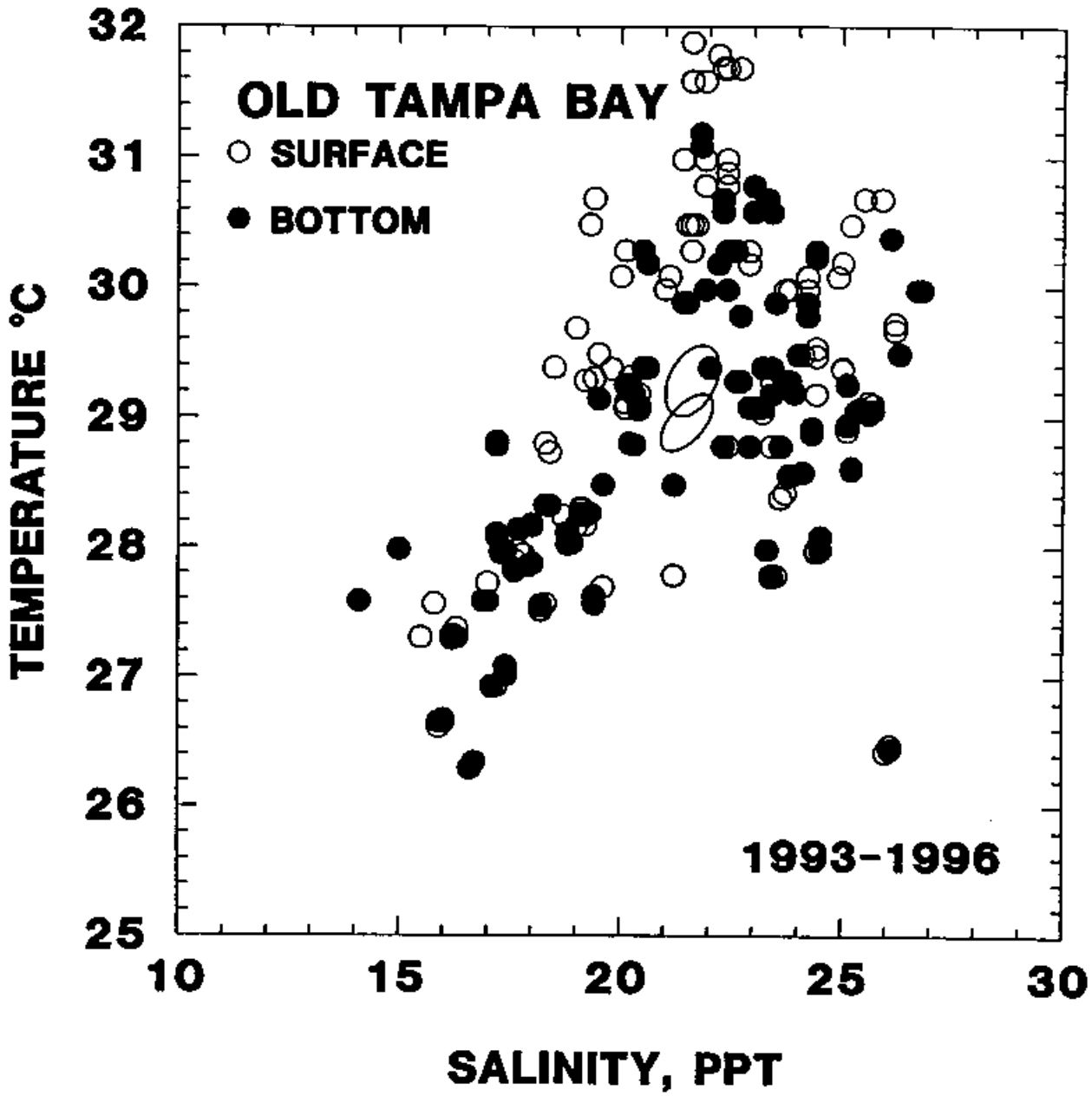

Figure 10. Relationship between temperature and salinity in the Old Tampa Bay segment of Tampa Bay, surface and bottom depths, by year. Ellipses represent bivariate 95% confidence limits of mean temperature and salinity.

Table 2. ANOVA Summary: Dissolved oxygen by bay segment, year, and relative sample depth (surface *vs.* bottom). Summary of *p* values.

	OTB	HB	MTB	LTB	BCB	TCB	MR
Year	***	NS	***	***	*	***	NS
Relative Depth	***	***	**	***	NS	*	***
Year x Relative Depth	NS	*	NS	NS	NS	*	NS

***: p<.001 **: p<.01 *: p<.05 NS: p>.05

Bonferroni tests: Year (underlined means are =)

OTB: 1993 1994 1995 1996

MTB: 1993 1994 > 1996 1995

BCB: 1995 > 1996

LTB: 1996 1995 > 1993 1994

Bonferroni tests: Year x Relative Depth

HB: 94S 93S 95S 96S 96B 95B 94B 93B

TCB: 94S 96B 93S 96S 93B 95S 94B > 95B

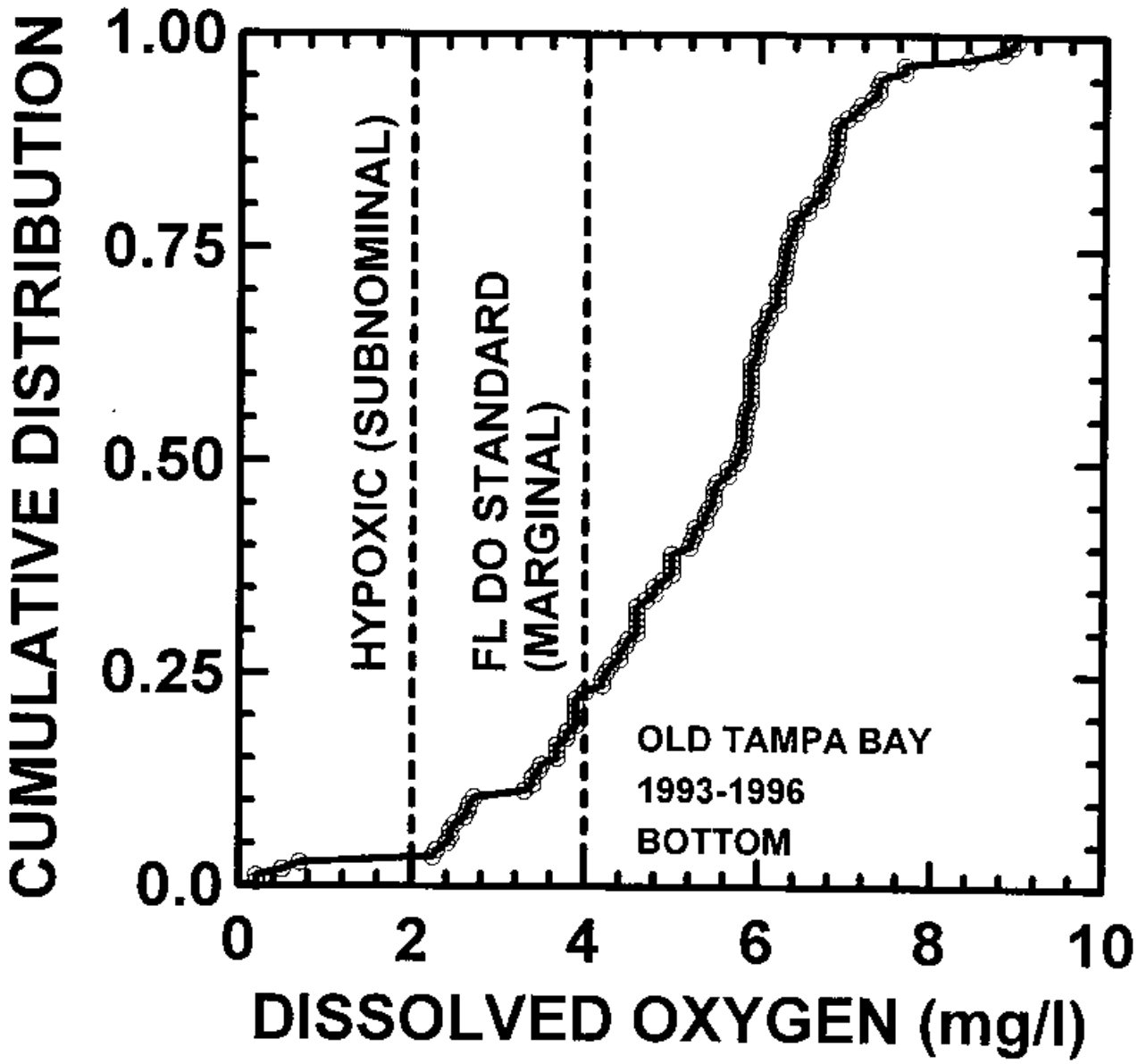

Figure 11. Cumulative frequency distribution of dissolved oxygen concentrations in near-bottom waters of Old Tampa Bay, 1993-1996.

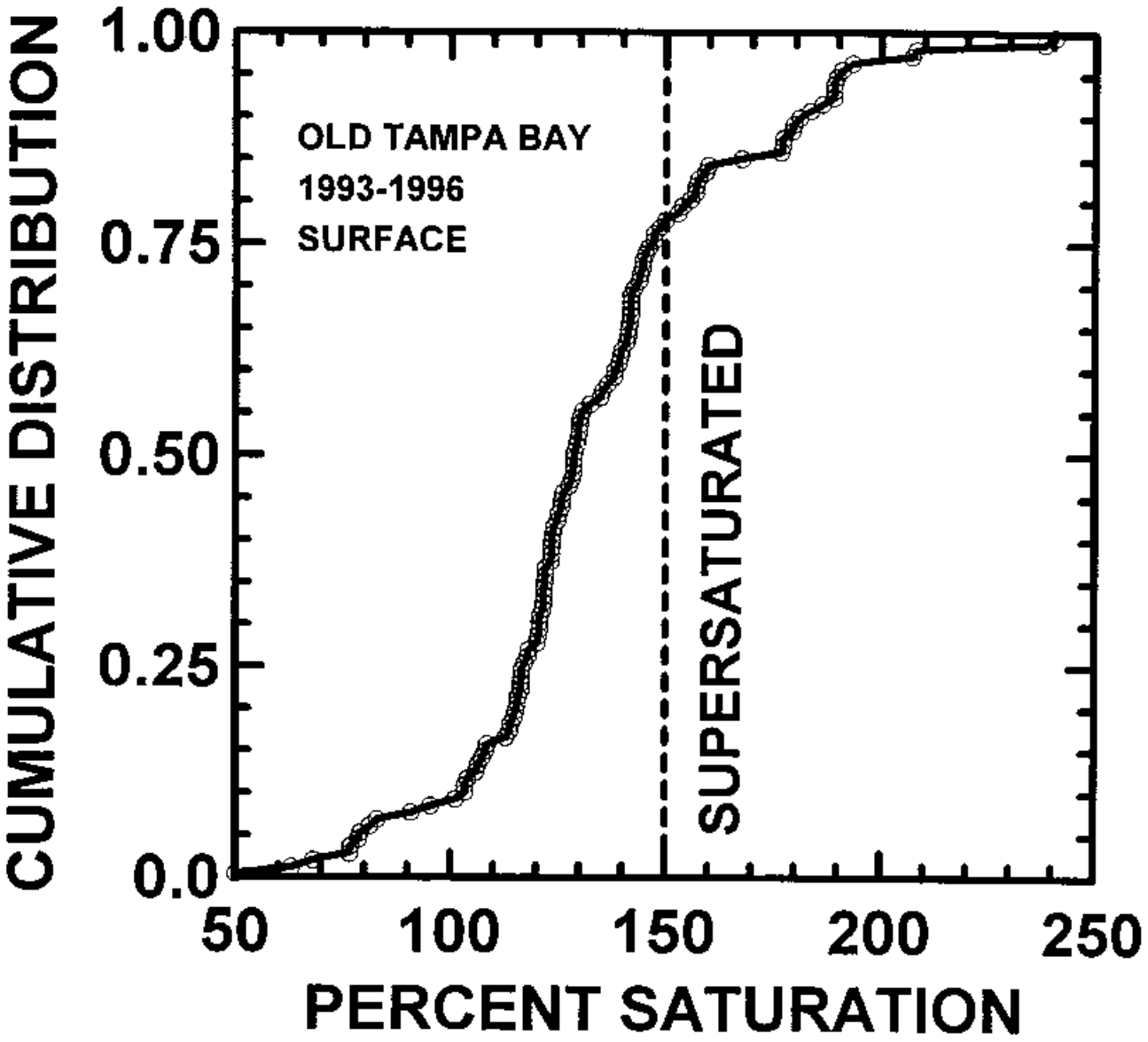

Figure 12. Cumulative frequency distribution of dissolved oxygen saturation in near-surface waters of Old Tampa Bay, 1993-1996.

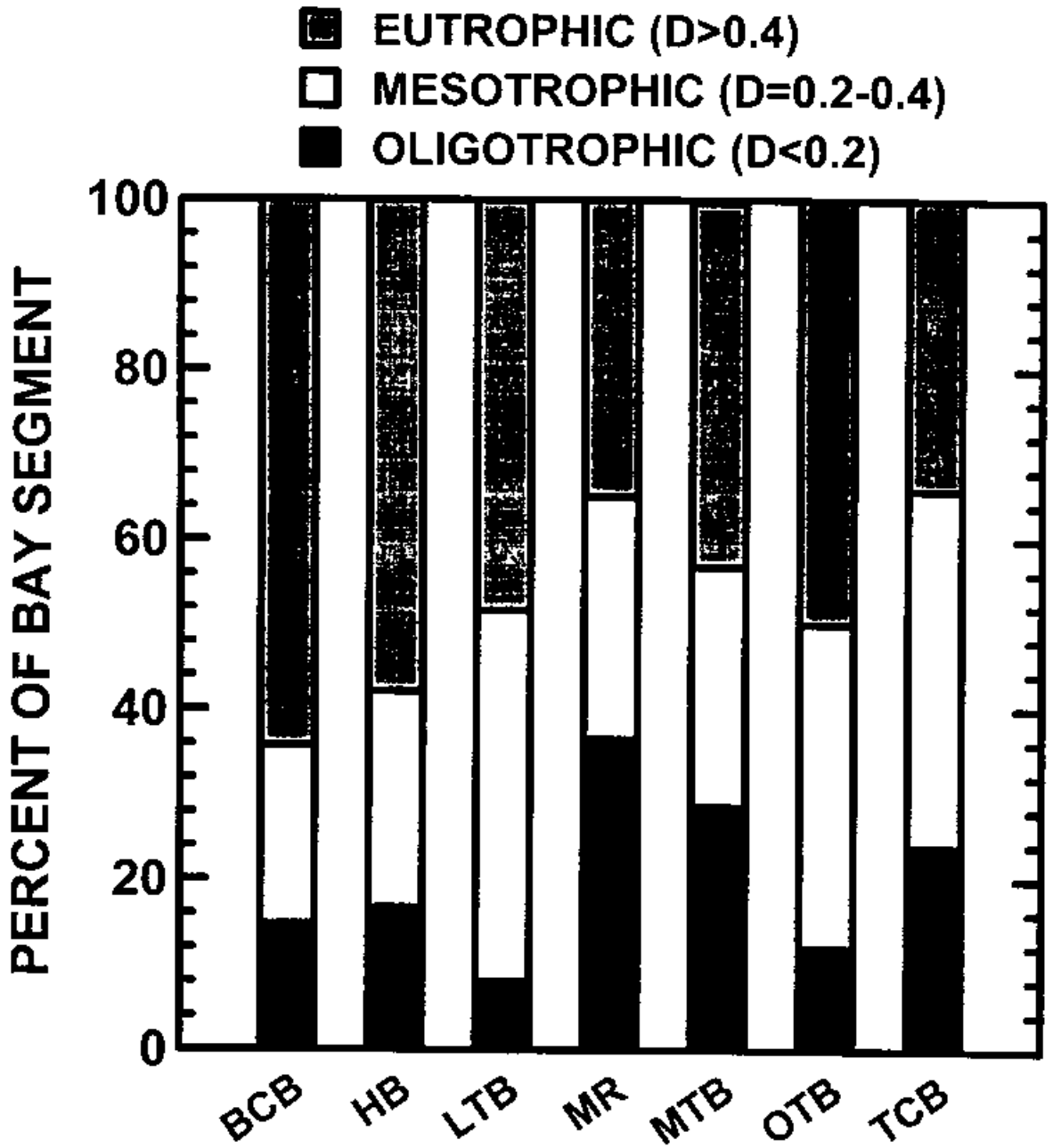

Figure 13. Percentages of bay segments characterized as oligotrophic, mesotrophic, and eutrophic by the dissolved oxygen index (D). Tampa Bay, 1993-1996.

Table 3. Summary of diel dissolved oxygen measurements, by bay segment: minimum DO and duration (hours) of marginal (<4 mg/l) and subnominal (<2 mg/l) DO.

	Station	Minimum DO	Hours <4 mg/l	Hours <2 mg/l
A. Old Tampa Bay				
	93OTB63	2.61	3:30	0
	95OTB07	5.58	0	0
	95OTB17	5.42	0	0
	95OTB18	5.57	0	0
	96OTB07	4.78	0	0
	96OTB13	1.82	1:15	0:45
	96OTB18	2.50	2:30	0
	96OTB19	2.93	>9:15	0
B. Hillsborough Bay				
	95HB08	5.55	0	0
	95HB13	4.29	0	0
	95HB16	0.64	>7:45	>7:15
	95HB37(1)	4.25	0	0
	95HB37(2)	3.63	1:45	0
	95HB40(1)	1.63	>7:45	>3:00
	95HB40(2)	4.91	0	0
	95HB42(1)	2.70	>8:45	0
	95HB42(2)	6.06	0	0
	95HB43(1)	2.97	1:15	0
	95HB43(2)	5.80	0	0
	95HB55	3.65	0:15	0
	96HB29	4.25	0	0
	96HB43	0.21	>12:45	>11:15
	96HB52	1.05	>15:30	>8:45
C. Middle Tampa Bay				
	93MTB48	5.17	0	0
	93MTB52	5.62	0	0
	93MTB57	3.60	1:45	0
	95MTB08	5.35	0	0
	95MTB19	7.04	0	0
	95MTB21	4.39	0	0
	95MTB29	3.70	>4:00	0
	95MTB30	1.42	>4:45	>0:30
	95MTB35	4.89	0	0

Table 3. Continued.

Station	Minimum DO	Hours <4 mg/l	Hours <2 mg/l
C. Middle Tampa Bay (continued)			
96MTB09	1.94	>17:00	>0:30
96MTB12	3.27	>1:15	0
96MTB14	0.85	>15:00	>9:30
96MTB15	4.98	0	0
96MTB17	4.57	0	0
96MTB19	5.24	0	0
96MTB20	0.60	>12:45	1:45
96MTB25	4.75	0	0
96MTB35	5.01	0	0
D. Lower Tampa Bay			
93LTB34	4.25	0	0
93LTB35	5.47	0	0
95LTB01	4.99	0	0
95LTB06	5.07	0	0
95LTB07	4.04	0	0
95LTB13	6.05	0	0
95LTB19	5.42	0	0
95LTB25	6.76	0	0
96LTB01	5.50	0	0
96LTB02	5.26	0	0
96LTB03	1.49	>4:15	>2:30
96LTB04	5.61	0	0
96LTB07	5.26	0	0
96LTB08	4.72	0	0
96LTB09	4.94	0	0
96LTB12	6.50	0	0
96LTB13	2.66	>3:45	0
96LTB15	6.23	0	0
96LTB18	7.13	0	0
96LTB19	7.42	0	0
96LTB20	6.29	0	0
96LTB21	6.18	0	0
96LTB23	6.48	0	0
96LTB24	6.20	0	0
E. Boca Ciega Bay			
95BCB16	1.19	>6:00	>2:30
95BCB17	6.63	0	0
95BCB18	8.73	0	0
95BCB19	7.41	0	0
95BCB20	9.04	0	0

Table 3. Continued.

	Station	Minimum DO	Hours <4 mg/l	Hours <2 mg/l
E. Boca Ciega Bay (continued)				
	96BCB02	4.36	0	0
	96BCB04	1.55	>10:30	1:45
	96BCB07	0.58	>10:00	>4:15
	96BCB08	3.46	>1:45	0
	96BCB12	2.64	>3:45	0
	96BCB13	1.17	>5:30	>1:45
	96BCB15	1.56	>2:30	>0:30
	96BCB19	6.65	0	0
	96BCB24	4.33	0	0
	96BCB26	7.10	0	0
	96BCB27	5.41	0	0
	96BCB30	7.00	0	0
	96BCB31	6.17	0	0
	96BCB34	6.01	0	0
	96BCB36	3.89	1:00	0
	96BCB39	6.48	0	0
	96BCB40a	2.46	>2:00	0
	96BCB40b	6.73	0	0
	96BCB41	7.17	0	0
	96BCB44a	2.22	>5:45	0
	96BCB44b	7.98	0	0
	96BCB46	5.24	0	0
	96BCB49a	2.21	>4:30	0
	96BCB49b	2.66	>3:45	0
F. Terra Ceia Bay				
	93TCB22	5.81	0	0
	93TCB37	3.36	>2	0
	93TCB38	5.87	0	0
	93TCB39	5.62	0	0
	93TCB40	6.29	0	0
	93TCB41	5.60	0	0
	93TCB42	5.38	0	0
	94TCB37	4.80	0	0
	94TCB38	4.33	0	0
	95TCB37	3.96	0:15	0
	95TCB38	4.89	0	0
	96TCB02	4.84	0	0
	96TCB03	5.59	0	0
	96TCB04	4.47	0	0
	96TCB05	4.93	0	0
	96TCB07	5.47	0	0

Table 3. Continued.

	Station	Minimum DO	Hours <4 mg/l	Hours <2 mg/l
G. Manatee River				
	93MR23	5.46	0	0
	93MR24	5.11	0	0
	93MR25	4.59	0	0
	93MR26	4.34	0	0
	93MR27	5.06	0	0
	93MR28	6.01	0	0
	93MR29	5.01	0	0
	93MR31	4.14	0	0
	93MR32	4.46	0	0
	93MR34	4.12	0	0
	93MR43	4.82	0	0
	94MR25	5.17	0	0
	94MR26	5.34	0	0
	94MR31	5.09	0	0
	94MR34	3.56	0:30	0
	94MR43	6.24	0	0
	95MR24	4.81	0	0
	95MR28	4.67	0	0
	95MR29	4.87	0	0
	95MR34	5.09	0	0
	95MR43	5.48	0	0
	96MR09	5.58	0	0
	96MR11	5.86	0	0
	96MR12	5.15	0	0
	96MR13	3.90	0:15	0
	96MR14	4.53	0	0
	96MR16	4.12	0	0
	96MR19	3.19	>8:00	0

(1) & (2) indicates that datasondes were deployed over a 2-day period and each day is treated separately.

III.2. HILLSBOROUGH BAY: There was no evidence of water-column stratification by temperature during the study period, although there was salinity stratification (B>S) (Table 1). Water-mass characteristics did differ between years (Table 1; Figure 14). Mean water temperatures in 1993 and 1995 were higher than in 1996 and 1994. Mean salinities were lowest in 1995, primarily because low salinity sites in the Alafia and Hillsborough Rivers were sampled, which were not sampled in other years.

The interaction between year and relative depth was significant for DO in the Hillsborough Bay segment (Table 2; Figure 15). Surface concentrations were greater than bottom concentrations in each year except 1996 (Table 2; Figure 15). Marginal DO was estimated to affect approximately 23% (24 km^2) of Hillsborough Bay bottom waters over the four-year period; approximately 17% (18 km^2) of this segment was hypoxic (Figure 16). There were also two readings approximating anoxia (0.22 mg/l). More than 25% (26 km^2) of surface waters were supersaturated (Figure 17).

Mean D was 0.55 (eutrophic); only the Boca Ciega Bay segment (see III.5 below) had a higher mean D than the Hillsborough Bay segment. Almost 60% of Hillsborough Bay was classified as eutrophic (Figure 13),

Diel DO monitoring occurred at 11 sites, with three sites monitored over consecutive days in 1995 (Table 3). Seven sites had DO minima C 4 mg/l. At five sites DO < 4 mg/l persisted for more than seven hours. Four sites had DO minima <2 mg/l and the duration of hypoxia exceeded seven hours at three of the four sites.

At three of the four stations sampled over consecutive days (95HB40, 95HB42, and 95HB43) there were marked differences in the DO regimes. On the first of the two days the DO minimum was considerably lower then on day two; marginal and subnominal conditions at two of these locations lasted for more than seven hours on day one. Neither tide nor photoperiod appeared to affect DO at these stations (Appendix D).

III.3. MIDDLE TAMPA BAY: There was no evidence of water column stratification by either temperature or salinity during the study period (Table 1). Water-mass characteristics did differ between years (Table 1; Figure 18). Mean water temperature was lowest in 1994 and mean salinities were highest in 1996 and 1993 (Table 1).

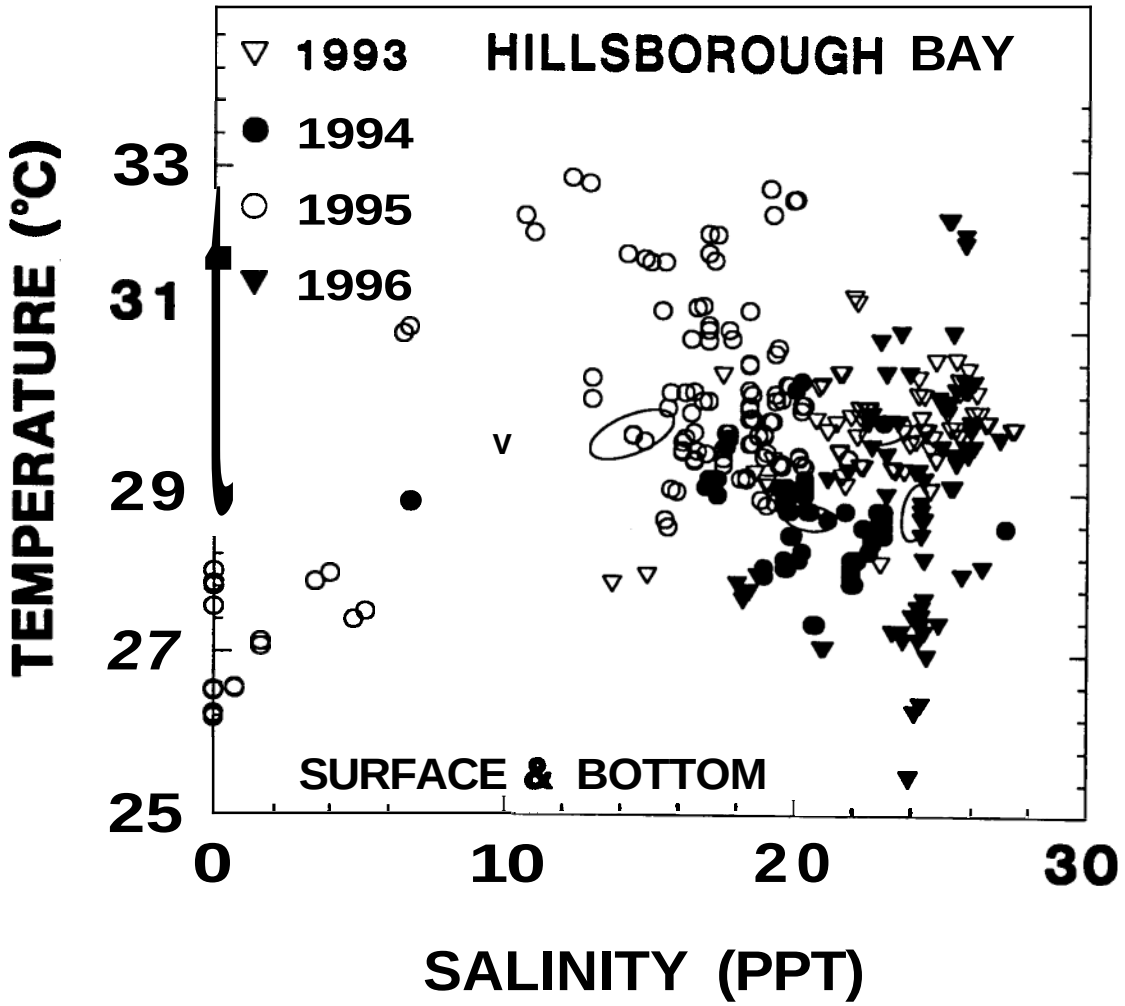

Figure 14. Relationship between temperature and salinity in the Hillsborough Bay segment of Tampa Bay, surface and bottom depths, by year. Ellipses represent bivariate 95% confidence limits of mean temperature and salinity.

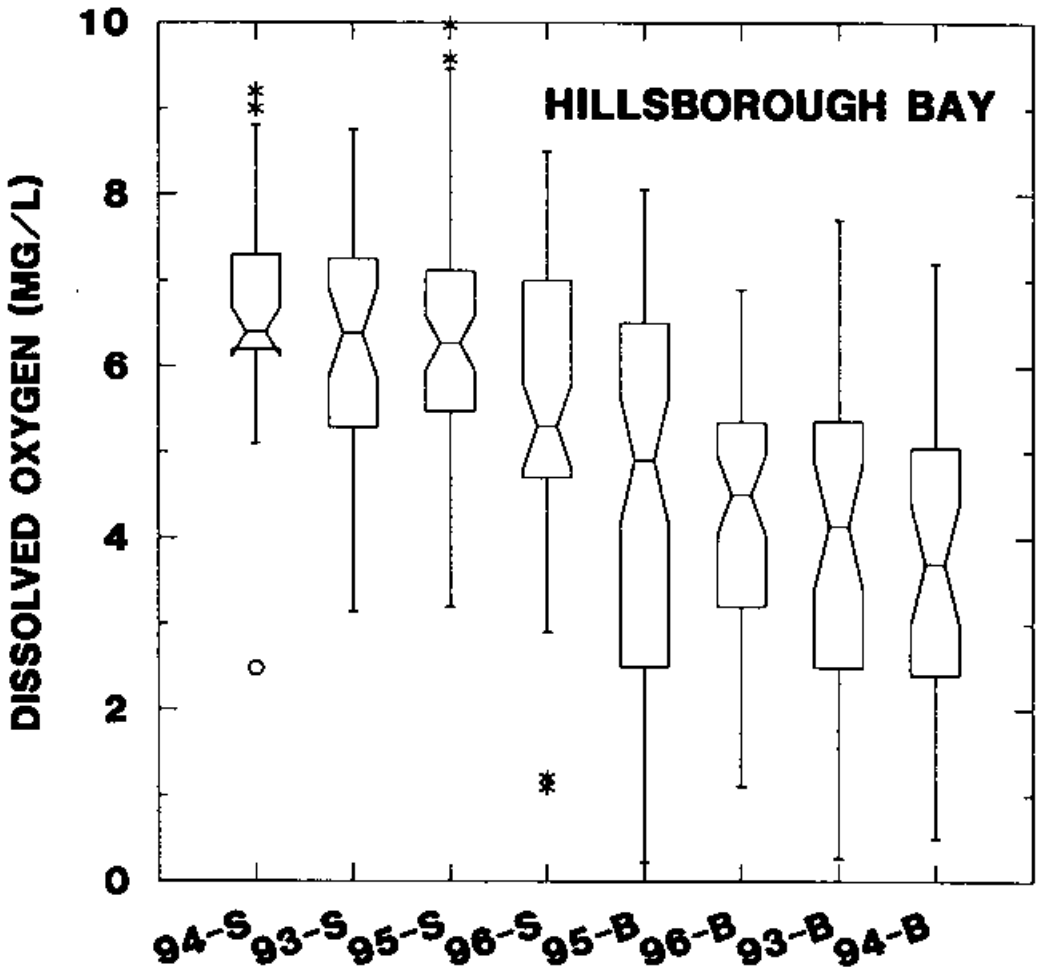

Figure 15. Notched box plot of DO by year and relative depth in Hillsborough Bay, 1993-1996. Horizontal line represents the median; hinges represent the 25% and 75% values.

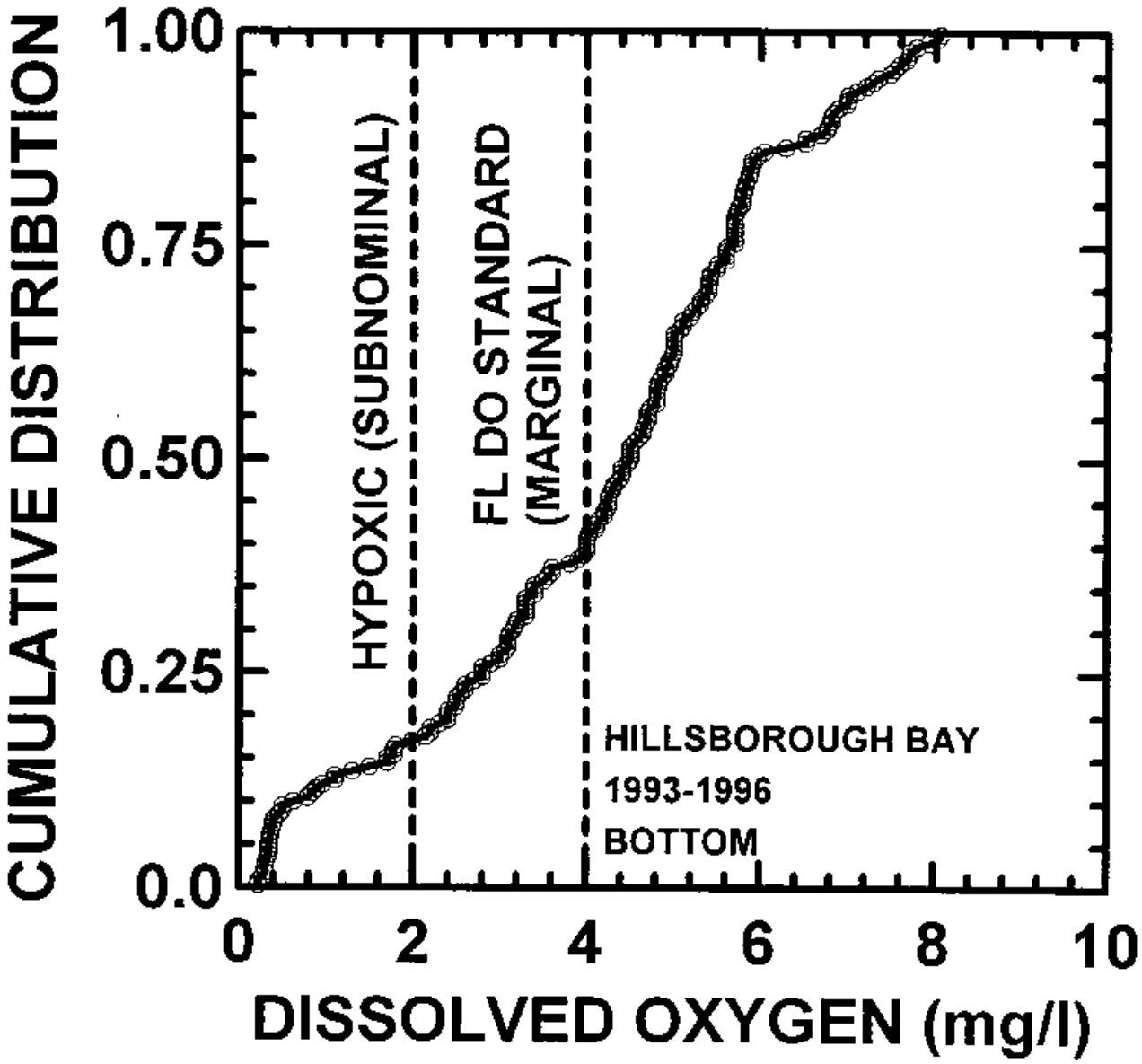

Figure 16. Cumulative frequency distribution of dissolved oxygen concentrations in near-bottom waters of Hillsborough Bay, 1993-1996.

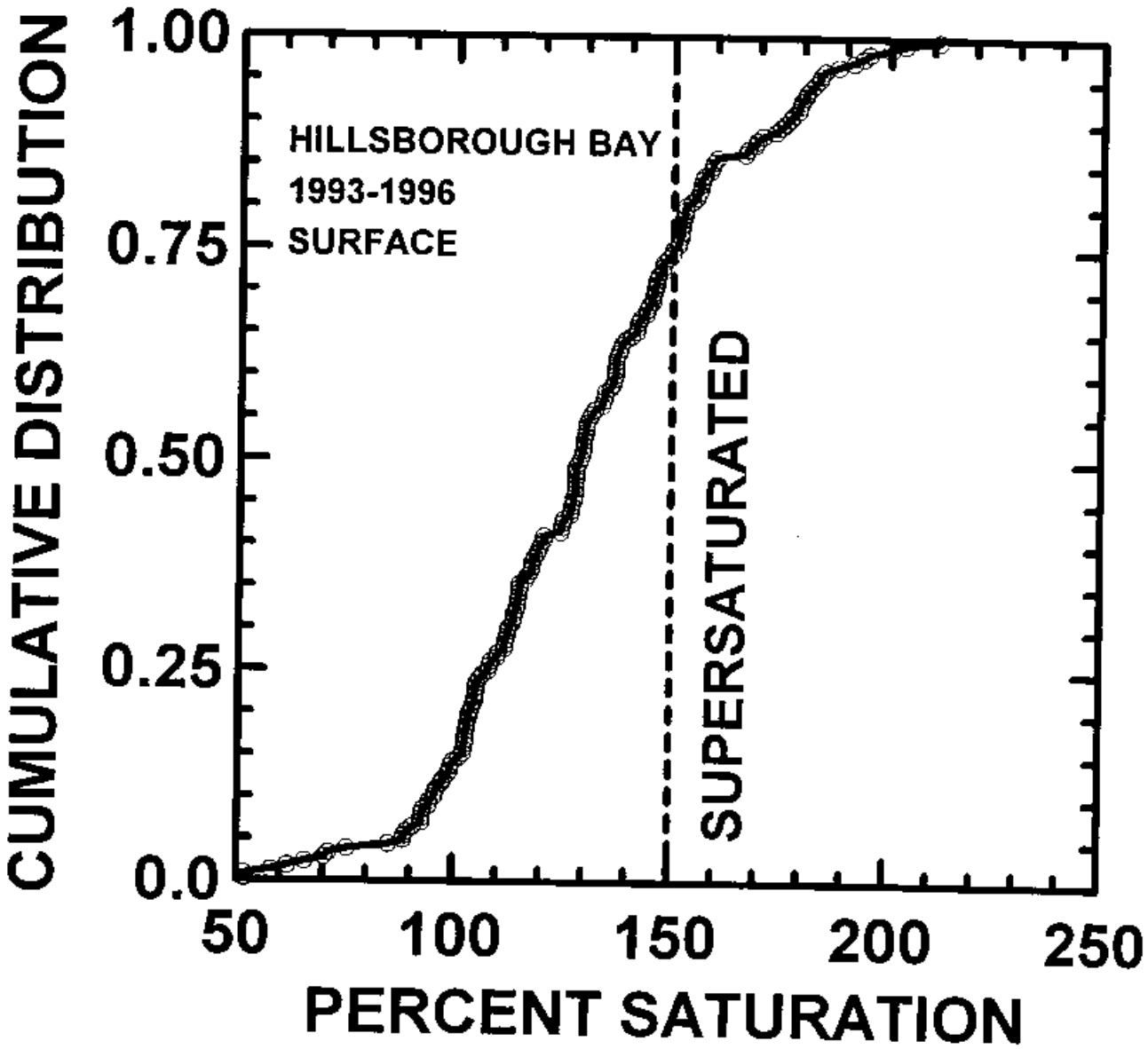

Figure 17. Cumulative frequency distribution of dissolved oxygen saturation in near-surface waters of Hillsborough Bay, 1993-1996.

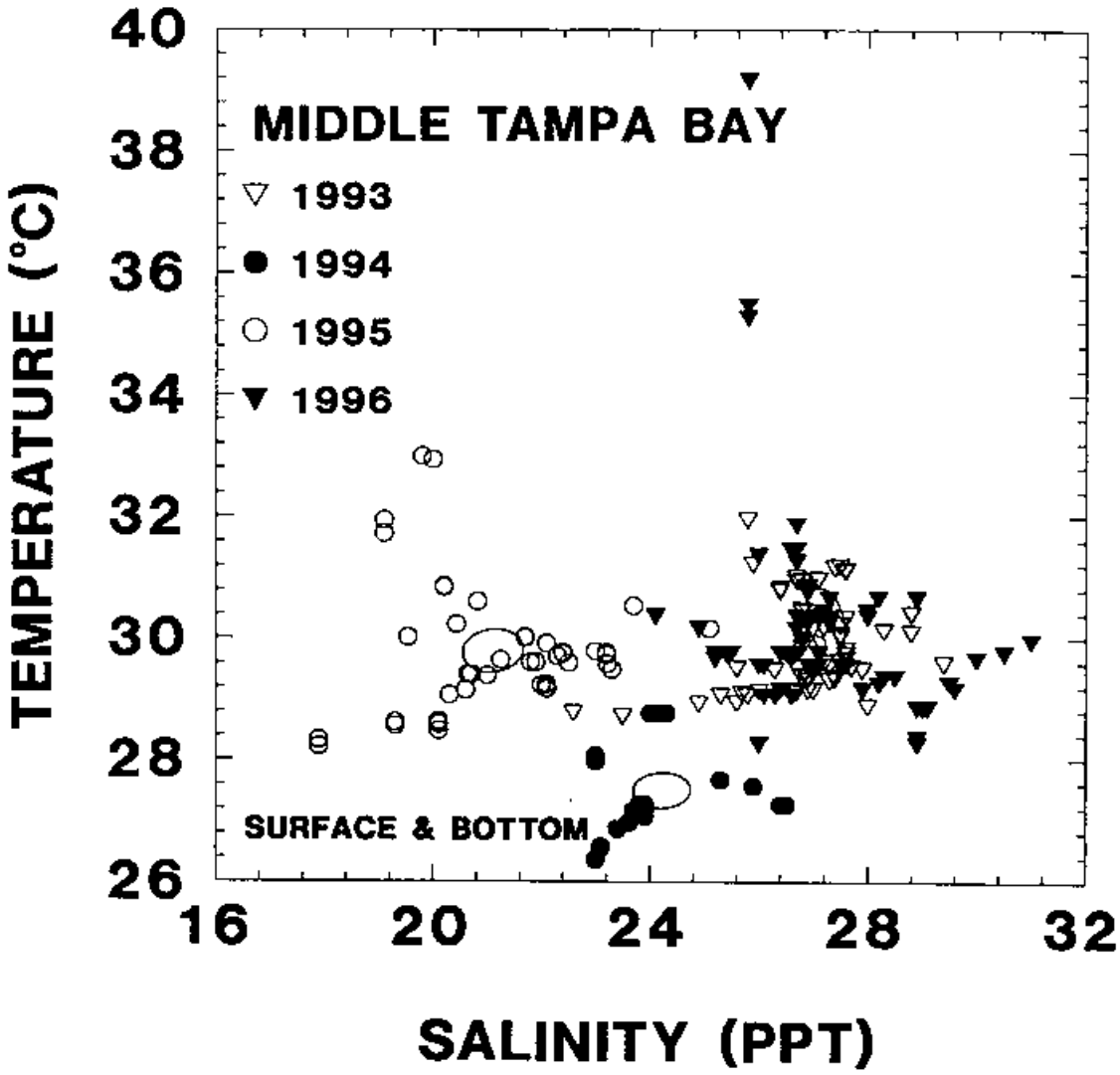

Figure 18. Relationship between temperature and salinity in the Middle Tampa Bay segment of Tampa Bay, surface and bottom depths, by year. Ellipses represent bivariate 95% confidence limits of mean temperature and salinity.

Mean DO differed between years, with concentrations higher in 1993 and 1994 than in 1996 and 1995 (Table 2). DO was also stratified (S>B).

Approximately 10.5%(33.4 km^2) of this segment had marginal DO concentrations over the study period; 1.5%(4.6 km^2) of this segment was subnominal for DO (hypoxic) (Figure 19).

Between 0 and 40% (overall 19% or 57 km^2) of this segment showed evidence of supersaturated surface waters (Figure 20).

Mean D (0.42) indicated that this segment was also eutrophic. Although almost 30% of this segment was oligotrophic, more than 40% was eutrophic (Figure 13).

Diel DO monitoring occurred at 18 sites (Table 3). DO <4mg/l occurred at seven sites, exceeding ten hours duration at three of the sites. Four of these locations were hypoxic, with the duration exceeding nine hours at one of these locations.

III.4. LOWER TAMPA BAY: There was no evidence of water column stratification by either temperature or salinity during the study period (Table 2). Water-mass characteristics did differ between years (Table 2; Figure 21). Mean water temperatures were higher in 1993 and 1995 than in 1994 and 1996. Mean salinity was highest in 1993 and lowest in 1994.

Mean DO differed between years, with concentrations higher in 1996 and 1995 than in 1993 and 1994 (Table 3). DO was also stratified (S>B).

Less than 3% (7 km^2) of this segment was estimated to have marginal DO concentrations in near-bottom waters for the study period (Figure 22). There was no evidence of hypoxia in Lower Tampa Bay. In surface waters, supersaturated conditions affected almost 22%(53 km^2) of this segment (Figure 23).

Based upon the oxygen index (D), 8%of the LTB segment was oligotrophic and 48% was eutrophic (Figure 13); overall, the Lower Tampa Bay segment was eutrophic (D=0.46).

Diel DO monitoring occurred at 20 sites (Table 3). Only two stations had marginal DO for any period of time and one of the sites was hypoxic.

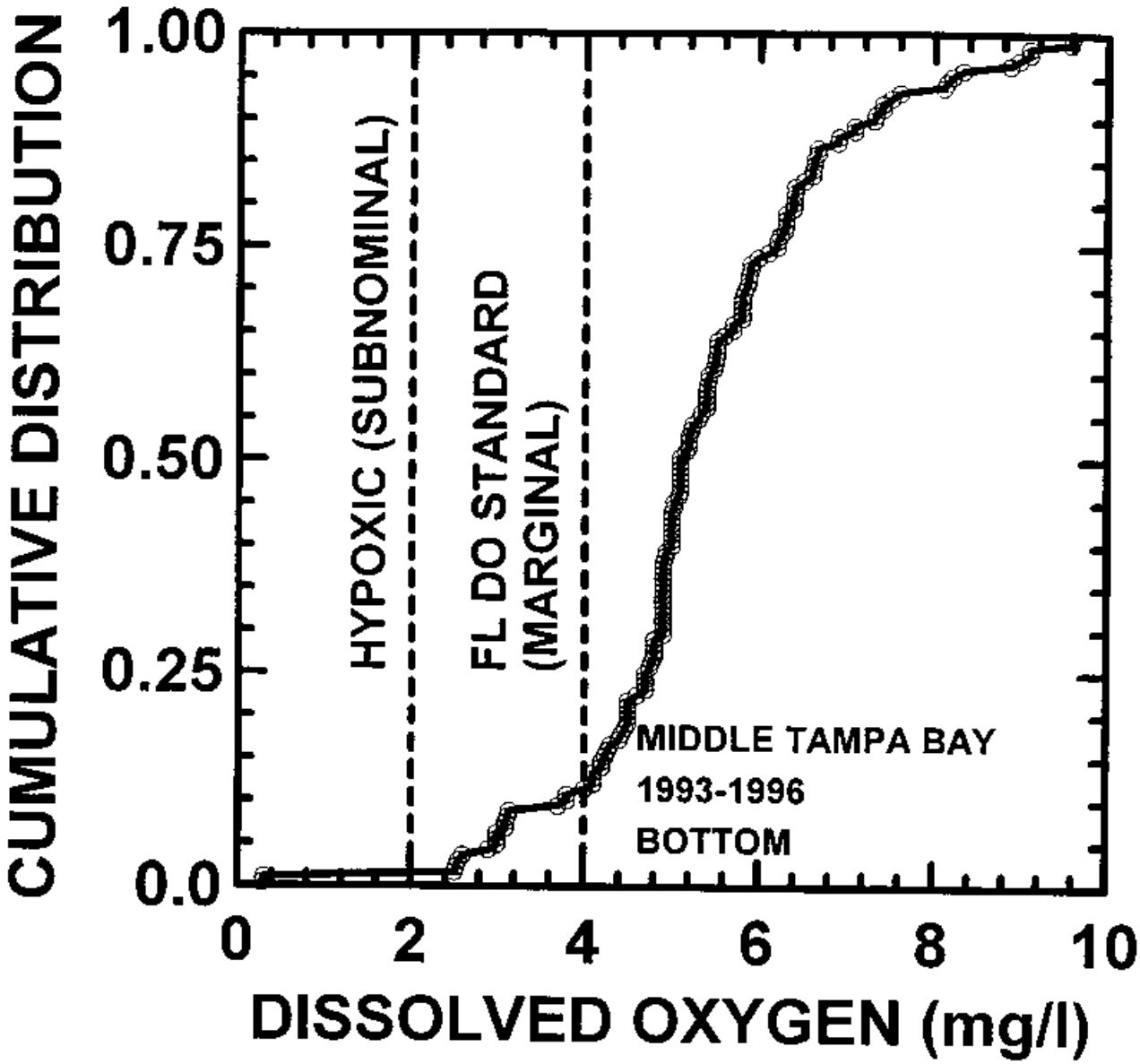

Figure 19. Cumulative frequency distribution of dissolved oxygen concentrations in near-bottom waters of Middle Tampa Bay, 1993-1996.

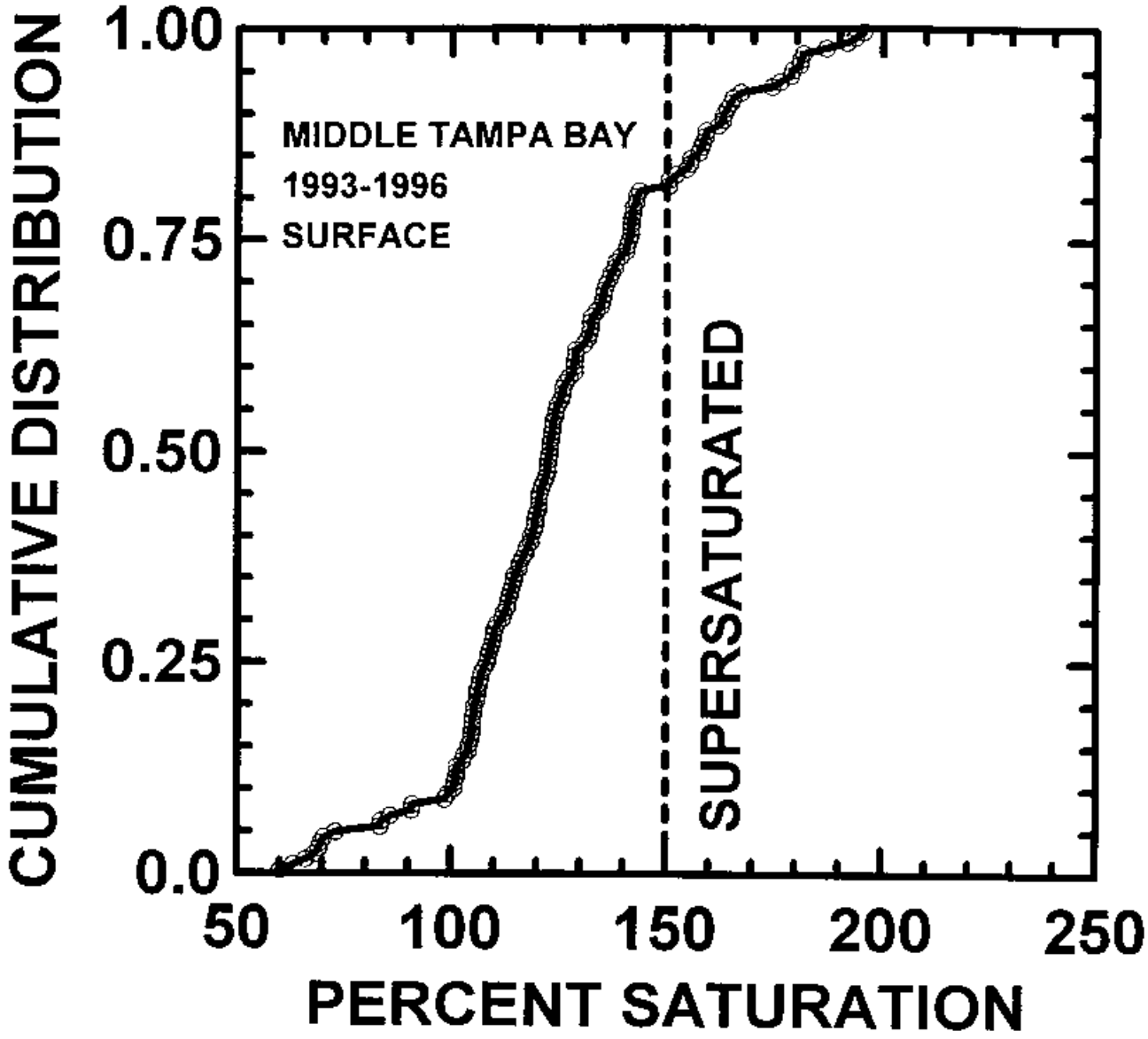

Figure 20. Cumulative frequency distribution of dissolved oxygen saturation in near-surface waters of Middle Tampa Bay, 1993-1996.

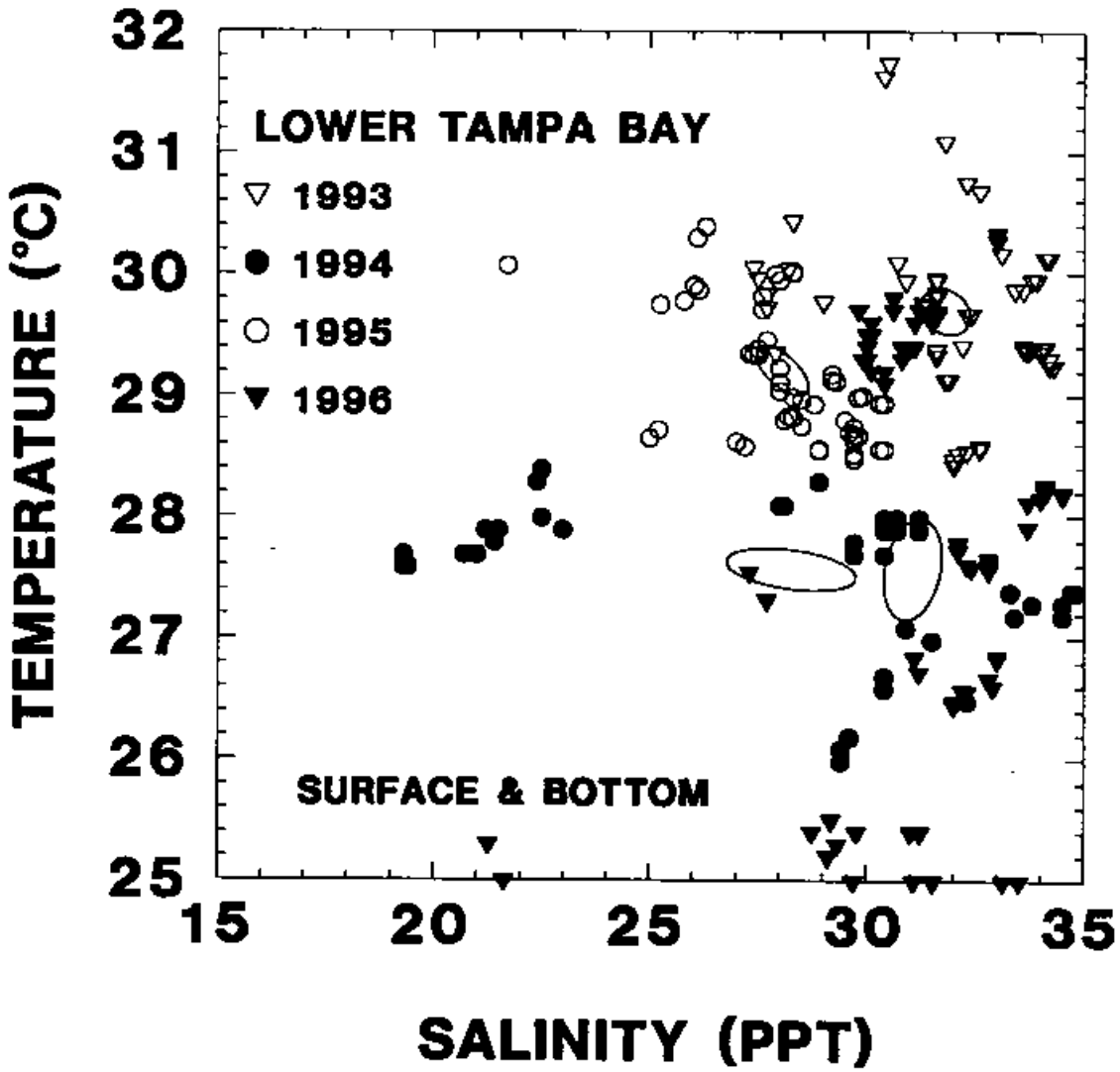

Figure 21. Relationship between temperature and salinity in the Lower Tampa Bay segment of Tampa Bay, surface and bottom depths, by year. Ellipses represent bivariate 95% confidence limits of mean temperature and salinity.

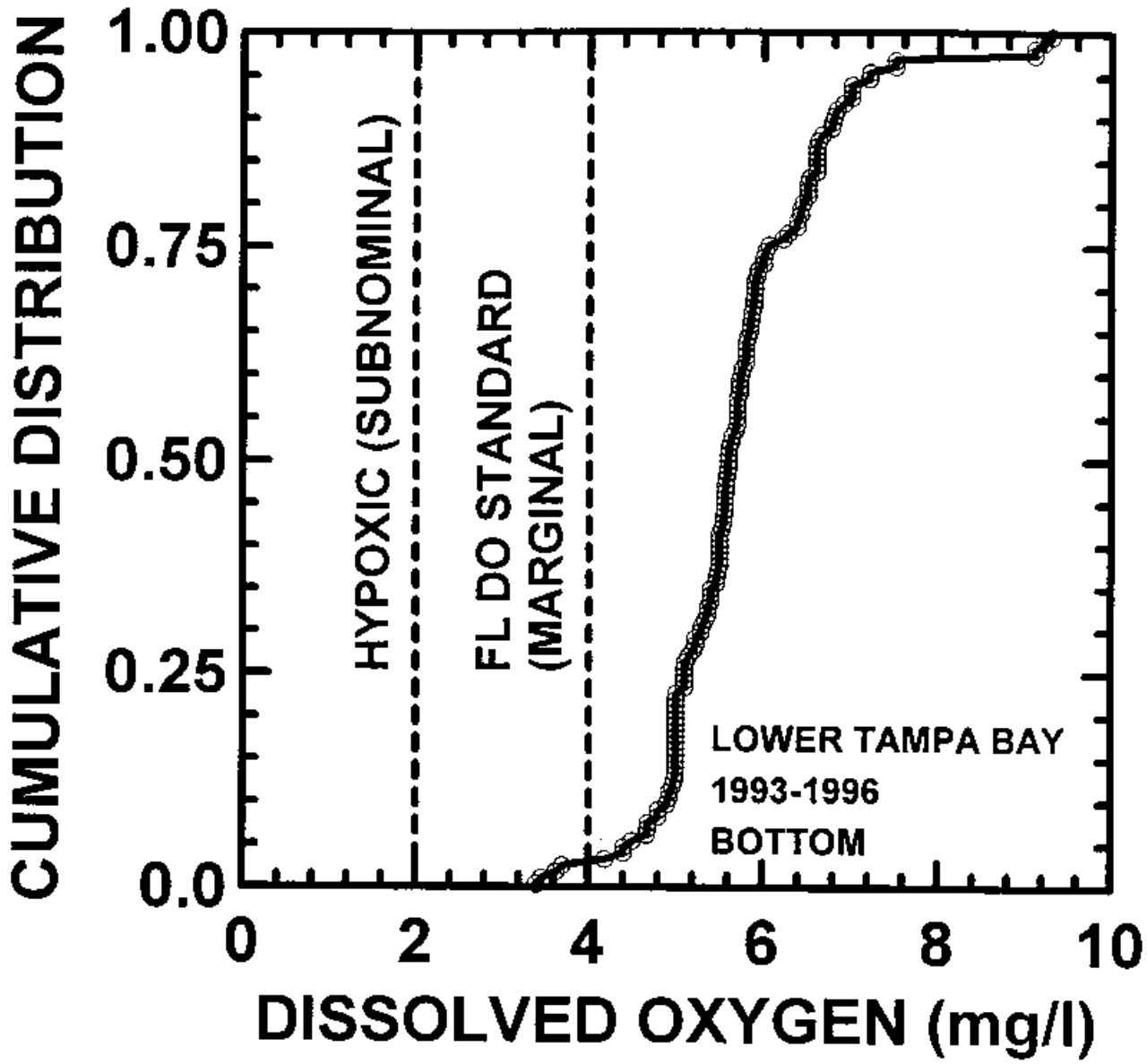

Figure 22. Cumulative frequency distribution of dissolved oxygen concentrations in near-bottom waters of Lower Tampa Bay, 1993-1996.

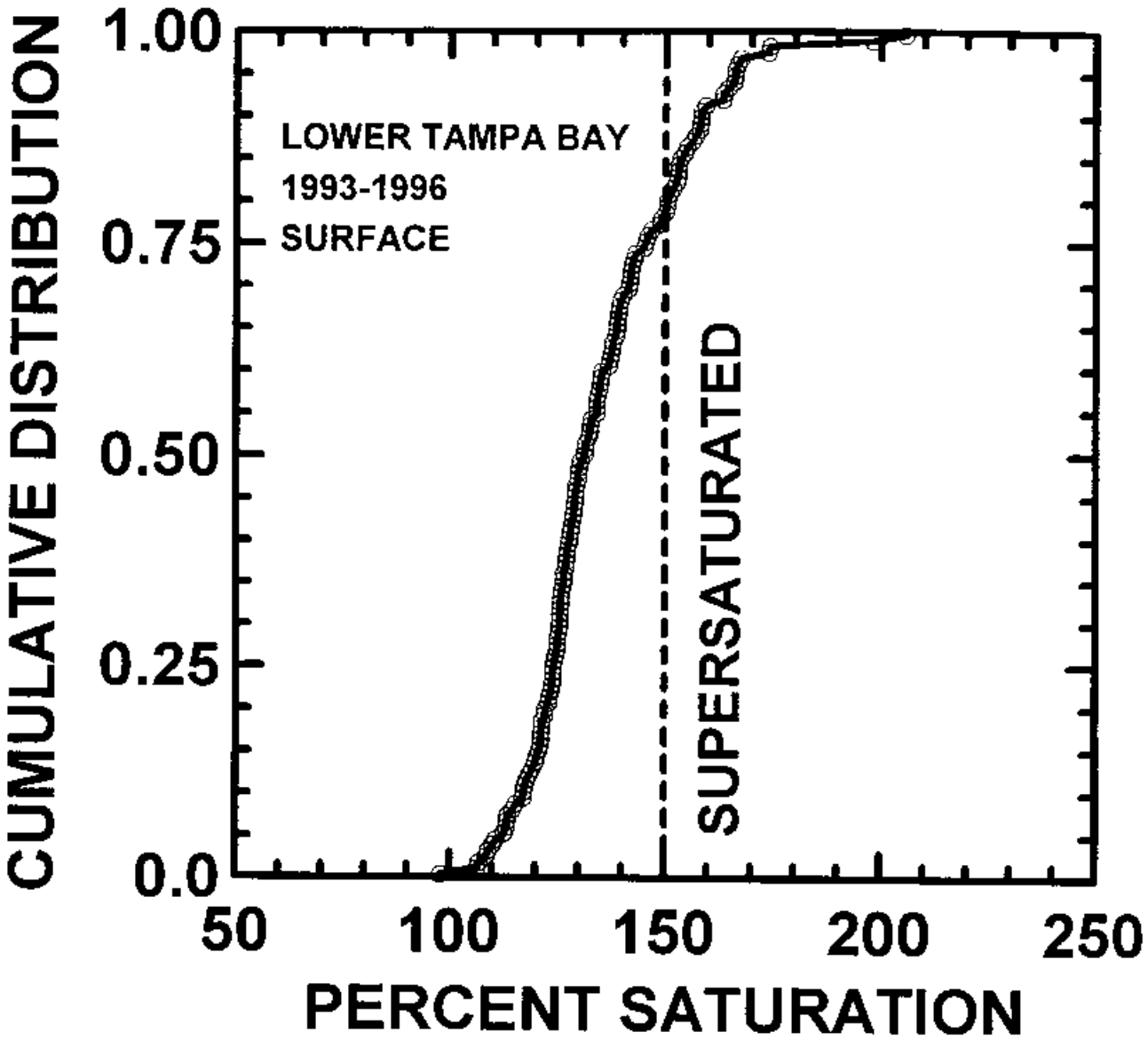

Figure 23. Cumulative frequency distribution of dissolved oxygen saturation in near-surface waters of Lower Tampa Bay, 1993-1996.

III.5. BOCA CIEGA BAY: There was no evidence of water column stratification by temperature and salinity during the two years of study (Table 2). Temperature-salinity characteristics did differ between years because mean salinity was higher in 1996 than in 1995 (Table 2; Figure 24).

Mean DO was higher in 1995 then in 1996 (Table 3). Less than 5% of Boca Ciega Bay was estimated to have marginal DO concentrations (Figure 25). There were no occurrences of hypoxia during either of the years in these daytime samples. Supersaturated conditions were estimated to involve almost 30% of Boca Ciega Bay's surface waters (Figure 26).

Mean D was higher in Boca Ciega Bay (0.56) then in any of the other bay segments. Almost 15% of this segment was oligotrophic and almost two-thirds was eutrophic (Figure 13).

Die1 monitoring occurred at 30 locations (only five sites in 1995). Substandard DO was detected at 12 of these locations, and exceeded 10 hours at two locations. Subnominal conditions were detected at five of these sites, but never lasted more than 4.25 hours (Table 3).

III.6. TERRA CEIA BAY: This bay segment demonstrated differences in water-mass characteristics by relative depth and year (Table 1). The differences were likely due to higher salinities in 1996 and 1993 than in 1994 and 1995 and to lower temperatures in 1995 (Table 2; Figure 27).

The year by relative depth interaction was also significant for DO (Table 2). Surface concentrations were generally higher than bottom concentrations in each year although the only statistically significant difference was that mean bottom DO in 1995 was less than other combinations (Figure 28).

Approximately 8% of Terra Ceia Bay was determined to have marginal bottom DO; there was no evidence of hypoxia during these surveys (Figure 29). Supersaturated conditions were estimated to affect barely 2% of Terra Ceia Bay's surface waters-- the lowest fraction of any of the bay segments (Figure 30).

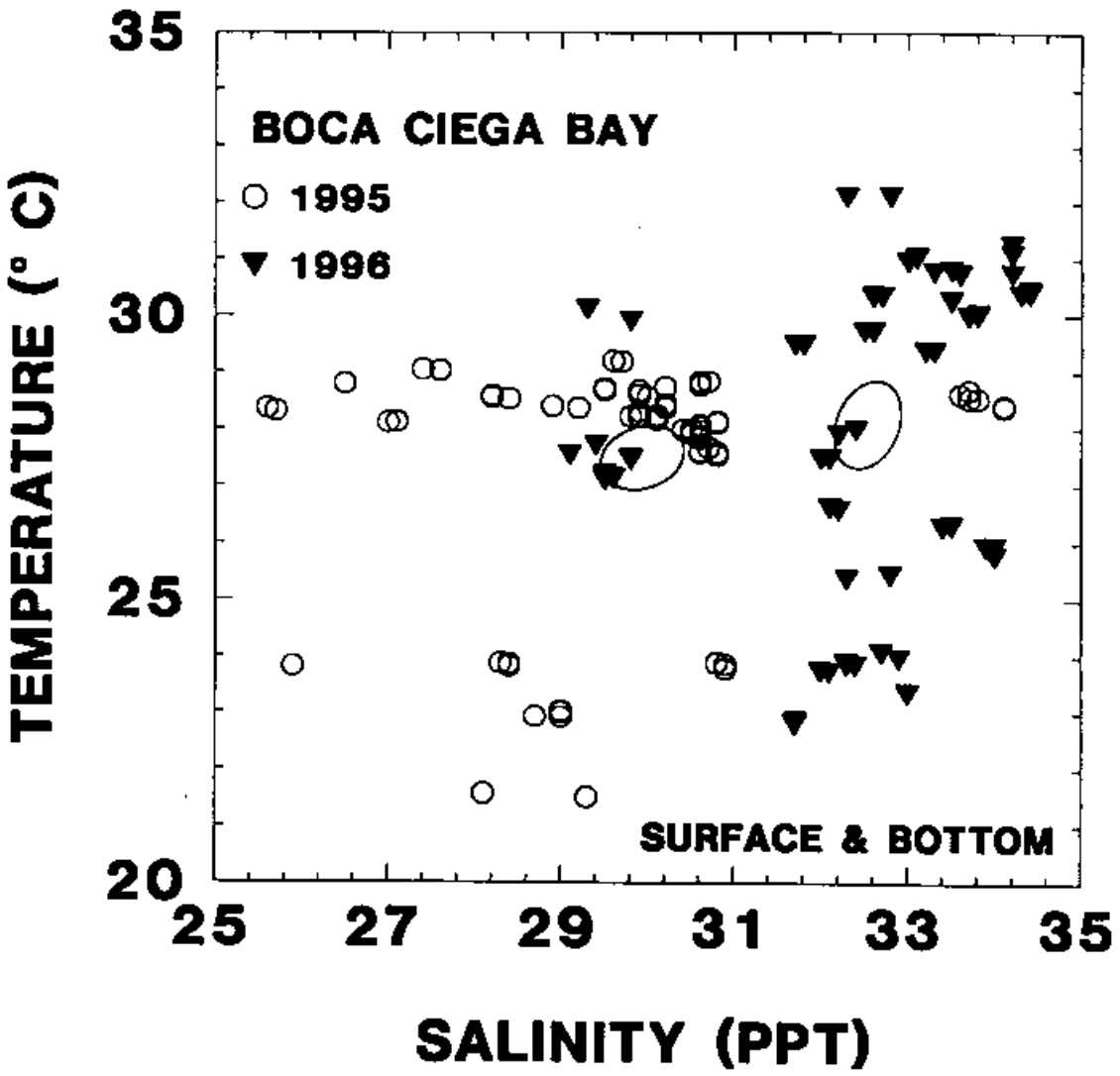

Figure 24. Relationship between temperature and salinity in the Boca Ciega Bay segment of Tampa Bay, surface and bottom depths, by year. Ellipses represent bivariate 95% confidence limits of mean temperature and salinity.

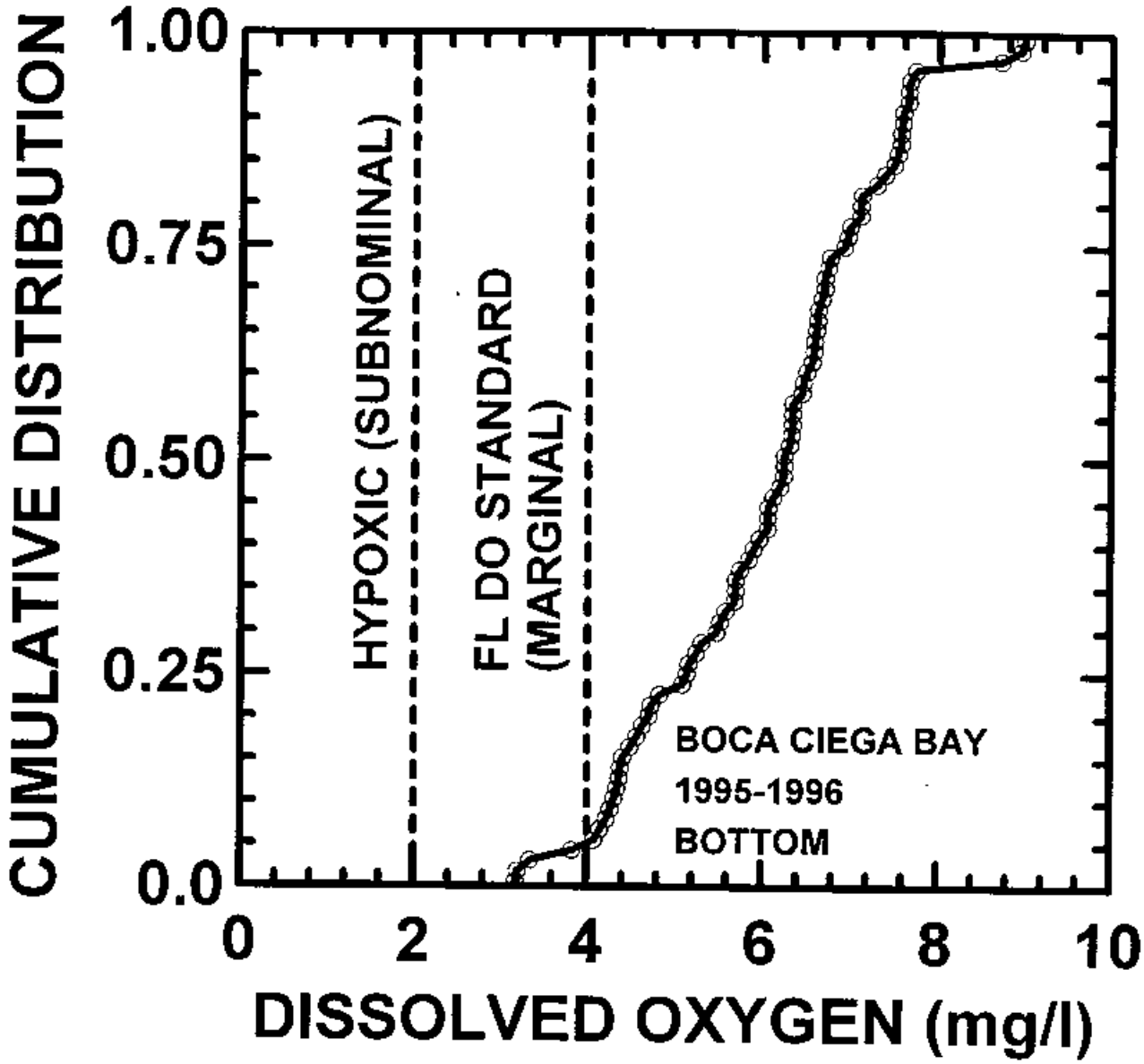

Figure 25. Cumulative frequency distribution of dissolved oxygen concentrations in near-bottom waters of Boca Ciega Bay, 1995-1996.

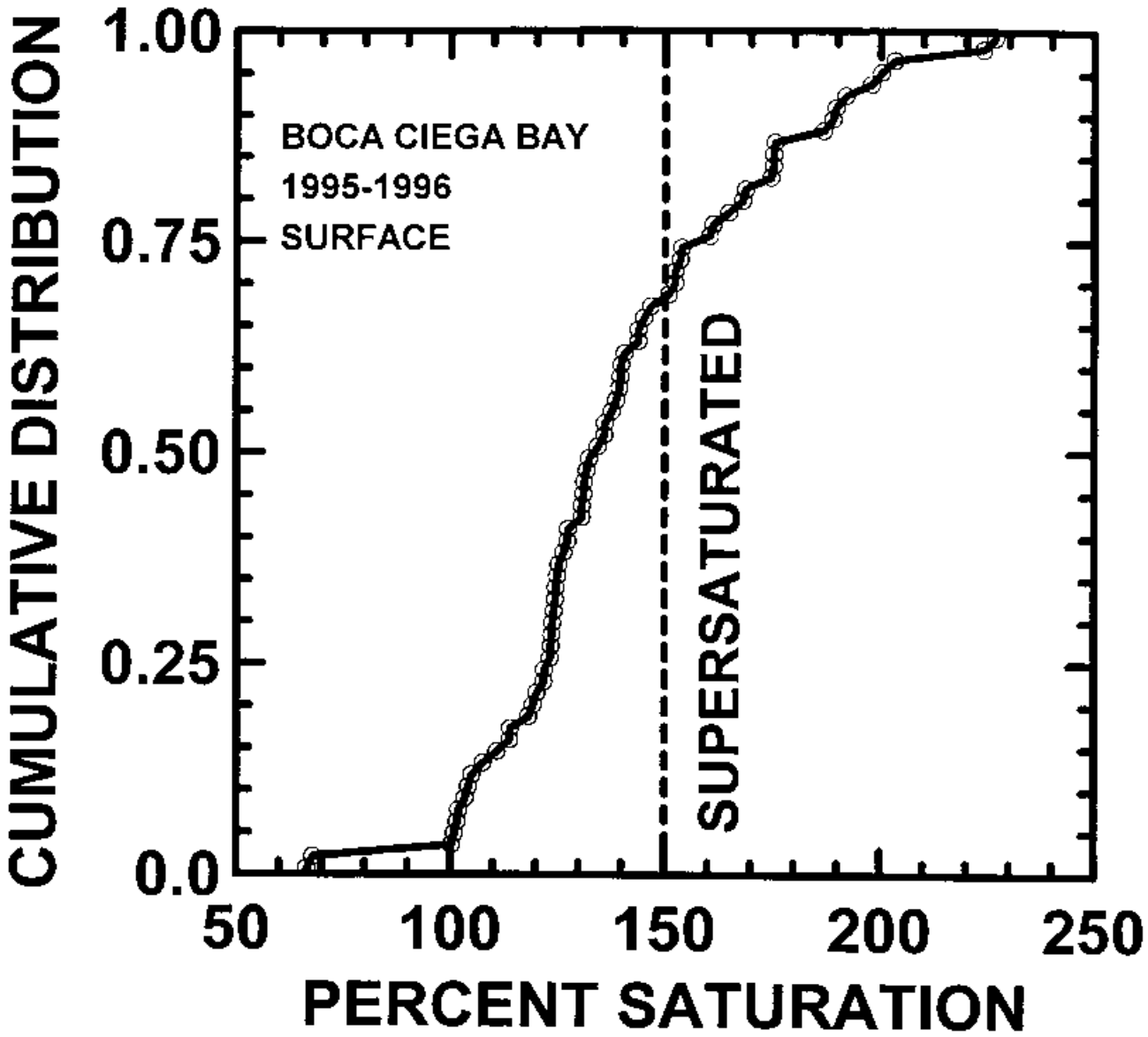

Figure 26. Cumulative frequency distribution of dissolved oxygen saturation in near-surface waters of Boca Ciega Bay, 1995-1996.

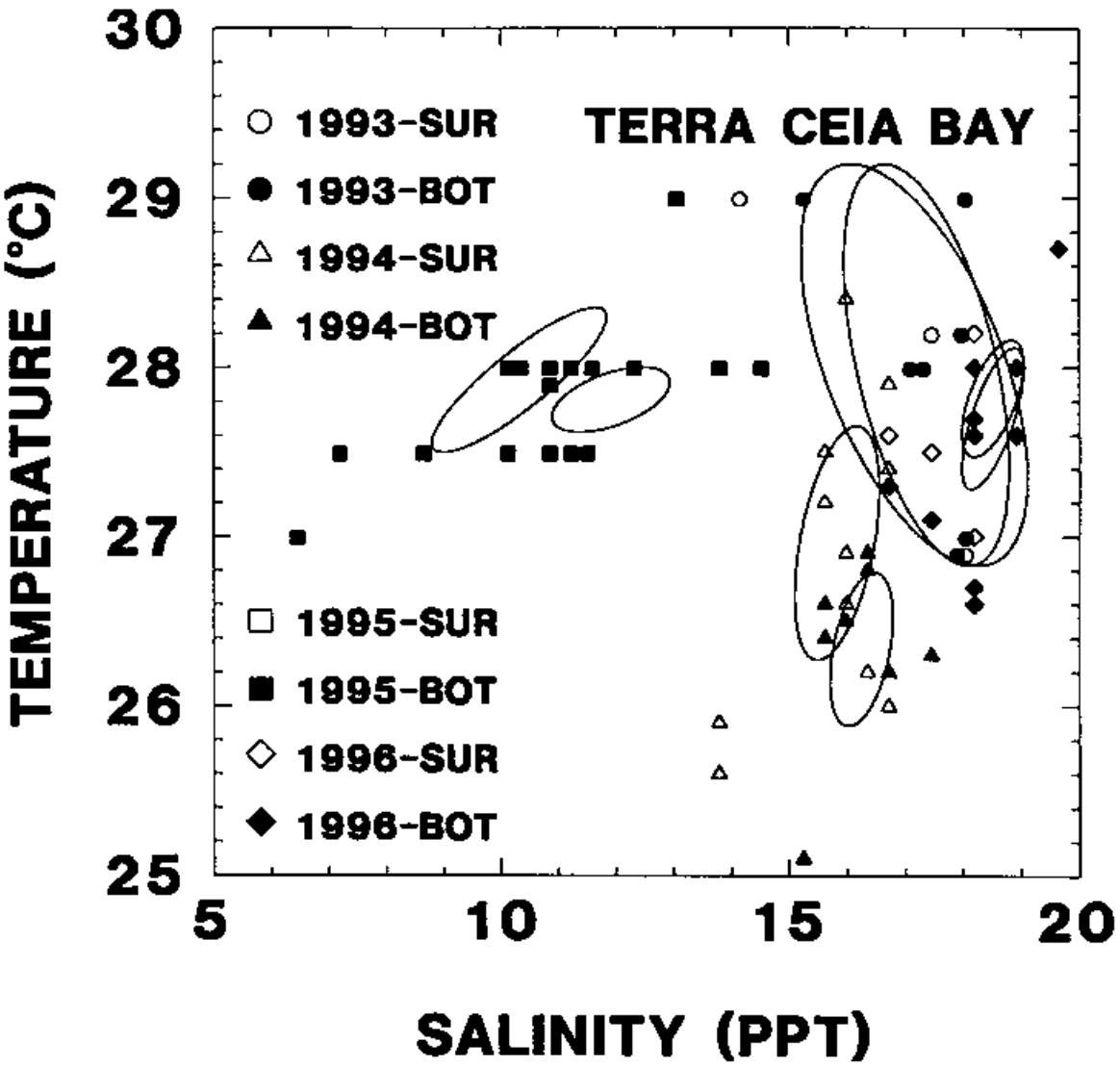

Figure 27. Relationship between temperature and salinity in the Terra Ceia Bay segment of Tampa Bay by relative depth (surface and bottom) and year. Ellipses represent bivariate 95% confidence limits of mean temperature and salinity.

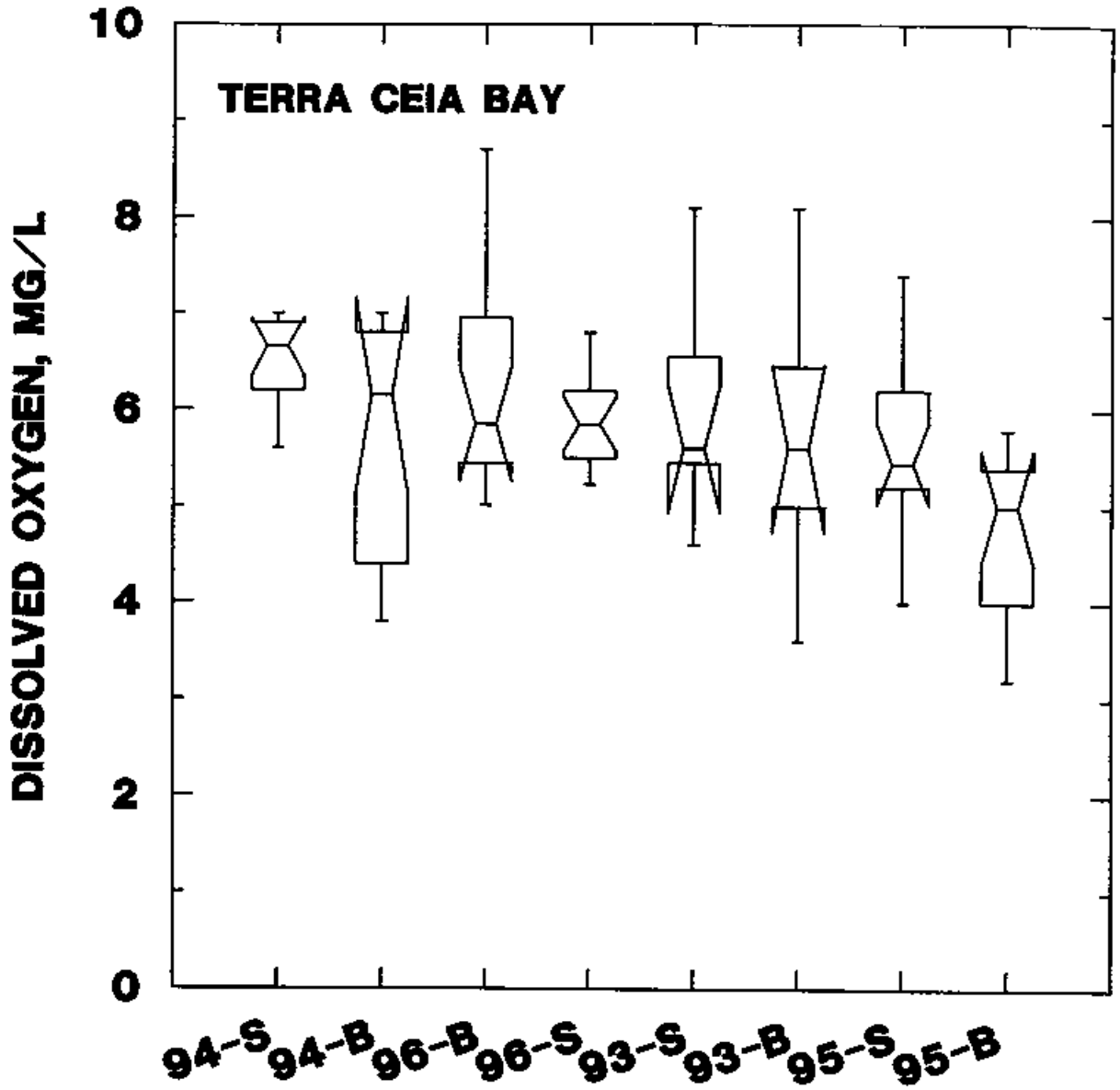

Figure 28. Notched box plot of DO by year and relative depth in the Terra Ceia Bay segment, 1993-1996. Horizontal line represents the median; hinges represent the 25% and 75% values.

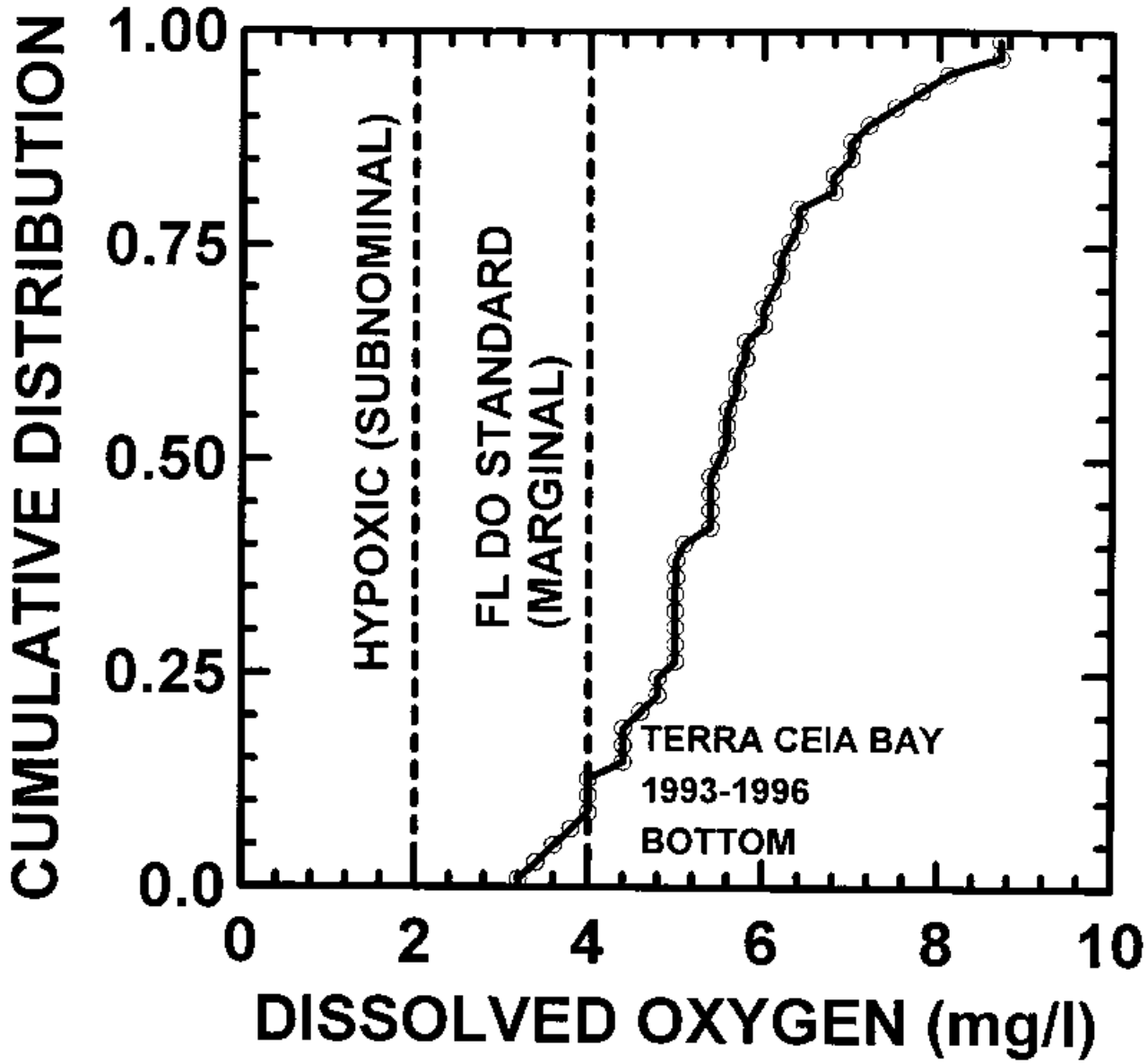

Figure 29. Cumulative frequency distribution of dissolved oxygen concentrations in near-bottom waters of the Terra Ceia Bay segment, 1993-1996.

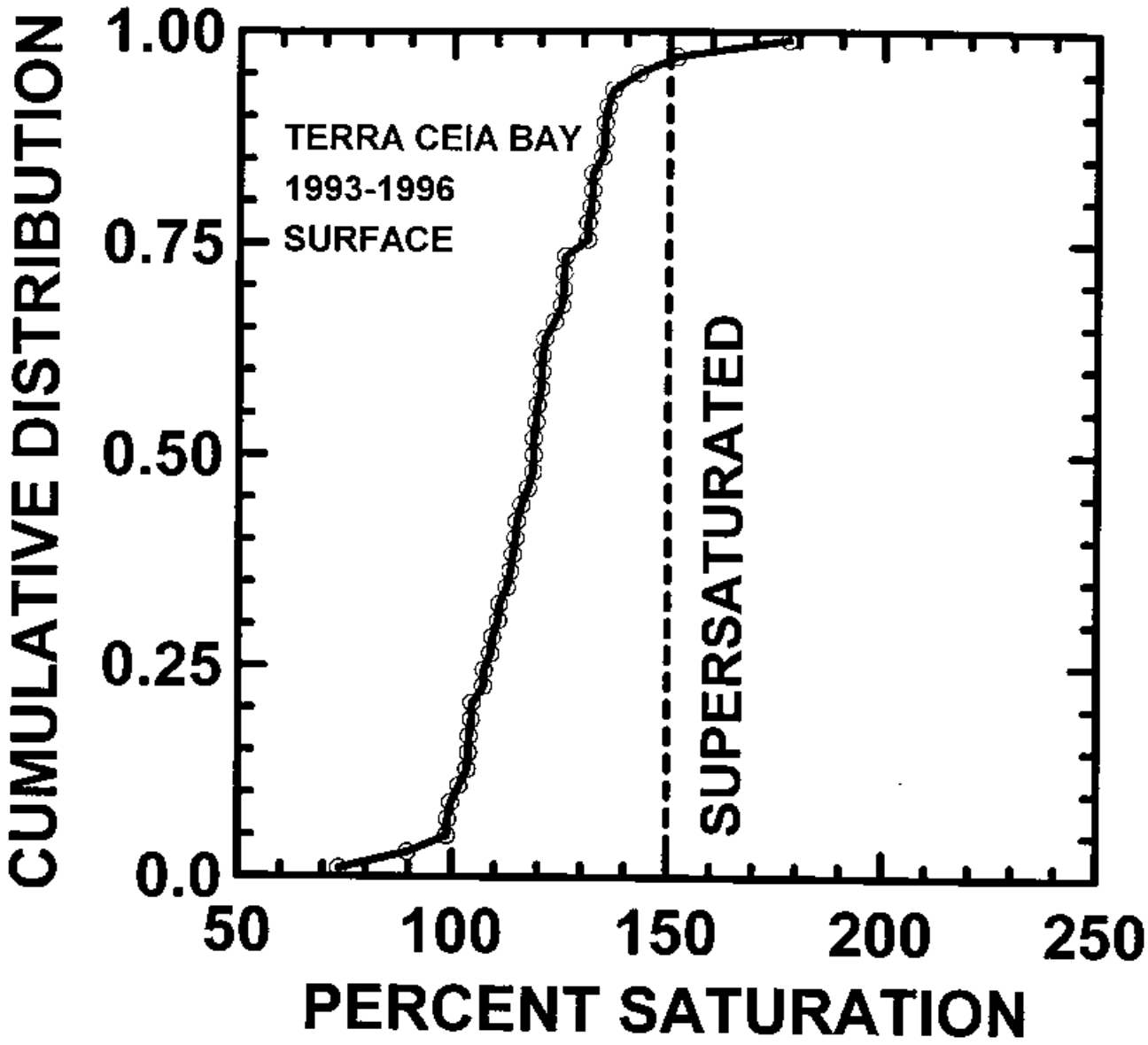

Figure 30. Cumulative frequency distribution of dissolved oxygen saturation in near-surface waters of the Terra Ceia Bay segment, 1993-1996.

Mean D was lower in Terra Ceia Bay (0.37) then in any of the other bay segments, except the Manatee River. Almost 25% of this segment was oligotrophic and only 36% was eutrophic (Figure 13).

Diel monitoring occurred at 16 sites (Table 3). Brief periods (not more than 2 hours) of marginal DO were observed only at Station TCB37 in 1993 and 1995

III.7. MANATEE RIVER: Salinity stratification was evident in this bay segment, but the water-masses did not differ by relative depth (Table 1). There were significant differences in water-mass characteristics between years (Table 1; Figure 31). Water temperatures were warmer in 1996 and 1996 than in 1993 and 1994. Mean salinity was lowest in 1995.

Mean DO differed by relative depth (S > B), but there were no differences between years (Table 2). Marginal DO affected more than 20% (11.5 km^2) of the Manatee River segment (Figure 32); 10% (5.5 km^2) of this segment was hypoxic. Barely 4% (2 km^2) of surface waters in this segment were supersaturated (Figure 33).

Mean D was 0.37--tied with the Terra Ceia Bay segment for the lowest mean D of the seven bay segments. The Manatee River was the only bay segment in which the area defined as oligotrophic exceeded that defined as eutrophic (Figure 13).

Overnight DO data were collected at 28 sites (Table 3). Three sites had DO minima which fell into the "marginal" range. Only at Station 96MR19 was this condition pervasive (> 8 hours).

III.8. SYNTHESIS: These data indicate that, overall, almost 12% of Tampa Bay showed evidence of marginal DO and 3.4% of the bay had subnominal DO *(i.e.,* hypoxic) (Table 4). The area impaired by supersaturated surface waters exceeded 200 km^2 (20.6% of the bay). Based on the dissolved oxygen index (D), eutrophic waters occupied 230% of the area occupied by oligotrophic waters (Table 4). The ratio of eutrophic to oligotrophic area was greater in Lower Tampa Bay (6:1) then in bay segments considered more impaired by other DO measures: *e.g.* ,Old Tampa Bay (4.3:l), Hillsborough Bay (3.5:1) and Boca Ciega Bay (3.8:l).

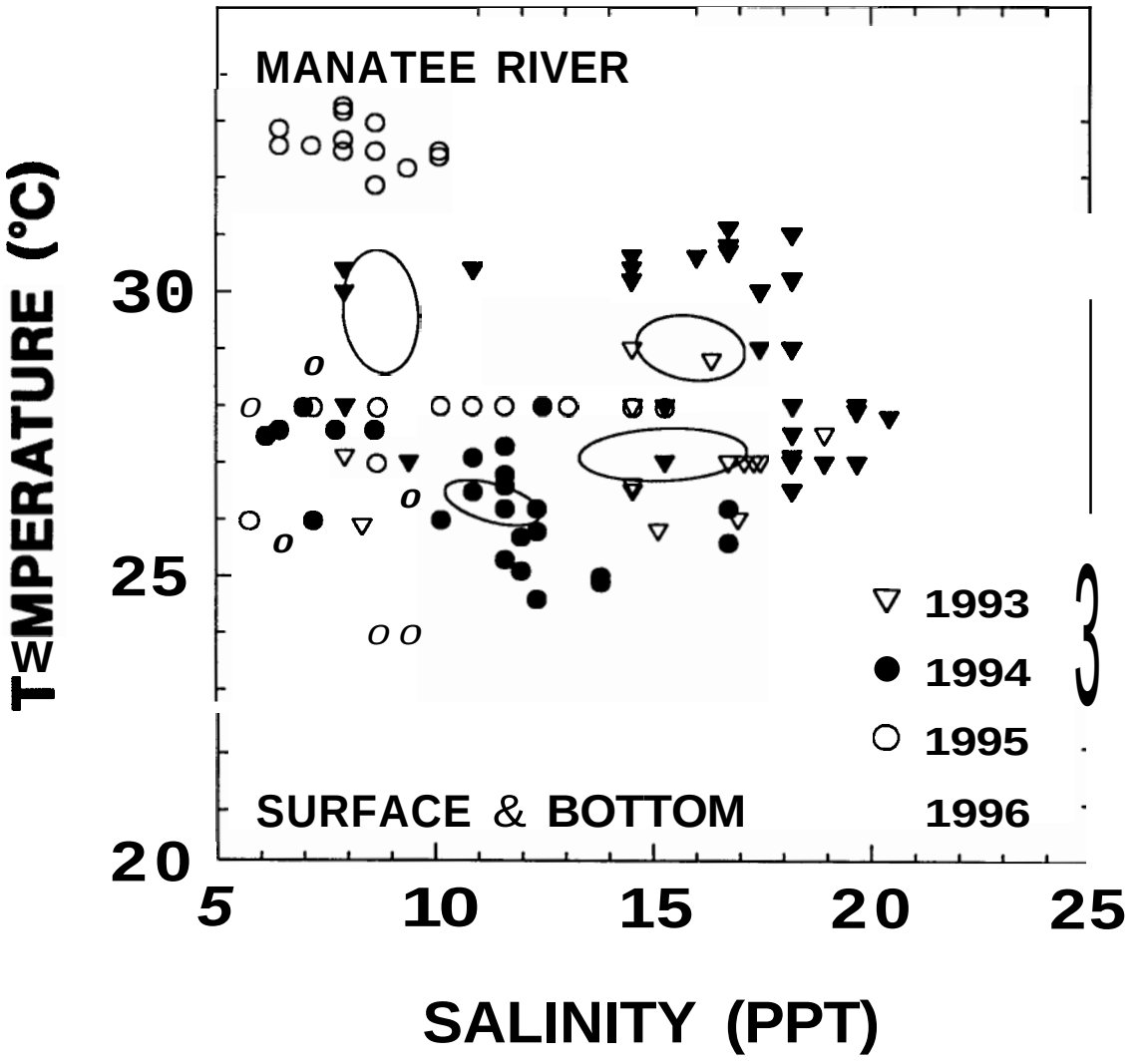

Figure 31. Relationship between temperature and salinity in the Manatee River segment of Tampa Bay, surface and bottom depths, by year. Ellipses represent bivariate 95% confidence limits of mean temperature and salinity.

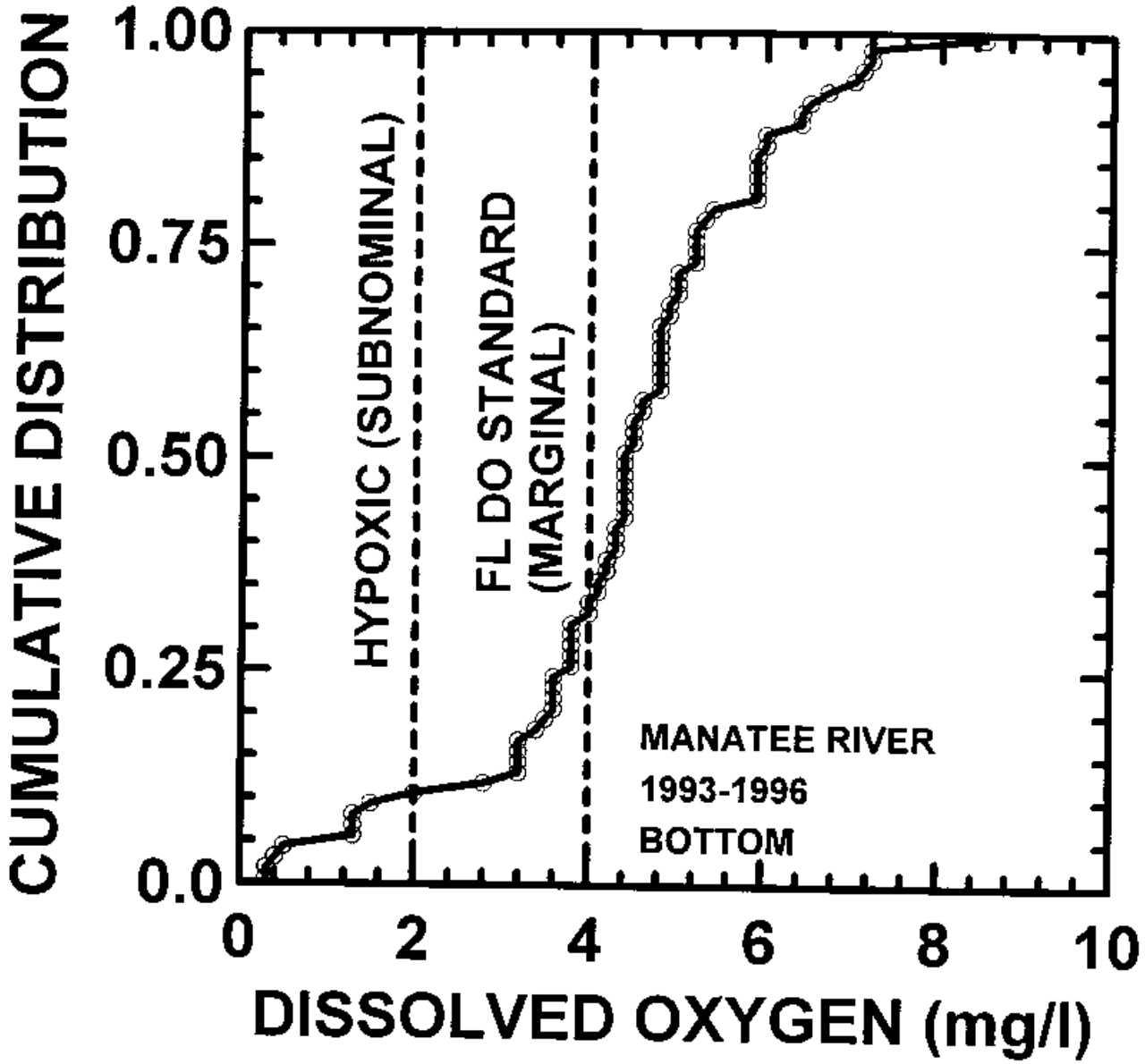

Figure 32. Cumulative frequency distribution of dissolved oxygen concentrations in near-bottom waters of Manatee River segment, 1993-1996.

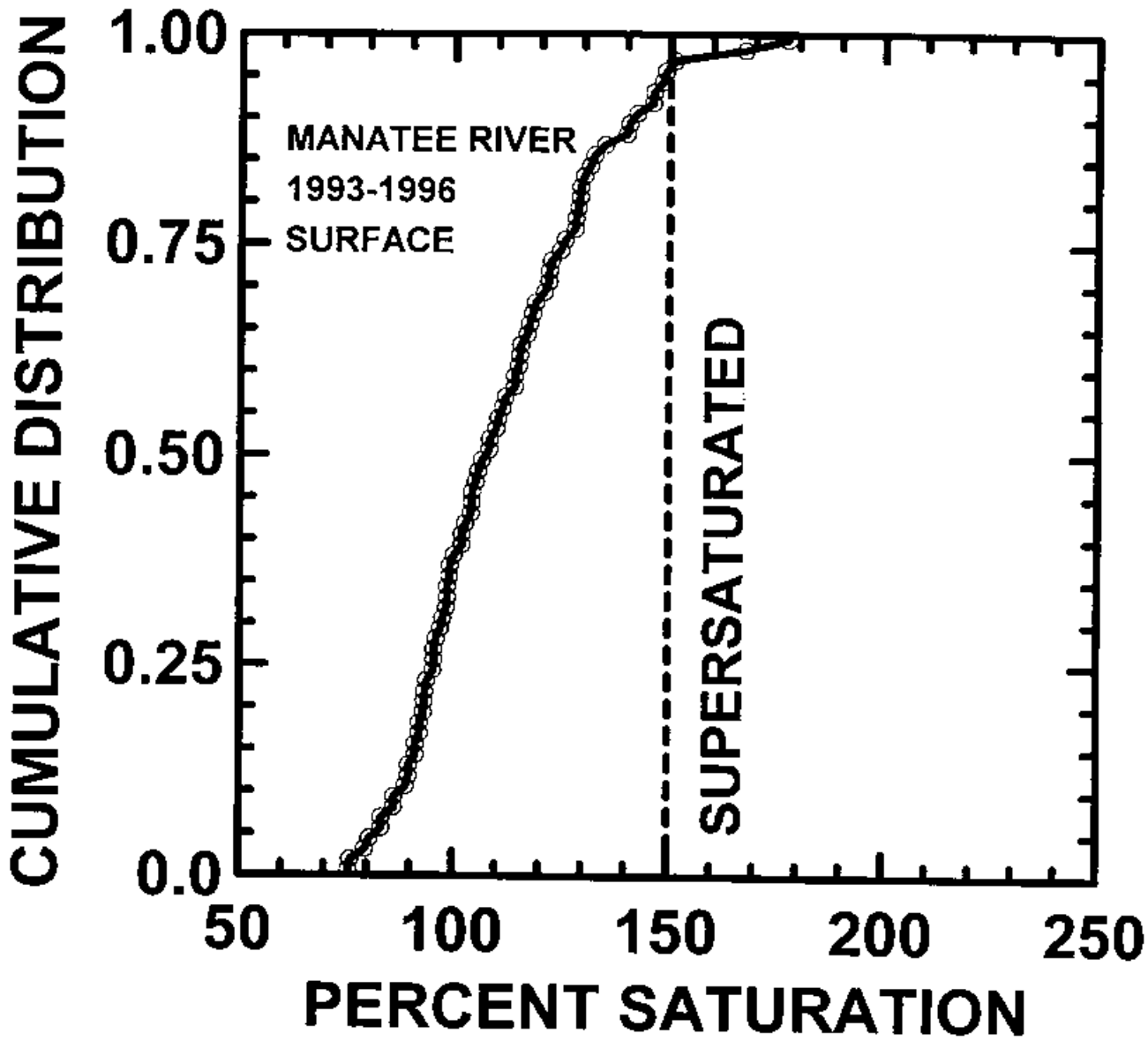

Figure 33. Cumulative frequency distribution of dissolved oxygen saturation in near-surface waters of the Manatee River segment, 1993-1996.

Table 4. Areal (km^2) estimates of "marginal"(DO > 2 < 4) and "subnominal"(DO < 2) bottom dissolved oxygen concentrations, supersaturation of surface waters, and oligotrophic and eutrophic conditions, as defined by the Oxygen Index. Tampa bay estuarine system, 1993-1996.

Bay Segment (area, km^2)	DO>2<4	DO<2	Supersaturated	Oligotrophic	Eutrophic
Old Tampa Bay (200.7)	38.8	7.4	42.8	23.7	101.2
Hillsborough Bay (105.3)	24.2	17.9	26.8	17.5	61.1
Middle Tampa Bay (309.9)	33.2	4.6	59.5	88.9	132.0
Lower Tampa Bay (246.6)	6.9	0	53.0	19.7	118.9
Boca Ciega Bay (93.1)	4.5	0	27.3	16.0	60.0
Terra Ceia Bay (20.6)	1.6	0	0.4	4.9	7.4
Manatee River (54.6)	11.6	5.5	2.0	19.9	19.2
TOTAL (1030.8)	120.7	35.4	211.8	190.6	439.8
% OF BAY	11.8	3.4	20.6	18.5	42.7

SECTION IV
DISCUSSION

These data summarize the "baseline" status for dissolved oxygen in the Tampa Bay estuarine system. Future analyses will assess trends based upon a four-year moving average from this baseline-- as is the intent of the study design (Holland 1990).

Extreme measures of dissolved oxygen are an indicator of impairment due to eutrophication (Rabalais 1992). When surface waters are supersaturated with dissolved oxygen it is most often the result of photosynthesis by phytoplankton. Such productivity is invariably driven by excess amounts of nutrients in the water column.

In waters which are highly productive, the oxygen concentrations can undergo profound changes over a daily cycle, often leading to oxygen depletion at night. Decomposition of algae "blooms" also results in lowered DO and is often associated with fish kills (Steimle & Radosh 1979; Rabalais 1992).

The dissolved oxygen status of Tampa Bay is a concern because "marginal" dissolved oxygen concentrations (greater than 2 mg/l and less than 4 mg/l) can encourage the emigration of fish, and other invertebrates from their preferred habitat (Steimle & Radosh 1979; Thoemke 1979; Pihl *et al*. 1991). "Subnominal" dissolved oxygen concentrations (hypoxia) can, if they persist, contribute to the death of benthic infauna (Steimle & Radosh 1979; Santos & Simon 1980; Harper *et al*. 1981; Gaston 1985; Rabalais 1992).

Diel monitoring of DO took place to ascertain the daily DO minimum as well as the duration of suboptimal DO. Lack of equipment and logistical constraints preclude deployment of monitoring instruments at each and every station. The data collected to date have shown that subnominal DO may persist over a fairly large fraction of the day. The duration of hypoxic conditions is much less, but at some sites hypoxia extended for more than one-quarter of a 24-h cycle.

The Hillsborough Bay segment, where episodes of hypoxia have been previously documented (Santos & Simon 1980), was the most impaired on a percetage basis. On an absolute basis, the Old Tampa Bay segment had the largest area of marginal and subnomial DO (46 km^2) and Terra Ceia Bay had the smallest absolute area of marginal and subnominal DO. Three segments (Lower Tampa Bay, Boca Ciega Bay, and Terra Ceia Bay)

showed no evidence of hypoxia during daytime hours. Overall, almost 12% of Tampa Bay was estimated to be affected by marginal DO conditions and an additional 3.4% of the bay was characterized as hypoxic. The extents of hypoxia estimated for Tampa Bay compare favorably with the 5% estimated by EPA for the Virginian Province (Cape Cod, MA south to the mouth of Chesapeake Bay, VA) (Strobe1 *et al.* 1995).

These data also showed that a larger area of the bay as a whole was impacted by supersaturated surface waters than was impacted by marginal and subnominal DO in bottom waters. This condition was most pronounced in the Lower Tampa Bay and Boca Ciega Bay segments. Overall, the Boca Ciega Bay segment had the largest relative area affected by supersaturation and Middle Tampa Bay had the largest absolute area affected. The Terra Ceia and Manatee River segments were least affected. It must be noted that color values in the Manatee River are of sufficient magnitude that primary production is likely inhibited (G. Blanchard, MCEMD, pers. comm.) and supersaturation as a consequence of photosynthesis is unlikely.

The DO index (D) was developed by Justic (1991) to quantify the trophic status of coastal waters with depths of between 15 and 35-m (Justic, pers. comm. 14 April 1997). Justic (pers. comm., 14 April 1997) cautions that this Index may not be appropriate for shallow, well-mixed systems such as Tampa Bay unless DO and density stratification is demonstrated. DO stratification was, in fact, evident throughout Tampa Bay and either temperature or salinity stratification was observed in four of the segments.

Application of this Index to Tampa Bay showed that the system as a whole is remains eutrophic. Eutrophication of Tampa Bay has been well-documented (Estevez 1989; Lewis 1989; Boler 1995). This condition has, however, been ameliorated with the addition of the Hookers Point WWTP in 1979 (Lewis 1989; Boler 1995). Nutrient recycling from the sediments (Fanning & Bell 1985; Brooks & Doyle 1991) and nitrogen loadings from stormwater and atmospheric deposition to Tampa Bay remain (Tampa Bay National Estuary Program 1996) as major sources of nitrogen for phytoplankton. Overall, phosphorus concentrations in Tampa Bay remain "high"(> 0.1mg/l; Quinn *et* al. 1989; *cf.* Boler 1995) and nitrogen concentrations remain in NOAA's "medium" range (0.1-1.0mg/l; Quinn *et al.* 1989; *cf.* Boler 1995).

More than 40% of the bay had D>0.4,which was more than twice the area which could be considered oligotrophic (D<0.2). Boca Ciega and Hillsborough bays had the highest mean index scores. Only Terra Ceia Bay and the Manatee River segments had a mean D indicative of mesotrophic conditions.

SECTION V
CONCLUSIONS

1. Each bay segment showed differences between years in water-mass (temperature and salinity) characteristics. There were also significant differences in water-mass characteristics between surface and bottom waters in Old Tampa Bay and in relative depth by year in Terra Ceia Bay.

2. Mean dissolved oxygen concentrations differed between year and depth in the Hillsborough and Terra Ceia Bay segments of Tampa Bay. There were differences between years for mean DO in each segment except Hillsborough Bay and the Manatee River. DO was stratified (S>B) in all but the Boca Ciega Bay segment.

3. 15% of the Tampa Bay estuary exhibited marginal to subnominal (DO<4 mg/l) dissolved oxygen concentrations during 1993-1996.More than 30% of both the Hillsborough Bay and Manatee River segments were so affected.

4. 3.4% of the estuary was hypoxic (DO <2mg/l); only four readings came close (0.20-0.27mg/l) to being anoxic (DO <0.2mg/l). The Hillsborough Bay and Manatee River segments were most affected by hypoxia. There was no evidence of hypoxia in the Lower Tampa Bay, Boca Ciega Bay, and Terra Ceia Bay segments.

5. Supersaturated surface waters, an indicator of nutrient enriched conditions, were estimated to involve between 19% and 29% of the Old Tampa Bay, Hillsborough Bay, Middle Tampa Bay, Lower Tampa Bay, and Boca Ciega Bay segments. Middle Tampa Bay had the greatest area affected (59.5 km^2)

6. The dissolved oxygen index showed that, baywide, nutrient enriched (eutrophic) conditions occupied more than twice the area of low nutrient (oligotrophic) conditions, Mean index scores were indicative of nutrient enrichment in all but the Terra Ceia Bay and Manatee River segments of the bay. Index scores were highest (D >0.54) in Boca Ciega Bay and Hillsborough Bay. Oligotrophic conditions were most evident in the Manatee River segment (36.5%) and least in Lower Tampa Bay (8%).

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APPENDICES

APPENDIX A

LOUISIANA STATE UNIVERSITY
AND AGRICULTURAL AND MECHANICAL COLLEGE
Center for Coastal, Energy & Environmental Resources • Coastal Ecology Institute
Baton Rouge, LA 70803; 504/388-6515 • FAX 504/388-6331

April 14, 1997.

Mr. Stephen Grabe
EPC of Hillsborough Co.
1410 N. 21st Street
Tampa, FL 33605

Dear Mr. Grabe:

I am sorry for taking so long to respond to your letter. Unfortunately, it took several weeks for your letter sent to the University of Zagreb (Croatia) to be forwarded to my present address.

I read Mr. Blanchard's comments with great interest. His criticism of the DO index, however, is largely based on misinterpretation of the index design and its underlying theoretical basis. I hope the following remarks will be useful.

The index computes the Euclidean distance of a point, whose coordinates are x and y, from the origin of axes in the Cartesian coordinate system (CCS) ($X = 0$, $y = 0$; or $X_s = 0$, $X_b = 0$, in the notation used in the text). The origin of axes is implicitly assumed to be the state of hypothetical oligotrophy, and any deviation from that point is considered to represent a shift in the trophic state from oligotrophy towards eutrophy. Computationally, the index does not distinguish between positive and negative oxygen anomaly, and solution can theoretically be found in any of the four quadrants of the CCS. An oxygen deficit of 30% in the surface layer ($X_s = -0.3$), for example, has the same weight as a surface oxygen surplus of 30% ($X_s = 0.3$). The same is true for the bottom layer. In the natural waters, however, the vast majority of the oxygen concentrations fall into the category $Xs > 0$; $X_b > 0$ (the first CCS quadrant), and that is why this notation is used in index formulation.

During the past 7 years, the oxygen index was used to assess trophic conditions in different freshwater, estuarine and marine systems worldwide. The comments that I received were generally favorable, and the index seemed to provide useful characterization of the long-term eutrophication trends. In case of data series extending over periods of 20 years or longer, this index appeared to have an advantage over similar eutrophication indices that were based on nutrient concentrations, chlorophyll a, and C^{14} measurements. This is because the Winkler method for determination of DO (which is also used for calibration of polarographic DO sensors) has remained fundamentally unchanged since 1888, while most other methods have changed considerably with time, thus preventing any comparison of the modem data with historical records.

Most of the ecosystems studied, however, were between 15 and 35 m deep, showed a marked density stratification, and were characterized by seasonally prevalent hypoxia in the bottom waters. I am not aware of any previous attempt to use the index for assessing environmental conditions in an ecosystem that is as shallow as Tampa Bay. If the water column is well mixed most of the time, and there are no gradients in DO between the surface and the bottom, then this index may be of little practical value.

My advice would be to use the DO index only for the assessment of long-term trends, while keeping the sampling protocol comparable with the one that was used in earlier studies. In assessing seasonal or spatial aspects of the eutrophication process, however, I would use one of the other eutrophication indices that are available in the literature.

Sincerely,

D. Justic

Dr. Dubravko Justic
Associate Professor

APPENDIX B

Mean temperature, salinity, and dissolved oxygen concentration, in surface and bottom waters, by bay segment: Tampa Bay 1993-1996. (n=number of observations)

		(n)	Temperature (C)	Salinity (ppt)	DO(mg/l)
A. Old Tampa Bay					
Surface-	1993	(28)	28.8	24.5	7.0
	1994	(31)	29.7	22.4	6.8
	1995	(40)	28.2	18.2	5.9
	1996	(30)	30.6	22.4	5.6
Bottom-	1993	(31)	28.8	24.4	6.0
	1994	(31)	29.3	23.2	6.0
	1995	(55)	28.0	18.1	5.4
	1996	(30)	30.3	23.0	4.2
B. Hillsborough Bay					
Surface-	1993	(38)	29.8	21.8	6.6
	1994	(37)	28.8	19.5	6.6
	1995	(76)	29.6	13.4	6.4
	1996	(53)	29.1	24.0	5.4
Bottom-	1993	(38)	29.8	24.4	3.8
	1994	(38)	28.6	21.5	3.8
	1995	(80)	29.4	15.6	4.5
	1996	(55)	28.8	25.2	4.2
C. Middle Tampa Bay					
Surface-	1993	(40)	30.0	26.7	6.4
	1994	(16)	27.4	23.9	6.1
	1995	(34)	29.8	20.1	5.5
	1996	(48)	30.4	27.0	5.3
Bottom-	1993	(40)	29.7	27.1	6.1
	1994	(28)	27.6	24.5	5.5
	1995	(36)	29.7	20.7	5.0
	1996	(48)	30.2	27.4	4.9

APPENDIX B (continued)

		(n)	Temperature (C)	Salinity (ppt)	DO (mg/l)
D. Lower Tampa Bay					
Surface-	1993	(34)	29.9	31.3	5.9
	1994	(32)	27.5	27.9	6.1
	1995	(44)	29.6	27.8	6.4
	1996	(46)	27.2	30.2	6.2
Bottom-	1993	(34)	29.6	32.3	5.4
	1994	(36)	27.6	28.6	5.2
	1995	(47)	29.4	29.1	5.9
	1996	(47)	27.3	30.1	6.6
E. Boca Ciega Bay					
Surface-	1995	(38)	27.7	29.7	6.8
	1996	(38)	28.2	32.3	6.2
Bottom-	1995	(42)	27.3	30.2	6.4
	1996	(42)	27.9	32.7	6.0
F. Terra Ceia Bay'					
Surface-	1993	(7)	28.0	17.2	6.0
	1994	(14)	27.0	15.8	6.5
	1995	(14)	27.9	10.3	5.6
	1996	(16)	27.8	18.5	5.9
Bottom-	1993	(7)	29.0	17.4	5.7
	1994	(14)	26.3	16.2	5.6
	1995	(14)	27.8	11.9	4.7
	1996	(16)	27.7	18.5	6.3
G. Manatee River'					
Surface-	1993	(11)	27.0	13.1	5.8
	1994	(21)	26.5	10.7	5.8
	1995	(22)	28.8	6.7	5.3
	1996	(26)	29.2	16.0	5.8
Bottom-	1993	(11)	27.0	14.4	4.6
	1994	(21)	25.9	12.1	3.8
	1995	(22)	29.2	9.2	4.1
	1996	(26)	28.8	15.8	5.0

1 Salinity computed from conductivity where:
Salinity= -3.806 + 0.000733*Conductivity

APPENDIX C

Monthly rainfall (inches) in the vicinity of Tampa Bay, August-October 1993-1993. Data provided by SWFWMD.

	Bradenton	St. Petersburg	Gulfport	Tampa Internat. Airport
August				
1993				
1994	9.45	6.10	9.03	8.37
1995	11.30	17.75	12.32	13.75
1996	2.80	3.67	2.37	7.39
September				
1993	4.08	5.60	6.14	6.60
1994	7.24	9.29	10.29	8.20
1995	8.25	3.10	2.27	2.80
1996		3.56	2.65	5.44
October				
1993	7.09	4.63	4.57	4.23
1994	3.53	2.53	2.40	1.48
1995	5.12	5.37	4.60	4.72
1996	4.94	3.50	-	3.12

- = no data

APPENDIX D

Diel physicichemical data collected over consecutive days at four stations.

Log File Name : 95-H-37(1)
Setup Date (MMDDYY) : 100295
Setup Time (HHMMSS) : 065245
Starting Date (MMDDYY) : 100295
Starting Time (HHMMSS) : 180000
Stopping Date (MMDDYY) : 100395
Stopping Time (HHMMSS) : 080000
Interval (HHMMSS) : 001500
Warmup : Enable

==> Setup Variables and Calibration <==

Variable or Calibration changed at 100295 065825 => changes ignored!
Variable or Calibration changed at 100295 065846 => changes ignored!

Date MMDDYY	Time HHMMSS	Temp degC	pH units	SpCond mS/cm	Salin ppt	DO %Sat	DO mg/l	Depth meters	Batt volts
100295	180000	29.56	8.11	31.8	19.8	116.5	7.86	3	13.7
100295	181500	29.54	8.11	31.7	19.7	114.5	7.73	3	13.7
100295	183000	29.54	8.11	31.7	19.7	113.5	7.67	3	13.7
100295	184500	29.54	8.11	31.7	19.7	111	7.5	3.1	13.6
100295	190000	29.54	8.11	31.8	19.8	108.4	7.32	3.1	13.7
100295	191500	29.54	8.11	31.8	19.8	106.8	7.22	3.1	13.7
100295	193000	29.52	8.11	31.8	19.8	106.5	7.19	3.2	13.7
100295	194500	29.5	8.11	31.7	19.7	106.5	7.2	3.2	13.7
100295	200000	29.48	8.11	31.7	19.7	107.5	7.27	3.2	13.6
100295	201500	29.48	8.1	31.8	19.8	107.3	7.26	3.3	13.6
100295	203000	29.46	8.1	31.8	19.8	106.3	7.19	3.3	13.7
100295	204500	29.44	8.1	31.8	19.8	105.7	7.15	3.3	13.6
100295	210000	29.42	8.1	31.7	19.8	104.1	7.05	3.3	13.6
100295	211500	29.4	8.09	31.7	19.8	103.7	7.02	3.4	13.6
100295	213000	29.38	8.1	31.7	19.8	102.9	6.97	3.4	13.6
100295	214500	29.38	8.1	31.7	19.8	101.8	6.89	3.4	13.6
100295	220000	29.36	8.1	31.7	19.8	101.1	6.85	3.4	13.6
100295	221500	29.38	8.1	31.7	19.7	100.6	6.82	3.4	13.6
100295	223000	29.42	8.11	31.7	19.8	101.8	6.89	3.4	13.5
100295	224500	29.44	8.1	31.8	19.8	100.2	6.78	3.4	13.5
100295	230000	29.46	8.1	31.8	19.8	99.6	6.74	3.4	13.5
100295	231500	29.46	8.09	31.8	19.8	99	6.69	3.5	13.5
100295	233000	29.46	8.09	31.8	19.8	97.5	6.59	3.5	13.5
100295	234500	29.42	8.08	31.7	19.8	96.8	6.55	3.5	13.5
100395	0	29.4	8.07	31.7	19.8	94.8	6.42	3.5	13.6
100395	1500	29.38	8.07	31.8	19.8	95	6.43	3.5	13.5
100395	3000	29.36	8.06	31.7	19.8	94	6.37	3.5	13.5
100395	4500	29.32	8.07	31.7	19.7	93.4	6.33	3.4	13.4
100395	10000	29.3	8.07	31.7	19.7	93.8	6.36	3.4	13.5

Log File Name : 95-H-37(1)
Setup Date (MMDDYY) : 100295
Setup Time (HHMMSS) : 065245
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Starting Time (HHMMSS) : 180000
Stopping Date (MMDDYY) : 100395
Stopping Time (HHMMSS) : 080000
Interval (HHMMSS) : 001500
Warmup : Enable

==> Setup Variables and Calibration <==

Variable or Calibration changed at 100295 065825 => changes ignored!
Variable or Calibration changed at 100295 065846 => changes ignored!

Date MMDDYY	Time HHMMSS	Temp degC	pH units	SpCond mS/cm	Salin ppt	DO %Sat	DO mg/l	Depth meters	Batt volts
100395	11500	29.26	8.08	31.7	19.7	94.9	6.44	3.4	13.5
100395	13000	29.26	8.07	31.6	19.7	94.2	6.4	3.4	13.5
100395	14500	29.26	8.08	31.6	19.7	92.7	6.29	3.4	13.5
100395	20000	29.26	8.07	31.6	19.7	91.5	6.21	3.4	13.5
100395	21500	29.26	8.07	31.6	19.6	90.8	6.17	3.4	13.5
100395	23000	29.24	8.07	31.6	19.6	89.9	6.11	3.4	13.5
100395	24500	29.24	8.07	31.5	19.6	89.5	6.08	3.4	13.4
100395	30000	29.24	8.07	31.4	19.6	90.1	6.12	3.3	13.4
100395	31500	29.26	8.08	31.4	19.5	92.2	6.27	3.3	13.4
100395	33000	29.28	8.05	31.6	19.6	86.8	5.89	3.3	13.4
100395	34500	29.26	8.02	31.8	19.8	83.5	5.66	3.3	13.7
100395	40000	29.24	8.02	31.8	19.8	82.3	5.58	3.3	13.4
100395	41500	29.2	8.01	31.9	19.9	80.8	5.49	3.3	13.4
100395	43000	29.18	8	32	19.9	79.6	5.4	3.4	13.4
100395	44500	29.18	8	32	19.9	78.2	5.31	3.4	13.4
100395	50000	29.16	8	32	20	78.7	5.35	3.4	13.4
100395	51500	29.16	8	32	20	77.6	5.27	3.4	13.4
100395	53000	29.14	8	32	20	76.7	5.21	3.4	13.4
100395	54500	29.14	7.99	32	20	74.9	5.09	3.5	13.4
100395	60000	29.14	7.98	32	20	73.8	5.01	3.5	13.4
100395	61500	29.14	7.97	32	20	72.4	4.92	3.5	13.4
100395	63000	29.12	7.96	32	20	70.2	4.77	3.5	13.4
100395	64500	29.14	7.96	32.1	20	68.3	4.64	3.6	13.4
100395	70000	29.16	7.94	32.1	20	66.3	4.5	3.6	13.4
100395	71500	29.16	7.94	32.1	20	65.2	4.43	3.6	13.3
100395	73000	29.14	7.93	32.2	20	64.5	4.38	3.6	13.3
100395	74500	29.12	7.92	32.2	20	63.2	4.29	3.6	13.4
100395	80000	29.12	7.92	32.2	20	62.6	4.25	3.6	13.3

Recovery finished at 020789 134908

Log File Name : 95-H-37(2)
Setup Date (MMDDYY) : 100295
Setup Time (HHMMSS) : 114221
Starting Date (MMDDYY) : 100395
Starting Time (HHMMSS) : 180000
Stopping Date (MMDDYY) : 100495
Stopping Time (HHMMSS) : 080000
Interval (HHMMSS) : 001500
Warmup : Enable

==> Setup Variables and Calibration <==

Date MMDDYY	Time HHMMSS	Temp degC	pH units	SpCond mS/cm	Salin ppt	DO %Sat	DO mg/l	Depth meters	Batt volts
100395	180000	28.83	8.04	31.5	19.6	87.1	5.96	3.2	13.6
100395	181500	28.85	8.05	31.4	19.5	86.2	5.9	3.2	13.5
100395	183000	28.85	8.05	31.4	19.5	84.5	5.79	3.2	13.5
100395	184500	28.89	8.05	31.4	19.5	84.8	5.8	3.3	13.5
100395	190000	28.91	8.07	31.2	19.4	89.5	6.12	3.3	13.5
100395	191500	28.89	8.03	31.4	19.5	79.7	5.45	3.3	13.5
100395	193000	28.89	8.03	31.4	19.5	77.8	5.33	3.3	13.5
100395	194500	28.89	8.02	31.4	19.5	76.4	5.23	3.4	13.4
100395	200000	28.91	8.01	31.4	19.5	74.1	5.07	3.4	13.4
100395	201500	28.93	8	31.4	19.6	73	4.99	3.4	13.4
100395	203000	28.93	7.99	31.4	19.6	71.3	4.87	3.4	13.4
100395	204500	28.93	7.98	31.4	19.6	69.1	4.72	3.5	13.4
100395	210000	28.93	7.97	31.4	19.6	68.1	4.66	3.5	13.4
100395	211500	28.93	7.98	31.4	19.5	68.5	4.68	3.5	13.4
100395	213000	28.93	7.97	31.4	19.5	67.8	4.64	3.6	13.4
100395	214500	28.93	7.97	31.4	19.5	64.4	4.41	3.6	13.4
100395	220000	28.93	7.95	31.4	19.5	61.8	4.23	3.6	13.3
100395	221500	28.93	7.95	31.4	19.5	61.2	4.18	3.7	13.3
100395	223000	28.93	7.94	31.4	19.5	59.4	4.06	3.7	13.3
100395	224500	28.93	7.93	31.4	19.6	57.6	3.94	3.7	13.3
100395	230000	28.91	7.93	31.4	19.5	57.9	3.96	3.7	13.3
100395	231500	28.91	7.92	31.4	19.5	55.8	3.82	3.7	13.3
100395	233000	28.91	7.91	31.4	19.5	55.1	3.76	3.7	13.3
100395	234500	28.91	7.9	31.4	19.5	54.8	3.75	3.7	13.3
100495	0	28.91	7.89	31.4	19.5	53.1	3.63	3.7	13.3
100495	1500	28.87	7.9	31.3	19.5	55.6	3.82	3.7	13.3
100495	3000	28.85	7.93	31.2	19.4	59	4.05	3.8	13.3
100495	4500	28.77	7.98	30.9	19.2	69.5	4.77	3.8	13.3
100495	10000	28.67	8.02	30.7	19	80.2	5.53	3.7	13.3

Log File Name : 95-H-37(2)
Setup Date (MMDDYY) : 100295
Setup Time (HHMMSS) : 114221
Starting Date (MMDDYY) : 100395
Starting Time (HHMMSS) : 180000
Stopping Date (MMDDYY) : 100495
Stopping Time (HHMMSS) : 080000
Interval (HHMMSS) : 001500
Warmup : Enable

==> Setup Variables and Calibration <==

Date MMDDYY	Time HHMMSS	Temp degC	pH units	SpCond mS/cm	Salin ppt	DO %Sat	DO mg/l	Depth meters	Batt volts
100495	11500	28.61	8.03	30.6	19	76.7	5.28	3.7	13.3
100495	13000	28.49	8.1	30.3	18.8	95.2	6.58	3.7	13.3
100495	14500	28.49	8.13	30.4	18.8	99.6	6.88	3.7	13.2
100495	20000	28.47	8.14	30.4	18.8	100.9	6.98	3.7	13
100495	21500	28.47	8.14	30.4	18.8	100.3	6.94	3.7	13.2
100495	23000	28.43	8.14	30.3	18.8	100.4	6.95	3.7	13.2
100495	24500	28.42	8.14	30.3	18.8	100.7	6.98	3.7	13.2
100495	30000	28.4	8.14	30.3	18.8	100.4	6.95	3.6	13.2
100495	31500	28.4	8.14	30.3	18.8	99.4	6.88	3.6	13.2
100495	33000	28.36	8.14	30.3	18.8	99.9	6.93	3.6	13.2
100495	34500	28.34	8.14	30.3	18.7	100.5	6.97	3.6	13.3
100495	40000	28.34	8.14	30.3	18.8	99.7	6.92	3.5	13.2
100495	41500	28.32	8.14	30.3	18.8	99.5	6.9	3.5	13.2
100495	43000	28.32	8.14	30.4	18.8	99.9	6.93	3.5	13.2
100495	44500	28.3	8.15	30.4	18.8	100.3	6.96	3.5	13.2
100495	50000	28.3	8.15	30.5	18.9	100.3	6.95	3.5	13.2
100495	51500	28.3	8.14	30.4	18.9	99.5	6.9	3.5	13.2
100495	53000	28.28	8.15	30.6	19	99.9	6.93	3.5	13.2
100495	54500	28.28	8.14	30.6	19	99	6.87	3.5	13.2
100495	60000	28.28	8.14	30.4	18.9	99.2	6.89	3.5	13.2
100495	61500	28.26	8.13	30.4	18.9	97.5	6.77	3.5	13.2
100495	63000	28.26	8.12	30.4	18.9	95.9	6.66	3.6	13.2
100495	64500	28.22	8.11	30.4	18.8	95	6.6	3.6	13.2
100495	70000	28.16	8.1	30.4	18.8	94.9	6.6	3.7	13.2
100495	71500	28.18	8.1	30.3	18.8	95.5	6.64	3.7	13.1
100495	73000	28.2	8.1	30.2	18.7	94.5	6.57	3.7	13.1
100495	74500	28.18	8.09	30.3	18.8	92.3	6.42	3.8	13.1
100495	80000	28.18	8.07	30.3	18.8	89.9	6.25	3.8	13.1

Recovery finished at 020789 135245

Log File Name : 95-H-40(1)
Setup Date (MMDDYY) : 092695
Setup Time (HHMMSS) : 125450
Starting Date (MMDDYY) : 092695
Starting Time (HHMMSS) : 200000
Stopping Date (MMDDYY) : 092795
Stopping Time (HHMMSS) : 080000
Interval (HHMMSS) : 001500
Warmup : Enable

==> Setup Variables and Calibration <==

Date MMDDYY	Time HHMMSS	Temp degC	pH units	SpCond mS/cm	Salin ppt	DO %Sat	DO mg/l	Depth meters	Batt volts
92695	200000	29.74	7.49	28.195	17.3	36	2.46	1	12.1
92695	201500	29.76	7.47	28.199	17.3	31.8	2.17	0.9	12.1
92695	203000	29.74	7.45	28.195	17.3	27.6	1.88	0.9	12
92695	204500	29.8	7.46	28.343	17.4	27.3	1.86	0.9	12
92695	210000	29.9	7.47	28.431	17.5	29.2	1.99	0.9	12
92695	211500	29.92	7.46	28.503	17.5	26.5	1.8	0.9	11.9
92695	213000	29.92	7.45	28.57	17.6	25.1	1.7	0.8	11.9
92695	214500	29.96	7.46	28.579	17.6	25.1	1.71	0.8	11.9
92695	220000	29.7	7.53	28.188	17.3	34.7	2.37	0.8	11.9
92695	221500	29.72	7.51	28.259	17.4	35.3	2.41	0.8	11.9
92695	223000	29.64	7.47	28.312	17.4	27.1	1.85	0.8	11.8
92695	224500	29.56	7.49	28.296	17.4	31.7	2.17	0.8	11.8
92695	230000	29.62	7.43	28.443	17.5	24.8	1.69	0.8	11.8
92695	231500	29.54	7.44	28.428	17.5	25.7	1.76	0.8	11.8
92695	233000	29.56	7.44	28.499	17.5	25.2	1.72	0.9	11.8
92695	234500	29.56	7.44	28.499	17.5	23.8	1.63	0.9	11.8
92795	0	29.5	7.46	28.488	17.5	27.3	1.87	1	11.7
92795	1500	29.46	7.48	28.48	17.5	29.2	2	1	11.7
92795	3000	29.44	7.49	28.476	17.5	32.7	2.24	1.1	11.7
92795	4500	29.42	7.49	28.472	17.5	32.6	2.23	1.1	11.7
92795	10000	29.4	7.49	28.469	17.5	32.4	2.22	1.1	11.7
92795	11500	29.36	7.49	28.461	17.5	32.8	2.25	1.1	11.7
92795	13000	29.32	7.45	28.453	17.5	29.6	2.04	1.2	11.7

Log File Name : 95-H-40(1)
Setup Date (MMDDYY) : 092695
Setup Time (HHMMSS) : 125450
Starting Date (MMDDYY) : 092695
Starting Time (HHMMSS) : 200000
Stopping Date (MMDDYY) : 092795
Stopping Time (HHMMSS) : 080000
Interval (HHMMSS) : 001500
Warmup : Enable

==> Setup Variables and Calibration <==

Date MMDDYY	Time HHMMSS	Temp degC	pH units	SpCond mS/cm	Salin ppt	DO %Sat	DO mg/l	Depth meters	Batt volts
92795	14500	29.2	7.54	28.161	17.3	39.6	2.73	1.2	11.6
92795	20000	29.2	7.65	27.958	17.2	51.4	3.55	1.2	11.7
92795	21500	29.24	7.72	27.763	17	58.6	4.04	1.2	11.6
92795	23000	29.24	7.73	27.763	17	59	4.07	1.2	11.6
92795	24500	29.26	7.75	27.699	17	62.3	4.3	1.3	11.6
92795	30000	29.26	7.77	27.699	17	63	4.34	1.3	11.6
92795	31500	29.26	7.78	27.699	17	63.9	4.41	1.3	11.6
92795	33000	29.18	7.73	27.685	17	60.5	4.18	1.3	11.6
92795	34500	29.1	7.72	27.738	17	59.9	4.14	1.4	11.6
92795	40000	28.94	7.63	27.777	17	52.3	3.62	1.4	11.6
92795	41500	29.12	7.72	27.741	17	59.7	4.13	1.3	11.6
92795	43000	29.2	7.77	27.621	16.9	64.3	4.44	1.3	11.5
92795	44500	29.16	7.76	27.613	16.9	64.1	4.43	1.3	11.5
92795	50000	29.12	7.74	27.539	16.9	61.7	4.27	1.3	11.5
92795	51500	28.96	7.68	27.443	16.8	56.5	3.92	1.3	11.5
92795	53000	28.98	7.68	27.379	16.8	56.1	3.89	1.2	11.5
92795	54500	28.89	7.66	27.294	16.7	54.7	3.8	1.2	11.5
92795	60000	28.75	7.64	27.069	16.6	53.4	3.72	1.1	11.5
92795	61500	28.63	7.66	26.982	16.5	54.7	3.83	1.1	11.5
92795	63000	28.65	7.7	26.985	16.5	58.1	4.06	1.1	11.4
92795	64500	28.75	7.72	26.867	16.4	62	4.33	1	11.4
92795	70000	28.83	7.76	26.813	16.4	68.4	4.77	1	11.4
92795	71500	28.85	7.76	26.749	16.3	67.1	4.68	1	11.4
92795	73000	28.85	7.75	26.749	16.3	66	4.6	0.9	11.4
92795	74500	28.89	7.78	26.688	16.3	69	4.81	0.9	11.4
92795	80000	28.89	7.78	26.62	16.3	68.7	4.79	0.9	11.4

Recovery finished at 092895 081055

Log File Name : 95-H-40(2)
Setup Date (MMDDYY) : 092695
Setup Time (HHMMSS) : 125549
Starting Date (MMDDYY) : 092795
Starting Time (HHMMSS) : 200000
Stopping Date (MMDDYY) : 092895
Stopping Time (HHMMSS) : 080000
Interval (HHMMSS) : 001500
Warmup : Enable

==> Setup Variables and Calibration <==

Date MMDDYY	Time HHMMSS	Temp degC	pH units	SpCond mS/cm	Salin ppt	DO %Sat	DO mg/l	Depth meters	Batt volts
92795	200000	30.3	8.09	19.258	11.4	106.9	7.49	1.4	11.7
92795	201500	30.34	8.12	19.264	11.4	107.6	7.53	1.4	11.5
92795	203000	30.24	8.13	19.318	11.4	108.1	7.57	1.4	11.5
92795	204500	30.5	8.13	19.355	11.5	107.1	7.47	1.4	11.4
92795	210000	30.56	8.14	19.432	11.5	108	7.52	1.5	11.4
92795	211500	30.58	8.14	19.435	11.5	107	7.45	1.5	11.4
92795	213000	30.54	8.13	19.429	11.5	104.5	7.28	1.4	11.4
92795	214500	30.48	8.11	19.42	11.5	102.5	7.15	1.4	11.3
92795	220000	30.4	8.08	19.34	11.5	98.8	6.9	1.4	11.3
92795	221500	30.38	8.09	19.338	11.5	98.7	6.9	1.4	11.3
92795	223000	30.42	8.08	19.412	11.5	94.1	6.57	1.4	11.2
92795	224500	30.44	8.09	19.482	11.6	95.7	6.68	1.4	11.2
92795	230000	30.4	8.1	19.34	11.5	98.6	6.89	1.4	11.2
92795	231500	30.34	8.07	19.264	11.4	94.7	6.63	1.4	11.2
92795	233000	30.04	8.09	19.154	11.3	97.8	6.88	1.4	11.1
92795	234500	30.04	8.03	19.358	11.5	87.6	6.16	1.4	11.1
92895	0	29.84	8.08	19.194	11.4	93.3	6.59	1.4	11.1
92895	1500	29.9	8.12	19.202	11.4	97.3	6.86	1.5	11.2
92895	3000	29.74	8.11	19.113	11.3	96	6.79	1.5	11.1
92895	4500	29.58	8.08	19.092	11.3	94.5	6.71	1.6	11
92895	10000	29.54	8.04	19.087	11.3	90.3	6.41	1.6	11
92895	11500	29.5	8.05	19.082	11.3	92.2	6.55	1.6	11
92895	13000	29.48	8.06	19.079	11.3	92.2	6.55	1.7	11
92895	14500	29.54	8.08	19.087	11.3	94.2	6.69	1.7	11

Log File Name : 95-H-40(2)
Setup Date (MMDDYY) : 092695
Setup Time (HHMMSS) : 125549
Starting Date (MMDDYY) : 092795
Starting Time (HHMMSS) : 200000
Stopping Date (MMDDYY) : 092895
Stopping Time (HHMMSS) : 080000
Interval (HHMMSS) : 001500
Warmup : Enable

==> Setup Variables and Calibration <==

Date MMDDYY	Time HHMMSS	Temp degC	pH units	SpCond mS/cm	Salin ppt	DO %Sat	DO mg/l	Depth meters	Batt volts
92895	20000	29.58	8.1	19.092	11.3	94.9	6.73	1.7	10.9
92895	21500	29.6	8.1	19.095	11.3	95	6.74	1.8	10.9
92895	23000	29.6	8.08	19.163	11.3	93.8	6.65	1.8	10.9
92895	24500	29.56	8.07	19.157	11.3	93.4	6.62	1.8	10.9
92895	30000	29.52	8.05	19.152	11.3	91.4	6.49	1.9	10.9
92895	31500	29.4	8.03	19.137	11.3	89.9	6.39	1.9	10.9
92895	33000	29.26	7.99	19.119	11.3	87.5	6.24	1.9	10.9
92895	34500	29.22	8	19.114	11.3	87.2	6.22	1.9	10.9
92895	40000	29.26	7.97	19.052	11.3	83.5	5.95	1.9	10.8
92895	41500	29.26	7.95	19.052	11.3	82.5	5.88	1.9	10.8
92895	43000	29.24	7.95	18.982	11.2	82.8	5.91	1.9	10.8
92895	44500	29.26	7.96	19.052	11.3	82.6	5.89	1.9	10.8
92895	50000	29.24	7.97	19.117	11.3	82.8	5.91	1.9	10.8
92895	51500	29.2	7.98	19.112	11.3	83.1	5.93	1.9	10.8
92895	53000	29.16	7.96	19.107	11.3	82.7	5.91	1.9	10.8
92895	54500	29.14	7.93	19.172	11.4	79.8	5.7	1.8	10.8
92895	60000	29.12	7.89	19.169	11.4	75.7	5.41	1.9	10.7
92895	61500	29.14	7.85	19.104	11.3	72.5	5.18	1.8	10.7
92895	63000	29.12	7.85	19.169	11.4	72.7	5.19	1.7	10.7
92895	64500	29.12	7.85	19.169	11.4	72	5.14	1.7	10.7
92895	70000	29.1	7.83	19.167	11.4	71.1	5.08	1.6	10.7
92895	71500	29.06	7.83	19.162	11.3	70.7	5.06	1.6	10.7
92895	73000	29.04	7.81	19.159	11.3	69.1	4.95	1.6	10.7
92895	74500	29.02	7.79	19.157	11.3	68.6	4.91	1.5	10.7
92895	80000	29	7.79	19.154	11.3	68.6	4.91	1.5	10.7

Recovery finished at 092895 081201

Log File Name : 95-H-42(1)
Setup Date (MMDDYY) : 092695
Setup Time (HHMMSS) : 151204
Starting Date (MMDDYY) : 092695
Starting Time (HHMMSS) : 200000
Stopping Date (MMDDYY) : 092795
Stopping Time (HHMMSS) : 080000
Interval (HHMMSS) : 001500
Warmup : Enable

==> Setup Variables and Calibration <==

Date MMDDYY	Time HHMMSS	Temp degC	pH units	SpCond mS/cm	Salin ppt	DO %Sat	DO mg/l	Depth meters	Batt volts
92695	200000	29.7	7.72	29.5	18.2	50.8	3.45	1.6	14.5
92695	201500	29.7	7.69	29.5	18.2	44.7	3.04	1.6	14.5
92695	203000	29.68	7.63	29.5	18.2	39.7	2.7	1.5	14.5
92695	204500	29.68	7.68	29.5	18.2	42.3	2.88	1.5	14.5
92695	210000	29.66	7.68	29.5	18.2	42.3	2.88	1.5	14.5
92695	211500	29.62	7.68	29.3	18.1	42.9	2.92	1.5	14.4
92695	213000	29.5	7.69	29	17.9	46.4	3.17	1.5	14.5
92695	214500	29.4	7.72	28.7	17.7	53	3.69	1.4	14.5
92695	220000	29.32	7.75	28.6	17.6	59.4	4.08	1.4	14.4
92695	221500	29.28	7.75	28.6	17.6	61.2	4.2	1.4	14.4
92695	223000	29.24	7.76	28.6	17.6	62.4	4.29	1.4	14.4
92695	224500	29.22	7.79	28.5	17.5	66.2	4.55	1.4	14.4
92695	230000	29.22	7.79	28.5	17.5	66.9	4.6	1.4	14.4
92695	231500	29.22	7.78	28.6	17.6	65.4	4.5	1.5	14.4
92695	233000	29.2	7.77	28.6	17.6	64.1	4.41	1.5	14.4
92695	234500	29.2	7.76	28.6	17.6	63.4	4.36	1.5	14.4
92795	0	29.2	7.76	28.6	17.6	62.5	4.3	1.6	14.4
92795	1500	29.2	7.76	28.6	17.6	62	4.26	1.6	14.3
92795	3000	29.2	7.76	28.6	17.6	62	4.26	1.7	14.3
92795	4500	29.2	7.76	28.6	17.6	61.6	4.24	1.7	14.4
92795	10000	29.22	7.75	28.7	17.7	60.3	4.14	1.8	14.3
92795	11500	29.22	7.74	28.7	17.7	58.7	4.04	1.8	14.3
92795	13000	29.22	7.74	28.8	17.7	57.6	3.96	1.8	14.3
92795	14500	29.24	7.72	28.8	17.7	56.4	3.87	1.8	14.3

Log File Name : 95-H-42(1)
Setup Date (MMDDYY) : 092695
Setup Time (HHMMSS) : 151204
Starting Date (MMDDYY) : 092695
Starting Time (HHMMSS) : 200000
Stopping Date (MMDDYY) : 092795
Stopping Time (HHMMSS) : 080000
Interval (HHMMSS) : 001500
Warmup : Enable

==> Setup Variables and Calibration <==

Date MMDDYY	Time HHMMSS	Temp degC	pH units	SpCond mS/cm	Salin ppt	DO %Sat	DO mg/l	Depth meters	Batt volts
92795	20000	29.24	7.72	28.8	17.7	55.6	3.82	1.9	14.3
92795	21500	29.2	7.69	28.8	17.7	54.3	3.73	1.9	14.3
92795	23000	29.18	7.68	28.7	17.7	53.3	3.67	1.9	14.3
92795	24500	29.18	7.68	28.7	17.7	53.1	3.65	1.9	14.3
92795	30000	29.2	7.68	28.7	17.7	51.7	3.56	2	14.3
92795	31500	29.2	7.69	28.7	17.7	51.3	3.53	2	14.2
92795	33000	29.2	7.69	28.7	17.7	51.8	3.57	2	14.2
92795	34500	29.22	7.68	28.7	17.7	52.4	3.6	2	14.2
92795	40000	29.2	7.67	28.7	17.7	51.5	3.54	2	14.2
92795	41500	29.18	7.66	28.7	17.7	50.8	3.49	2	14.2
92795	43000	29.18	7.65	28.7	17.7	50	3.44	2	14.2
92795	44500	29.16	7.63	28.8	17.7	48.5	3.34	2	14.2
92795	50000	29.18	7.61	28.8	17.8	46.5	3.2	2	14.2
92795	51500	29.16	7.61	28.8	17.8	46	3.16	1.9	14.2
92795	53000	29.12	7.61	28.8	17.8	45.8	3.15	1.9	14.2
92795	54500	29.08	7.6	28.8	17.8	46.2	3.18	1.8	14.2
92795	60000	29	7.6	28.8	17.7	46.8	3.23	1.8	14.2
92795	61500	28.94	7.6	28.8	17.7	47	3.24	1.7	14.2
92795	63000	28.85	7.59	28.8	17.8	46.2	3.2	1.7	14.3
92795	64500	28.77	7.59	28.8	17.8	46.4	3.22	1.7	14.1
92795	70000	28.71	7.57	28.9	17.8	45.4	3.15	1.6	14.1
92795	71500	28.63	7.56	28.9	17.8	44.6	3.09	1.6	14.1
92795	73000	28.61	7.55	28.9	17.8	43.2	3	1.5	14.1
92795	74500	28.53	7.52	29	17.9	41.3	2.87	1.5	14.1
92795	80000	28.49	7.5	29	17.9	40.4	2.81	1.5	14.1

Recovery finished at 092895 081950

Log File Name : 95-H-42(2)
Setup Date (MMDDYY) : 092695
Setup Time (HHMMSS) : 151333
Starting Date (MMDDYY) : 092795
Starting Time (HHMMSS) : 200000
Stopping Date (MMDDYY) : 092895
Stopping Time (HHMMSS) : 080000
Interval (HHMMSS) : 001500
Warmup : Enable

==> Setup Variables and Calibration <==

Date MMDDYY	Time HHMMSS	Temp degC	pH units	SpCond mS/cm	Salin ppt	DO %Sat	DO mg/l	Depth meters	Batt volts
92795	200000	30.3	8.14	27.2	16.6	120.3	8.17	1.6	14.2
92795	201500	30.3	8.15	27.2	16.6	119.3	8.1	1.6	13.9
92795	203000	30.26	8.15	27.1	16.6	119.2	8.1	1.6	14.2
92795	204500	30.18	8.14	27.1	16.6	116.9	7.96	1.6	14.2
92795	210000	30.12	8.12	27.2	16.6	112.6	7.67	1.6	14.2
92795	211500	30.08	8.12	27.2	16.6	111.6	7.61	1.6	14.2
92795	213000	29.92	8.11	26.9	16.5	110.3	7.54	1.6	14.2
92795	214500	29.86	8.11	26.8	16.4	107.9	7.39	1.5	14.2
92795	220000	29.88	8.11	26.7	16.3	107.1	7.34	1.6	14.2
92795	221500	29.96	8.13	26.7	16.3	106	7.26	1.5	14.2
92795	223000	30.16	8.15	26.6	16.3	108.2	7.38	1.5	14.1
92795	224500	30.08	8.18	26.6	16.2	112.6	7.69	1.5	14.1
92795	230000	30.04	8.18	26.5	16.2	113.3	7.74	1.5	14.1
92795	231500	30.02	8.17	26.5	16.2	110.8	7.58	1.5	14.1
92795	233000	29.98	8.17	26.5	16.2	110.3	7.55	1.5	14.1
92795	234500	29.96	8.17	26.6	16.3	109.4	7.49	1.5	14.1
92895	0	29.68	8.14	26.5	16.2	106	7.3	1.6	14.1
92895	1500	29.42	8.07	26.4	16.1	99.5	6.88	1.6	14.1
92895	3000	29.3	8.05	26.4	16.1	98.1	6.79	1.6	14.1
92895	4500	29.4	8.08	26.4	16.1	101.5	7.02	1.7	14.1
92895	10000	29.46	8.07	26.4	16.1	100.9	6.97	1.7	14.1
92895	11500	29.46	8.05	26.5	16.1	99.4	6.87	1.8	14.1
92895	13000	29.4	8.04	26.4	16.1	97.5	6.74	1.8	14
92895	14500	29.26	8.02	26.5	16.2	93.7	6.49	1.8	14

Log File Name : 95-H-42(2)
Setup Date (MMDDYY) : 092695
Setup Time (HHMMSS) : 151333
Starting Date (MMDDYY) : 092795
Starting Time (HHMMSS) : 200000
Stopping Date (MMDDYY) : 092895
Stopping Time (HHMMSS) : 080000
Interval (HHMMSS) : 001500
Warmup : Enable

==> Setup Variables and Calibration <==

Date MMDDYY	Time HHMMSS	Temp degC	pH units	SpCond mS/cm	Salin ppt	DO %Sat	DO mg/l	Depth meters	Batt volts
92895	20000	29.26	8.03	26.5	16.2	95.9	6.64	1.9	14
92895	21500	29.34	8.03	26.6	16.2	96.3	6.66	1.9	14
92895	23000	29.46	8.04	26.6	16.2	96.9	6.69	1.9	14
92895	24500	29.46	8.04	26.6	16.2	95.8	6.62	2	14
92895	30000	29.3	8.02	26.6	16.2	94.3	6.53	2	14
92895	31500	29.34	8.01	26.5	16.2	93.4	6.46	2	14
92895	33000	29.4	8.03	26.5	16.2	92.8	6.41	2	14
92895	34500	29.38	8.06	26.5	16.2	95.9	6.63	2	14
92895	40000	29.28	8.07	26.5	16.2	96.1	6.66	2	14.1
92895	41500	29.36	8.08	26.5	16.2	96.5	6.68	2	14
92895	43000	29.46	8.09	26.5	16.1	96.3	6.65	2	13.9
92895	44500	29.5	8.08	26.5	16.2	95.7	6.61	2	14
92895	50000	29.46	8.07	26.5	16.2	96.9	6.69	2	14
92895	51500	29.44	8.06	26.5	16.2	96	6.63	2	14
92895	53000	29.38	8.05	26.5	16.2	95	6.57	2	14
92895	54500	29.32	8.04	26.5	16.2	94.5	6.54	2	13.9
92895	60000	29.26	8.04	26.5	16.2	94	6.51	1.9	13.9
92895	61500	29.18	8.07	26.5	16.2	94.4	6.55	1.9	13.9
92895	63000	29.12	8.07	26.4	16.1	92.8	6.45	1.8	13.9
92895	64500	29.18	8.04	26.4	16.1	89.2	6.2	1.8	13.9
92895	70000	29.08	8.06	26.3	16.1	88.1	6.13	1.8	13.9
92895	71500	29.1	8.08	26.3	16	88.5	6.16	1.7	13.9
92895	73000	29.08	8.07	26.3	16	87.9	6.12	1.7	13.9
92895	74500	29.02	8.06	26.2	16	87.1	6.06	1.7	13.9
92895	80000	28.96	8.05	26.2	16	86.9	6.06	1.6	13.9

Recovery finished at 092895 082137

Log File Name : 95-H-43(1)
Setup Date (MMDDYY) : 100295
Setup Time (HHMMSS) : 070539
Starting Date (MMDDYY) : 100295
Starting Time (HHMMSS) : 180000
Stopping Date (MMDDYY) : 100395
Stopping Time (HHMMSS) : 060000
Interval (HHMMSS) : 001500
Warmup : Enable

==> Setup Variables and Calibration <==

Variable or Calibration changed at 100295 071220 => changes ignored!
Variable or Calibration changed at 100295 071235 => changes ignored!

Date MMDDYY	Time HHMMSS	Temp degC	pH units	SpCond mS/cm	Salin ppt	DO %Sat	DO mg/l	Depth meters	Batt volts
100295	180000	29.82	8.11	29.198	18	118.6	8.05	3.6	15.1
100295	181500	29.94	8.12	29.222	18	120.2	8.15	3.6	15.1
100295	183000	29.8	8.13	29.126	18	115.9	7.87	3.7	15.1
100295	184500	29.74	8.13	29.046	17.9	113.8	7.74	3.7	15.1
100295	190000	29.82	8.1	29.062	17.9	111.8	7.59	3.7	15
100295	191500	29.76	8.09	29.118	18	108.4	7.37	3.8	15
100295	193000	29.78	8.09	29.054	17.9	108.9	7.4	3.8	15
100295	194500	29.7	8.1	28.97	17.9	109.1	7.43	3.8	15
100295	200000	29.64	8.11	28.958	17.8	108.5	7.4	3.9	14.9
100295	201500	29.56	8.12	28.875	17.8	109.2	7.46	3.9	15
100295	203000	29.56	8.11	29.078	17.9	108.2	7.38	3.9	14.9
100295	204500	29.54	8.1	29.074	17.9	106.8	7.29	4	14.9
100295	210000	29.54	8.1	29.074	17.9	107.3	7.32	4	14.9
100295	211500	29.52	8.09	29.137	18	105.1	7.18	4	14.9
100295	213000	29.46	8.09	29.058	17.9	104.6	7.15	4	15
100295	214500	29.44	8.08	29.054	17.9	103.6	7.1	4	14.8
100295	220000	29.4	8.09	28.979	17.9	104	7.12	4	14.8
100295	221500	29.36	8.08	28.971	17.9	102.5	7.02	4	14.8
100295	223000	29.38	8.09	28.908	17.8	103.5	7.09	4	15.1
100295	224500	29.42	8.1	29.05	17.9	102.1	6.99	4.1	14.8
100295	230000	29.4	8.13	29.182	18	106.3	7.27	4.1	14.8
100295	231500	29.36	8.13	29.174	18	106.5	7.29	4.1	14.8
100295	233000	29.32	8.14	29.234	18	107.7	7.37	4.1	14.7
100295	234500	29.3	8.15	29.297	18.1	107.4	7.36	4.1	14.7
100395	0	29.28	8.13	29.293	18.1	104.6	7.16	4.1	14.7
100395	1500	29.26	8.13	29.29	18.1	103.1	7.07	4.1	14.7
100395	3000	29.24	8.12	29.286	18.1	102.4	7.02	4.1	14.7
100395	4500	29.24	8.11	29.286	18.1	99.9	6.85	4.1	14.7
100395	10000	29.2	8.06	29.481	18.2	92.3	6.33	4.1	14.7

Log File Name : 95-H-43(1)
Setup Date (MMDDYY) : 100295
Setup Time (HHMMSS) : 070539
Starting Date (MMDDYY) : 100295
Starting Time (HHMMSS) : 180000
Stopping Date (MMDDYY) : 100395
Stopping Time (HHMMSS) : 080000
Interval (HHMMSS) : 001500
Warmup : Enable

==> Setup Variables and Calibration <==

Variable or Calibration changed at 100295 071220 => changes ignored!
Variable or Calibration changed at 100295 071235 => changes ignored!

Date MMDDYY	Time HHMMSS	Temp degC	pH units	SpCond mS/cm	Salin ppt	DO %Sat	DO mg/l	Depth meters	Batt volts
100395	11500	29.18	8.05	29.544	18.2	91.9	6.3	4.1	14.7
100395	13000	29.16	8.05	29.54	18.2	91.6	6.28	4	14.6
100395	14500	29.16	8.04	29.54	18.2	91.1	6.25	4	14.7
100395	20000	29.16	8.05	29.54	18.2	92.2	6.32	4	14.6
100395	21500	29.16	8.04	29.54	18.2	90.2	6.19	4	14.7
100395	23000	29.14	8.04	29.536	18.2	90.9	6.23	4	14.6
100395	24500	29.14	8.03	29.536	18.2	88.3	6.06	4	14.6
100395	30000	29.12	8.04	29.465	18.2	90.7	6.23	4	14.6
100395	31500	29.12	8.06	29.465	18.2	93.7	6.43	4	14.6
100395	33000	29.12	8.06	29.465	18.2	91.5	6.28	4	14.6
100395	34500	29.14	8.05	29.469	18.2	89.6	6.15	4	14.6
100395	40000	29.12	8.06	29.465	18.2	88.9	6.1	4	14.5
100395	41500	29.08	8.05	29.457	18.2	90.3	6.2	4	14.5
100395	43000	29.04	8.06	29.45	18.2	91.2	6.27	4	14.5
100395	44500	28.94	8.06	29.499	18.2	93.1	6.41	4	14.5
100395	50000	28.89	8.05	29.555	18.3	92.6	6.38	4	14.5
100395	51500	28.89	8.05	29.555	18.3	93.1	6.41	4.1	14.5
100395	53000	28.83	8.06	29.544	18.2	94.3	6.51	4.1	14.5
100395	54500	28.83	8.06	29.476	18.2	92.9	6.41	4.1	14.5
100395	60000	28.87	8.06	29.484	18.2	92.1	6.35	4.1	14.5
100395	61500	28.87	8.06	29.416	18.2	92	6.35	4.2	14.5
100395	63000	28.94	8.05	29.364	18.1	90.5	6.23	4.2	14.5
100395	64500	28.83	8.03	29.611	18.3	86.3	5.95	4.2	14.5
100395	70000	28.71	8.03	29.656	18.3	87.8	6.07	4.2	14.4
100395	71500	28.67	8.01	29.649	18.3	86.5	5.98	4.3	14.2
100395	73000	28.69	8.01	29.653	18.3	84.7	5.85	4.3	14.4
100395	74500	28.67	8	29.851	18.5	84	5.8	4.3	14.4
100395	80000	28.65	7.99	29.847	18.5	84	5.8	4.3	14.4

Variable or Calibration changed at 100495 101151 => changes ignored!
Recovery finished at 100495 101426

Log File Name : 95-H-43(2)
Setup Date (MMDDYY) : 100295
Setup Time (HHMMSS) : 084126
Starting Date (MMDDYY) : 100395
Starting Time (HHMMSS) : 180000
Stopping Date (MMDDYY) : 100495
Stopping Time (HHMMSS) : 080000
Interval (HHMMSS) : 001500
Warmup : Enable

==> Current Variables and Calibration <==

Date MMDDYY	Time HHMMSS	Temp degC	pH units	SpCond mS/cm	Salin ppt	DO %Sat	DO mg/l	Depth meters	Batt volts
100395	180000	29.06	8.1	29.521	18.2	105.9	7.28	4	14.5
100395	181500	29.06	8.09	29.521	18.2	100.7	6.92	4	14.5
100395	183000	29.06	8.09	29.521	18.2	100.7	6.92	4	14.5
100395	184500	29.06	8.08	29.521	18.2	99.4	6.83	4	14.5
100395	190000	29.06	8.07	29.521	18.2	97.6	6.71	4	14.5
100395	191500	29.06	8.08	29.521	18.2	97.3	6.69	4.1	14.4
100395	193000	29.06	8.07	29.521	18.2	95.7	6.58	4.1	14.6
100395	194500	29.06	8.08	29.521	18.2	96.3	6.62	4.1	14.4
100395	200000	29.04	8.07	29.517	18.2	94.6	6.5	4.1	14.4
100395	201500	29.04	8.08	29.45	18.2	95.5	6.57	4.1	14.4
100395	203000	29	8.09	29.375	[illegible]	97.9	6.74	4.2	14.4
100395	204500	29.06	7.97	29.791	18.4	71	4.87	4.2	14.4
100395	210000	29.02	7.85	30.053	18.6	51.2	3.51	4.2	14.4
100395	211500	29.04	7.82	30.191	18.7	47.6	3.26	4.3	14.4
100395	213000	29.04	7.79	30.259	18.7	43.9	3.01	4.3	14.3
100395	214500	29.02	7.76	30.255	18.7	43.3	2.97	4.4	14.3
100395	220000	28.98	7.84	30.18	18.7	58	3.98	4.4	14.3
100395	221500	28.96	7.9	30.109	18.6	69.2	4.75	4.4	14.3
100395	223000	28.91	7.93	30.03	18.6	75.4	5.19	4.4	14.3
100395	224500	28.87	7.97	29.955	18.5	82.5	5.68	4.5	14.3
100395	230000	28.87	8	29.955	18.5	85.3	5.87	4.5	14.3
100395	231500	28.83	8.01	29.88	18.5	87.9	6.06	4.5	14.3
100395	233000	28.79	8.01	29.873	18.5	89.7	6.19	4.5	14.2
100395	234500	28.81	8	29.876	18.5	87.5	6.03	4.5	14.3
100495	0	28.81	7.99	29.944	18.5	88.6	6.1	4.5	14.3
100495	1500	28.79	7.98	29.94	18.5	82.9	5.71	4.5	14.3
100495	3000	28.75	7.96	29.933	18.5	79.9	5.51	4.5	14.2
100495	4500	28.75	7.98	29.933	18.5	77.4	5.34	4.5	14.2
100495	10000	28.75	7.98	29.933	18.5	77.4	5.34	4.5	14.2

Log File Name : 95-H-43(2)
Setup Date (MMDDYY) : 100295
Setup Time (HHMMSS) : 084126
Starting Date (MMDDYY) : 100395
Starting Time (HHMMSS) : 180000
Stopping Date (MMDDYY) : 100495
Stopping Time (HHMMSS) : 080000
Interval (HHMMSS) : 001500
Warmup : Enable

==> Current Variables and Calibration <==

Date MMDDYY	Time HHMMSS	Temp degC	pH units	SpCond mS/cm	Salin ppt	DO %Sat	DO mg/l	Depth meters	Batt volts
100495	11500	28.73	8	29.929	18.5	76.5	5.28	4.5	14.2
100495	13000	28.73	7.99	29.929	18.5	72.7	5.02	4.5	14.2
100495	14500	28.73	8	29.862	18.5	71	4.9	4.5	14.2
100495	20000	28.71	8	29.858	18.5	69.5	4.8	4.5	14.2
100495	21500	28.73	7.99	29.727	18.4	67	4.63	4.4	14.2
100495	23000	28.71	7.99	29.993	18.6	68.2	4.7	4.5	14.2
100495	24500	28.69	7.99	29.989	18.6	66.9	4.62	4.4	14.2
100495	30000	28.71	7.98	29.925	18.5	66.7	4.61	4.4	14.2
100495	31500	28.69	7.98	30.056	18.6	65.9	4.55	4.4	14.1
100495	33000	28.69	7.98	30.392	18.8	68.2	4.7	4.3	13.9
100495	34500	28.69	7.98	30.46	18.9	68.3	4.71	4.3	14.2
100495	40000	28.67	7.98	30.523	18.9	68.1	4.69	4.3	14.2
100495	41500	28.65	7.99	30.519	18.9	68.5	4.72	4.3	14.2
100495	43000	28.65	7.99	30.519	18.9	68.4	4.71	4.3	14.2
100495	44500	28.65	7.99	30.519	18.9	69.2	4.77	4.3	14.1
100495	50000	28.63	8	30.448	18.9	71	4.89	4.3	14.2
100495	51500	28.63	8	30.583	19	70.6	4.86	4.3	14.1
100495	53000	28.63	8.02	30.65	19	70	4.83	4.3	14.1
100495	54500	28.61	8.03	30.646	19	70.1	4.83	4.3	14.1
100495	60000	28.61	8.03	30.646	19	70.3	4.85	4.3	14.1
100495	61500	28.59	8.03	30.642	19	69.3	4.78	4.3	14.1
100495	63000	28.59	8.02	30.576	19	68.1	4.69	4.4	14.1
100495	64500	28.59	8.02	30.642	19	66	4.55	4.4	14.1
100495	70000	28.57	8.02	30.706	19	64.4	4.44	4.4	14.2
100495	71500	28.55	8.01	30.77	19.1	62.3	4.3	4.4	14.1
100495	73000	28.55	7.99	30.837	19.1	59.8	4.12	4.5	14
100495	74500	28.53	7.99	30.766	19.1	60	4.14	4.5	14.1
100495	80000	28.53	7.99	30.631	19	59.5	4.11	4.6	14.1

Variable or Calibration changed at 100495 101151 => changes ignored!
Recovery finished at 100495 101632