



CLEAR TECHNICAL REPORT NO. 204:3

Western Basin Nearshore Study 1978-1979;
An Evaluation of the Temperature and
Dissolved Oxygen Data

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TEMPERATURE

Rationale

Fluctuations in the water temperature of Lake Erie occur annually due to natural climatic phenomena (Figure 1). However, changes also occur as a result of human activities. Industrial effluents, discharges of electric power plants and surface runoff all contribute to elevated water temperatures (Levin et al. 1972).

The importance of assessing water temperature data is often overlooked in limnological studies. Palatability of water is adversely affected at temperatures greater than 19°C . Increased temperatures decrease water quality in treatment processes, its value for industrial uses including cooling processes, and its suitability as a habitat for aquatic life while the toxicity of many elements increases. High water temperatures may cause decreased oxygen capacity, increased oxygen demand, formation of anaerobic zones, putrification of sludge deposits and growth of sewage fungus (McKeon and Wolf 1974).

For western Lake Erie, six different temperature standards and two temperature objectives have been established by several state and international agencies (Table 1). The Ohio EPA alone has established five standards, one for each of the western basin subdivisions. Each of the standards listed in Table 1 consists of a biweekly or monthly average and a daily permissible maxima. In all, there are over 170 different temperature standards depending on the time of year and geographic location.

Seasonal Variation

Western Lake Erie water temperatures followed the seasonal atmospheric temperature fluctuations in 1978 and 1979 (Figure 1). Spring cruises for both years were conducted shortly after "ice-out" when the lake temperature averaged 9°C and 5°C for 1978 and 1979, respectively. The 4°C difference in mean temperature can be explained by the two-week time difference in the spring sampling schedules in 1978 and 1979. The sampling schedule for the remainder of the cruises was similar for 1978 and 1979 and the cruise means were very similar. During the summer each year two cruises were undertaken when the western end of the lake had a mean temperature between 20°C - 24°C , while the fall cruises had mean temperatures of 14°C and 13°C respectively. The standard error of the mean throughout the study period was less than 0.2°C per cruise. However, temperature ranges of 15°C were observed on most cruises primarily due to high temperatures from stations located near power plant effluents (Figure 1). More detailed information regarding power plant stations will be discussed in the problem area section.

Geographic Variation

On an annual basis (April through November) inshore waters in western Lake Erie average approximately 1°C warmer than the offshore waters (Figures 2

through 13). However, spring variations are much greater with offshore waters averaging 4°C lower than inshore (Figures 4 and 10).

The thermal bar phenomenon suggested by Tikhomerov (1963) for Lake Ladoga has been observed in all the Laurentian Great Lakes (Rodgers 1965). The thermal bar by definition is a mixing zone of temperatures approximately 4°C . The thermal bar acts as a vertical barrier in the early spring, preventing surface runoff from moving offshore (4°C). For example, plumes of warmer, more turbid water from the Maumee River were visible along the south shoreline during the spring cruise of 1979 (Figure 14). Due to the lateness of the spring cruise of 1978, the thermal bar had already moved out of the nearshore area. Wetzel (1975) hypothesizes that thermal bars probably occur in all lakes; however, the duration in which the thermal bar is effective may be only transitory in some lakes. This is the case in the western basin of Lake Erie due to its shallowness and the rapidity with which it warms.

The reach with the warmest temperatures is most predominantly the Maumee Bay area (Reach 3); the second warmest area being reach 2, near Monroe, Michigan. The area with the coolest temperatures consists of reaches 5, 6 and 7 which covers the south shore area from Locust Point to Huron, Ohio. These cooler temperatures are the result of less industrial use, lower amounts of surface run-off and greater water column depth.

Problem Areas

Electric power production has increased rapidly over the years and it has been predicted that by 1985, a quarter of the total surface run-off in the United States will be used for cooling (Levin et al. 1972). Future electric power requirements in the United States are expected to double approximately every ten years (Levin et al. 1972). As of 1978, there were 13 nuclear power plants operating on the Great Lakes with 12 more under construction. The western end of Lake Erie alone has five power plants, four fossil fuel and one nuclear (Table 2). The highest annual temperature averages for 1978 and 1979 occurred at stations M16 (near the effluent for the Monroe Power Plant), 08 (near the effluent of the Bayshore Power Plant), and 029 (at the mouth of Muddy Creek) (Figure 15). The station closest to the Whiting power plant (M23) is at least one mile from the effluent source and did not demonstrate any warming effect which might be caused by the discharge. Davis-Besse Nuclear Power Plant discharge is located at station 016. Definite conclusions in regard to the temperature effect of Davis-Besse are difficult. The plant was only operational for four of the eight nearshore cruises. During these four "operating" cruises, 3 cruises showed the discharge as having a greater mean (by 0.3° , 0.5° and 0.7°C) than the corresponding offshore station. The fourth "operating" cruise resulted in the inshore and offshore station means being similar. For the four "non-operating" cruises, two cruises showed the inshore discharge station with warmer temperatures (1.1°C , 0.6°C) than the corresponding offshore station that had no available heat source. Of the two remaining "non-operating" cruises, one showed the offshore station as the warmer of the two stations, and the other with the discharge and offshore stations being similar.

The importance of analyzing the effects of western basin power plants is easily understood when one considers that the western basin represents the most intensely developed basin of all the Great Lakes for power production and industrial uses, and is, as well, the shallowest. Analysis of temperature data for several stations in the proximity of the western basin power plants demonstrates the effects of the individual plants. The only power plant not assessed by the Nearshore study was the Acme Plant in Toledo, Ohio. The Acme plant is used as a peaking plant, and thus supplies power only during peak demand periods. It has the lowest delta temperature (the difference between the intake and effluent temperatures) of all five western basin plants. The Acme plant is four miles upstream from the lake and therefore out of the realm of a nearshore study.

Of the four major power plants, Monroe by far is the largest (Table 2). It has a maximum generating capacity five times that of the Bayshore Plant. Davis-Besse by design has the second largest generating capacity but due to several malfunctions the plant has not been operational on a regular basis. It is not surprising that Monroe has the greatest observed thermal effect on the western basin (Tables 3 and 4). A five-degree difference between the effluent station and the ambient water was observed in 1978 and 1979. Doyle (1976) found that the Monroe Power Plant was responsible for a 2.8° increase in temperature for Maumee and Brest Bays. Bayshore had an observed $3-4^{\circ}\text{C}$ effect on ambient water during the 1978-79 study.

The International Joint Commission (1970) assessed the effect of heated waste water on Lake Erie and concluded the effect was not significant. The total heat input in Lake Erie by power generation and industry in 1970 during the period of warming (April to August) was 0.13 percent of the natural heat input. This low figure is undoubtedly a whole lake average and is not a good indication of the thermal enrichment to the shallow western basin. Since the 1970 assessment by the International Joint Commission, the Monroe (1971) and Davis-Besse (1979) power plants have come on line, quadrupling the amount of power production provided from the western basin. It may be time to reassess the effects of heated waste.

The implication is that there is a potential problem to be recognized from the operation of fossil fuel plants and a slight potential warming from nuclear power plants. Care must be exercised to follow long-term effects of temperature on Lake Erie and, in the future, location selections of power plants, as power plants will become larger, accompanied by multiple units at a single site.

Historical Trends

Long-term data analysis is useful in establishing the present status of the lake. Long-term data was supplied for the C and O dock in Toledo for 1970 through 1979 (similar to Nearshore station 02) and U. S. Gypsum Company's intake (similar to stations 031 and 032). The data has been filtered to include data points for April 1 to October 30th to correspond to the Nearshore data base. A preliminary analysis of the data demonstrates that there are no significant changes in the temperature of these two areas (Figures 16 and 17).

DISSOLVED OXYGEN

Rationale

When one mentions the importance of measuring dissolved oxygen (D.O.) in Lake Erie, people think immediately of the central basin hypolimnion and its oxygen depletion problems. However, there is value in measuring D.O. concentrations in other areas of Lake Erie. D.O. concentrations are extremely dependent on the water temperature, i.e., water has the ability to have in solution greater quantities of dissolved oxygen when the temperatures are cooler. Water at 9°C at 100% saturation will contain 11.2 mg/l of D.O. However, water at 23°C will contain only 8.4 mg/l D.O. when 100% saturated. Although the D.O. concentration will vary throughout the year, ideally the saturation should remain near 100%.

It is possible to have oxygen saturations that exceed 100%. Oxygen in excess of saturation is said to improve its palatability; it may also adversely affect the water by causing corrosion of metal pipes, and increasing the amount of disease and gill damage in fish (McKee and Wolf 1963).

Low concentrations of D.O. can cause an unfavorable environment for fish, result in odiferous products from anaerobic decomposition, enhance lethal effects in the presence of toxic substances, and cause species changes in benthic and fish populations.

These detrimental effects have all occurred in the western basin over the last 30 years. One of the most damaging events was recorded by Britt (1955) when oxygen concentrations lower than 1 ppm were found in the western basin during early September of 1953. During this sampling period, an average of 465 mayfly nymphs per square meter (all dead) were recorded. The effect of this population decrease on the fish population was monitored by fish stomach analysis. The volume of Hexagenia as percent of total stomach content dropped from 67% in September of 1952 to 4.5% in September of 1953, or approximately 15 fold. This was also accompanied by a decrease in the percentage of fish that had any food in their stomachs indicating the inability of fish to replace Hexagenia in their diet.

The D.O. standards established for Lake Erie's western basin take the biological requirements of benthos and fish populations into account. The most lenient standard (4.0 mg/l), established by the Ohio Environmental Protection Agency (1978), was for "excepted areas". The western basin "excepted areas" include Maumee Bay, Magee Marsh, Port Clinton Harbor, Sandusky Bay and Huron Harbor. The International Joint Commission (1978), the Ohio Environmental Protection Agency (1978) (for Lake Erie waters excluding excepted areas) and the Michigan Department of Natural Resources have all selected 6.0 mg/l as the new minimum Lake Erie D.O. standard. For an actual listing of nearshore stations that did not comply during 1978 and 1979 see

CLEAR Technical Report No. 176. The number of D.O. violations recorded was only 5 percent in 1978 and 3.5 percent in the 1979 field season. There was only one D.O. violation for the spring cruise each year and this occurred at station M3 near the dredge spoil area under construction off Point Mouillee. The remaining violations occurred during the early summer and late summer cruises at the Maumee River mouth and the stratified area near Huron, Ohio. There were no violations for D.O. found for the fall cruises.

Seasonal Variation

The highest D.O. concentrations were found during the spring cruises in both 1978 and 1979. As expected, the graph of seasonal D.O. concentrations is an inverse to the one shown for temperatures (Figure 18). Cruise means, maximum and minimum concentrations, the stations at which these extreme concentrations occur, standard errors and sample size may be seen in the tables in the water quality introduction.

The seasonal pattern for D.O. percent saturation was similar in both years with one exception. Usually the pattern was bimodal with the highest saturations (95%) in springtime and the second highest saturations in the fall (92%). The summer cruise means average around 90-91 percent saturation. The exception was the late summer (mid-September) cruise of 1979. During this time the western basin nearshore zone was experiencing a blue-green algal bloom. Blue-green algae were the dominant group at all stations during this cruise with a maximum biomass of 94 ug/l and a maximum concentration greater than 1×10^6 cells/ml. The taxa in order of predominance were Aphanizomenon flos-aquae, Oscillatoria agardhii, O. limnetica and O. tenuis.

In many areas the algae at the surface were so thick that a mat was observed. The coloration of this mat varied from pea-green to turquoise. In areas not covered by the algal mat, algal clumps were visible a meter below the water surface. The last recorded blue-green bloom in western Lake Erie occurred ca. 1970 (Taft 1981, personal communication).

Geographic Variation

The D.O. saturation varied from 0 to 185 percent during the nearshore western basin study with the cruise means consistently greater than 90 percent (Figure 19). The lowest D.O. saturations were found in the hypolimnetic waters in the Huron, Ohio area during the summer cruises. Occasionally there was stratification found at stations 047 and 050 and it was at these locations that anoxia was found in the thin hypolimnia. This area off Huron is subjected to temporary stratification caused by sloshing of the central basin hypolimnion on a day-to-day basis. For example, during our three days of repetitive sampling in the Huron area, stratification was observed only on the first day and again on the third day. The other area where low D.O. values were encountered was located at the mouth of the Maumee River. This station (02) was approximately 0.5 miles from the Toledo Sewage Treatment Plant.

The annual average dissolved oxygen concentrations are very similar for inshore and offshore stations (Figures 20-23). The lowest D.O. concentrations are found consistently at station 02 (inshore). Other inshore stations with relatively lower D.O. values are stations M16 (Monroe Power Plant), 08 (Bayshore Power Plant) and 044 (Huron River). The effect of the thermal plumes seem to be slightly influencing D.O. values (Figures 20 and 22). Only one offshore station was cited as having D.O. violations (Figures 21 and 23). Station M3 was observed to have concentrations below the 6 mg/l standard during the spring cruises of both years. The other offshore stations appear to be of uniform concentration. The inshore-offshore couplet data is presented by cruise in Figures 24-31.

Problem Areas

The low dissolved oxygen concentrations did not present a major problem in the nearshore zone during this study. However, the open lake areas of the western basin that are deep enough to stratify during quiescent periods present a significant potential problem as far as low D.O.'s are concerned. It was primarily at open western basin stations, not nearshore stations, that Britt (1955) recorded low D.O.'s and the extermination of mayfly nymphs.

The areas where low dissolved oxygen were recorded during the western basin nearshore 1978-1979 study bear watching. These areas are: (1) Point Mouille dredge spoil (under construction); (2) the effluent area of Monroe Power Plant; (3) the Toledo Sewage Treatment Plant; and (4) the stratified area near Huron, Ohio. Gregor and Ongley (1978) found very similar observations in their 1967-1973 data analysis of the nearshore and open waters of the western basin. In addition to the low D.O. areas reported for this study, they also reported a 'tongue' of water with low D.O. saturation levels extending from the Detroit River during the summer months.

Gregor and Ongley (1978) also observed average saturation levels up to 140% in the western basin. According to McKee and Wolf (1963), there are problems which can occur as a result of supersaturation of dissolved oxygen: (1) corrosion of metal pipes and boilers, and (2) disease and gill damage to fish. In ponds with 150% D.O. saturation the carp populations seemed to have a higher percentage of disease than ponds with saturations of 100-125% (McKee and Wolf, 1963). These effects of high D.O. saturation do not seem to be a problem in Lake Erie or other lakes. Hutchinson (1957) found from worldwide limnological studies that different authors reported from 7 to 48 percent of their samples to have supersaturated oxygen levels.

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TABLES

TABLE 1
WESTERN LAKE ERIE TEMPERATURE STANDARDS (OEPA¹ AND MDNR²)
AND OBJECTIVES (IJC³ AND OME⁴) WITH THE EXCEPTION OF MIXING ZONES

	OEPA WESTERN BASIN	OEPA CENTRAL BASIN	OEPA MAUMEE BAY	OEPA SANDUSKY BAY	EXPECTED AREAS	OEPA	DAILY MAX	DAILY MAX	DAILY MAX	OEPA LAKE ERIE
	Average	Daily Max	Average	Daily Max	Average	Daily Max	Average	Daily Max	Average	Daily Max
Jan. 1-31	-	1.7	-	1.7	8.3	11.1	8.3	11.1	-	11.1
Feb. 1-29	-	3.3	-	3.3	8.3	11.1	8.3	11.1	-	11.1
Mar. 1-15	-	3.9	-	3.9	8.9	11.7	8.9	11.7	-	12.8
Mar. 16-31	-	7.2	-	7.2	10.0	12.2	10.0	12.8	-	12.8
April 1-15	-	10.6	6.1	8.9	11.1	15.0	11.0	13.9	-	15.0
April 16-30	11.7	13.3	11.7	13.3	13.9	17.2	13.9	16.7	-	17.2
May 1-15	15.0	17.8	15.0	17.2	16.1	18.9	17.2	20.0	-	18.9
May 16-31	18.3	22.2	17.2	22.2	18.3	24.2	20.0	22.8	-	24.4
June 1-15	23.9	25.6	23.9	25.6	21.7	25.0	23.3	26.1	-	27.8
June 16-30	26.7	28.3	26.7	28.3	29.3	30.6	28.3	30.6	28.9	31.1
July 1-31	28.32	9.42	8.32	9.42	8.33	0.62	8.3	30.6	28.9	31.1
										26.7

TABLE 1 CONT.

	OEPA WESTERN BASIN	OEPA CENTRAL BASIN	OEPA MAUMEE BAY	OEPA SANDUSKY BAY	OEPA EXPECTED AREAS		OEPA LAKE ERIE	
					Daily Max	Daily Average		
Aug 1-31	28.3	29.4	28.3	29.4	30.6	28.3	30.6	28.9
Sept. 1-15	25.6	28.3	24.4	27.2	28.3	28.3	30.6	28.9
Sept. 16-30	24.4	27.2	21.7	24.4	23.9	26.7	23.9	26.7
Oct. 1-15	18.9	21.7	18.9	21.7	20.6	23.3	20.6	23.3
Oct. 16-31	15.6	18.3	14.4	17.2	17.8	20.6	17.8	20.6
Nov. 1-30	11.7	14.4	8.9	11.7	15.0	17.8	15.0	17.8
Dec. 1-31		7.8		7.8	8.3	11.1	8.3	11.1

FOOTNOTES

1. Ohio Environmental Protection Agency 1978.
2. Michigan Department of Natural Resources, Proposed 1978.
3. International Joint Commission 1970.
4. "There should be no change in temperature that would adversely affect any local or general use of the waters."
5. Ontario Ministry of the Environment 1970.
6. Applies to Lake Erie Central Basin which includes the area of Lake Erie east of a line drawn from Pelee Point, Canada, to Scott Point on Cattaraugus Island to the Pennsylvania-Ohio state line.
7. Applies to Maumee Bay which includes all waters of the state known as Maumee Bay including the Maumee River estuary and the estuary portions of all tributaries entering Maumee Bay to the Lake Erie mean high water level.
8. Applies to Sandusky Bay which includes all waters of the state known as Sandusky Bay including the Sandusky River estuary portions of all tributaries entering Sandusky Bay to the Lake Erie mean high water level.
9. Applies to Lake Erie Excepted Areas which include Magee Marsh Area, Fort Clinton, Huron, Vermilion, Lorain, Rocky River/Cleveland Harbor, Fairport/Painesville, Ashtabula, Conneaut, and Mentor. Usually included in the Excepted areas are the Maumee and Sandusky Bays which have special standards established for temperature only.
10. Applies to Lake Erie waters which lie within the state.

TABLE 2
WESTERN BASIN POWER PLANT CHARACTERISTICS

Characteristic	Monroe*	Whiting*	Bay Shore	Davis-Besse	Acme
Location	Western Shore Lake Erie, Monroe, Michigan	Western Shore Lake Erie	Southwest Corner of Maumee Bay, Toledo, Ohio	South Shore Western Basin, Locust Point, Ohio	City of Toledo, Ohio
Maximum Generating Capacity	3,150 Megawatts	345 Megawatts	623 Megawatts	906 Megawatts	322 Megawatts
Mean Annual Operation (%)**	62	68	100	33	33
Average Flow m/day	7.3×10^6	1.17×10^6	2.83×10^6	1.09×10^5	4.8×10^5
Gal. Per Min.	1,340,000	215,000	518,000	20,000	88,000
Intake Location	Raisin River Mile 0.1	North Maumee Bay	Maumee River Mile 0.1	914 meters off- shore, Water Depth 4 Meters submerged intake	Maumee River 3.7 miles upstream
Effluent Location	open discharge canal	open discharge canal	open discharge canal	offshore submerged discharge jet	open discharge canal
Temperature (°F) From Intake to Effluent	16.7 (summer) 17.8 (winter)	15.0 (summer) 18.0 (winter)	9.6	20	9.4
Heat Rejection	1.96×10^{11}	2.81×10^{10}	5.95×10^{10}	1.38×10^8	9.94×10^9
Special Features	Fish Pump Once-through cooling	Once-through cooling	Once-through cooling	Only operational power plant in western basin with cooling tower	Peaking Plant Once-through cooling

*Supplied by Chang Bek and Tom Doyle, Michigan Dept. of Natural Resources, 1981 (personal communication).
**Percentage of maximum generating capacity.

TABLE 3
1978 NEARSHORE WESTERN BASIN TEMPERATURE DATA
ANALYZED FOR POWER PLANT EFFECTS

Station No.	mean	Maximum concentration	Minimum concentration	n	S.E.	Station Description
M16	25.67	31.0	13.20	11	2.15	Mouth of Monroe Power Plant Discharge Canal
M12	19.90	26.0	7.70	11	1.98	Mouth of the Raisin River
M17	19.96	26.0	11.20	11	1.80	Mouth of La Plaisance Creek
08	23.12	31.0	15.00	10	2.32	500 m north of Outfall of Toledo Edison's Bayshore Plant
03	18.89	25.30	11.00	11	1.97	Maumee Channel
09	19.12	28.00	11.20	10	2.10	Maumee Bay near Cedar Point
016	17.77	23.40	9.80	11	1.77	Davis-Besse Power Plant Jet Discharge
015	17.71	23.50	9.00	11	1.83	Mouth of Sand Creek
017	17.28	23.20	9.50	11	1.70	Davis-Besse Submerged Intake
021	18.11	24.00	9.80	11	1.83	Mouth of Toussaint River
M24	19.46	26.0	10.60	11	1.92	2500 m offshore of Whitting Power Plant
M25	19.51	27.0	10.40	11	1.96	5000 m offshore of Whitting Power Plant
M23	19.28	27.0	12.00	11	1.83	Southeast of Whitting Power Plant

TABLE 4
1979 NEARSHORE WESTERN BASIN TEMPERATURE DATA
ANALYZED FOR POWER PLANT EFFECTS

Station No.	mean	Maximum concentration	Minimum concentration	n	S.E.	Station Description
M16	22.93	31.00	13.40	12	1.81	Mouth of Monroe Power Plant Discharge Canal
M12	17.65	26.30	7.60	12	1.94	Mouth of the Raisin River
M17	15.73	26.50	6.40	12	1.80	Mouth of La Plaisance Creek
08	18.54	30.00	5.40	12	2.41	500 m north of Outfall of Toledo Edison's Bayshore Plant
03	15.46	25.10	7.20	12	2.07	Maumee Channel
09	14.95	25.20	4.30	12	2.34	Maumee Bay near Cedar Point
016	15.43	25.50	3.00	12	2.52	Davis-Besse Power Plant Jet Discharge
015	15.99	24.50	2.00	11	2.48	Mouth of Sand Creek
017	16.05	24.70	4.00	11	2.36	Davis-Besse Submerged Intake
021	14.84	25.00	3.50	11	2.55	Mouth of Toussaint River
M24	15.42	24.60	4.30	12	2.16	2500 m offshore of Whitting Power Plant
M25	15.22	24.40	3.90	12	2.26	5000 m offshore of Whitting Power Plant
M23	14.51	25.20	5.90	11	2.19	Southeast of Whitting Power Plant

FIGURES

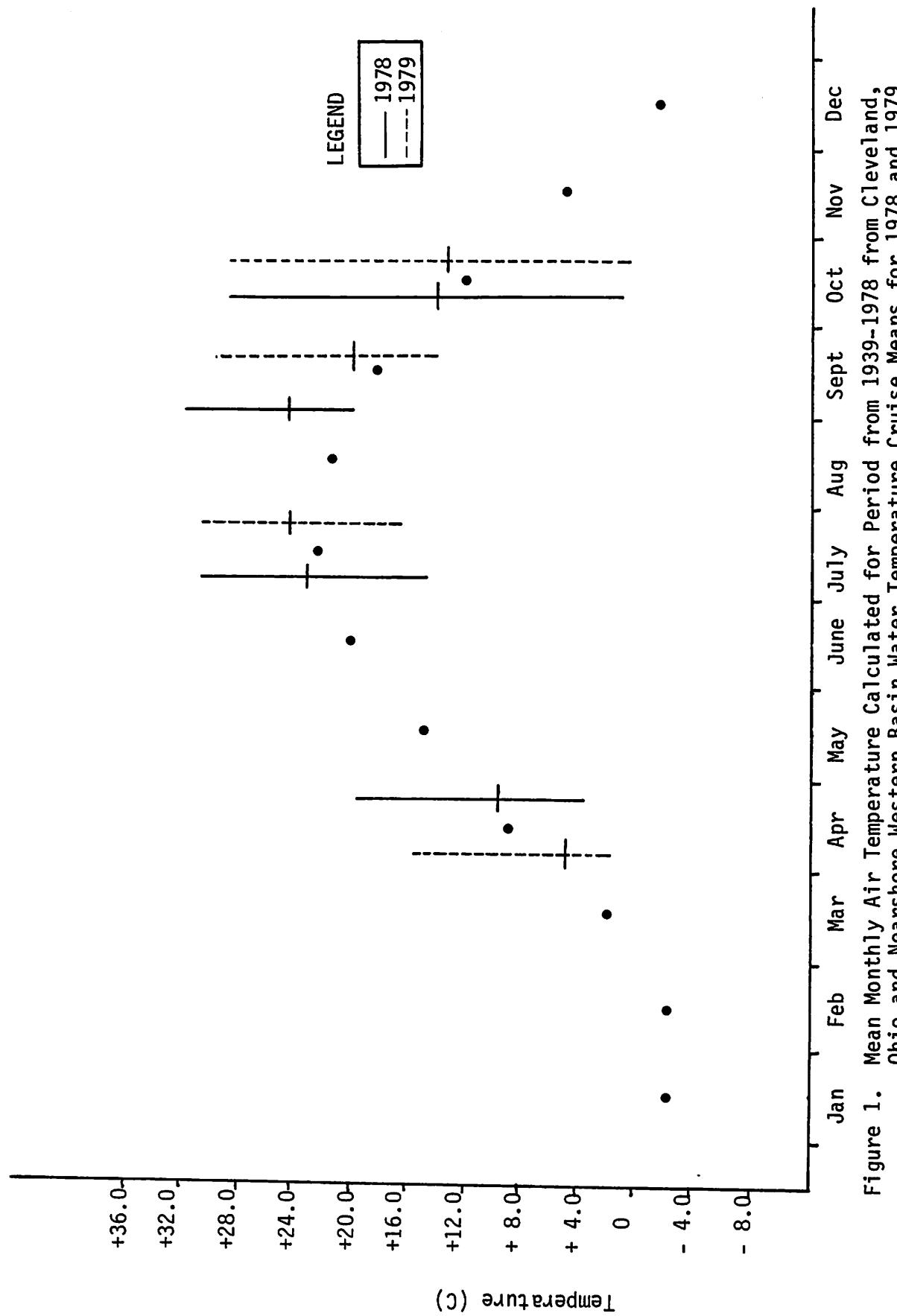


Figure 1. Mean Monthly Air Temperature Calculated for Period from 1939-1978 from Cleveland, Ohio and Nearshore Western Basin Water Temperature Cruise Means for 1978 and 1979.

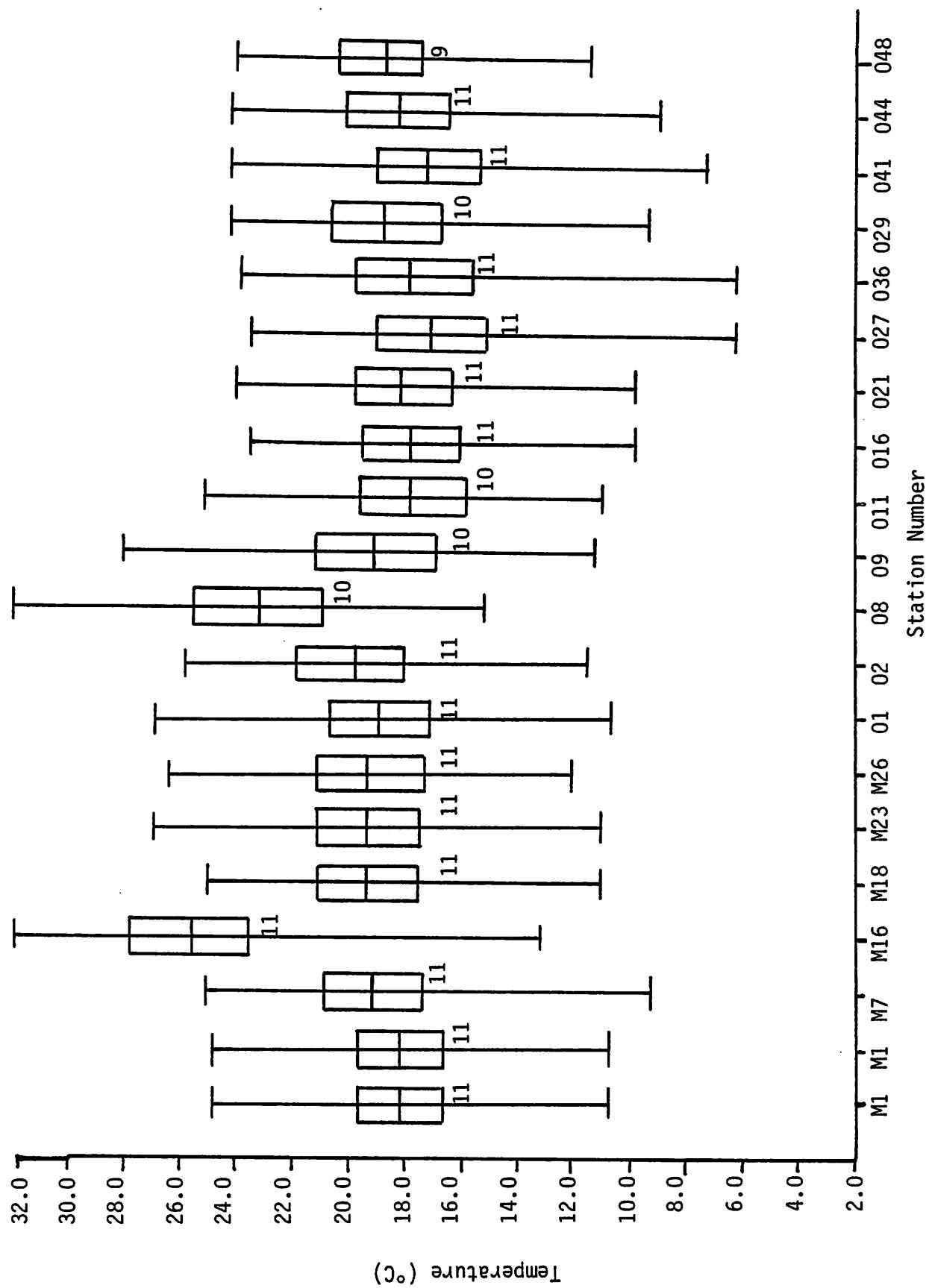


Figure 2. Annual Average Temperature at Inshore Stations in 1978.

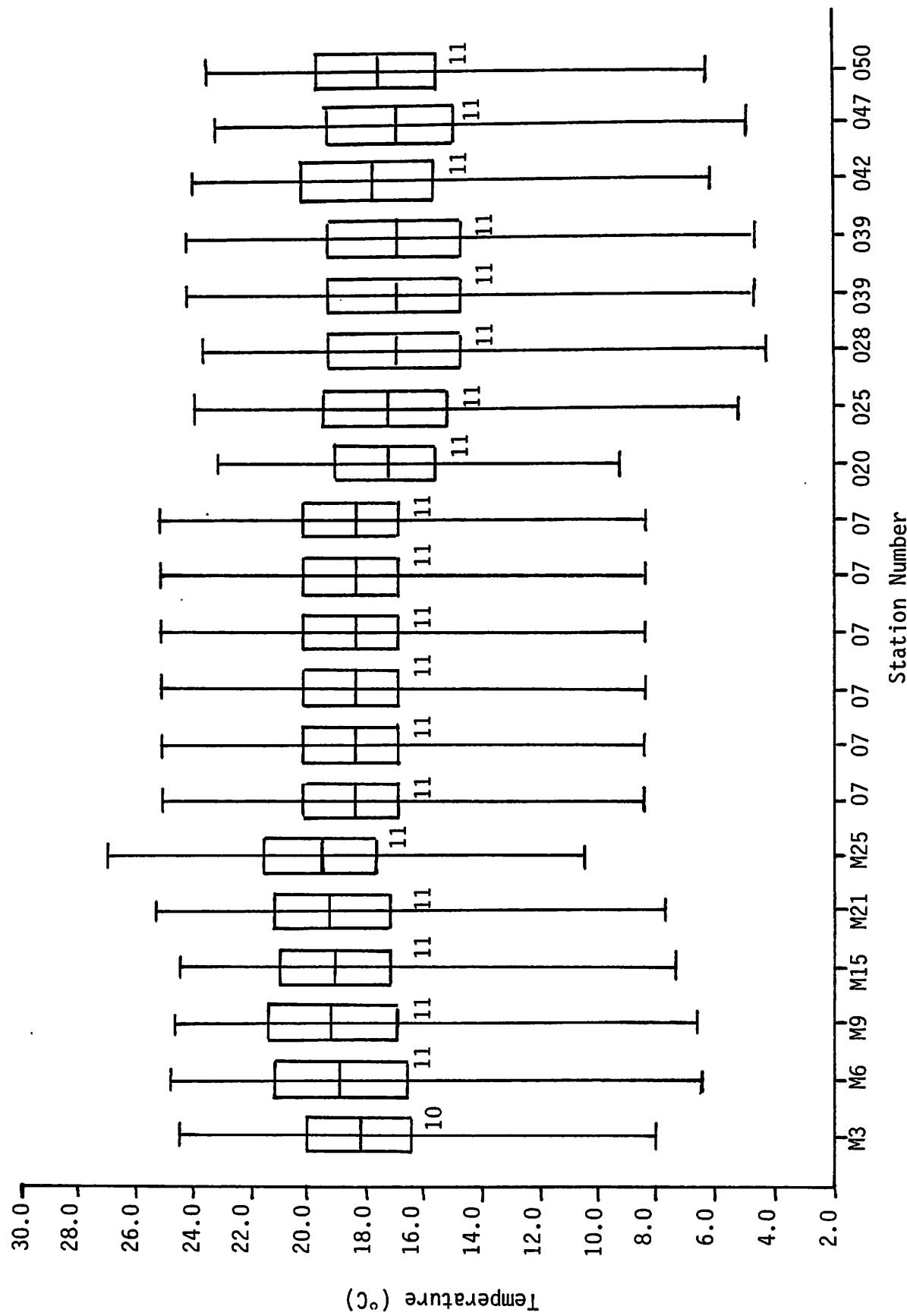


Figure 3. Annual Average Temperature at Offshore Stations in 1978.

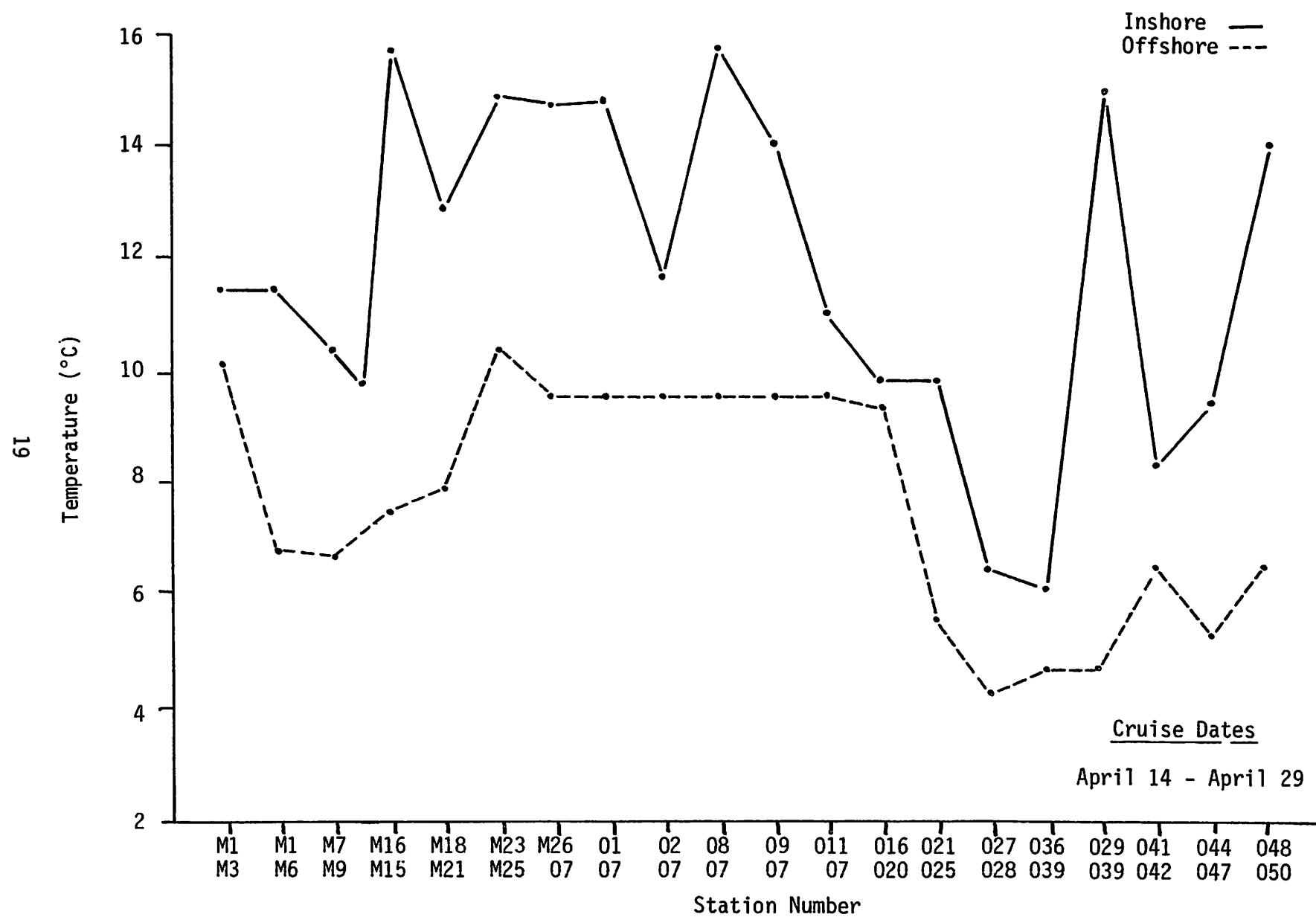


Figure 4: Temperature at Inshore and Offshore Stations for Cruise 1 of 1978.

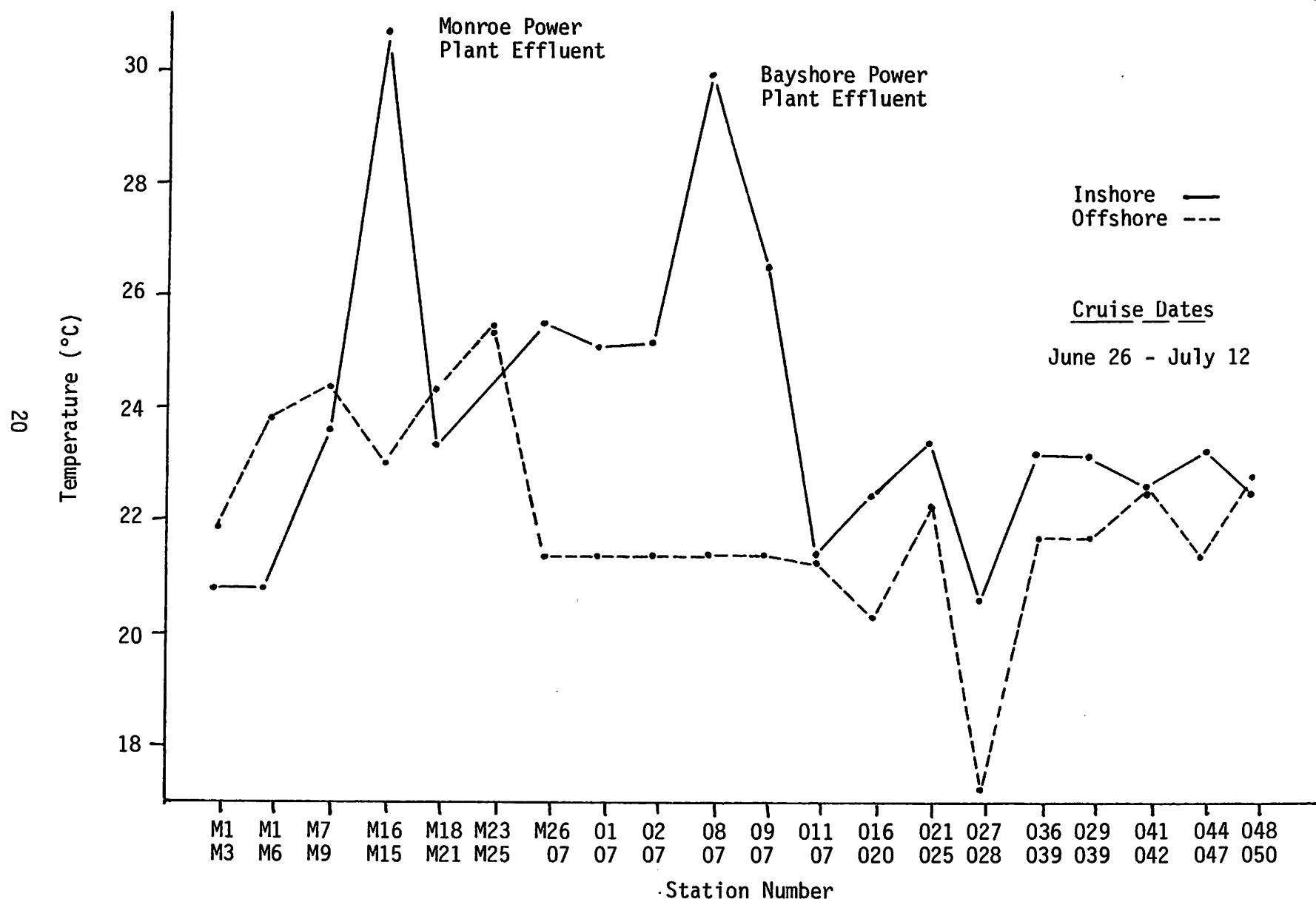


Figure 5. Temperature at Inshore and Offshore Stations for Cruise 2 of 1978.

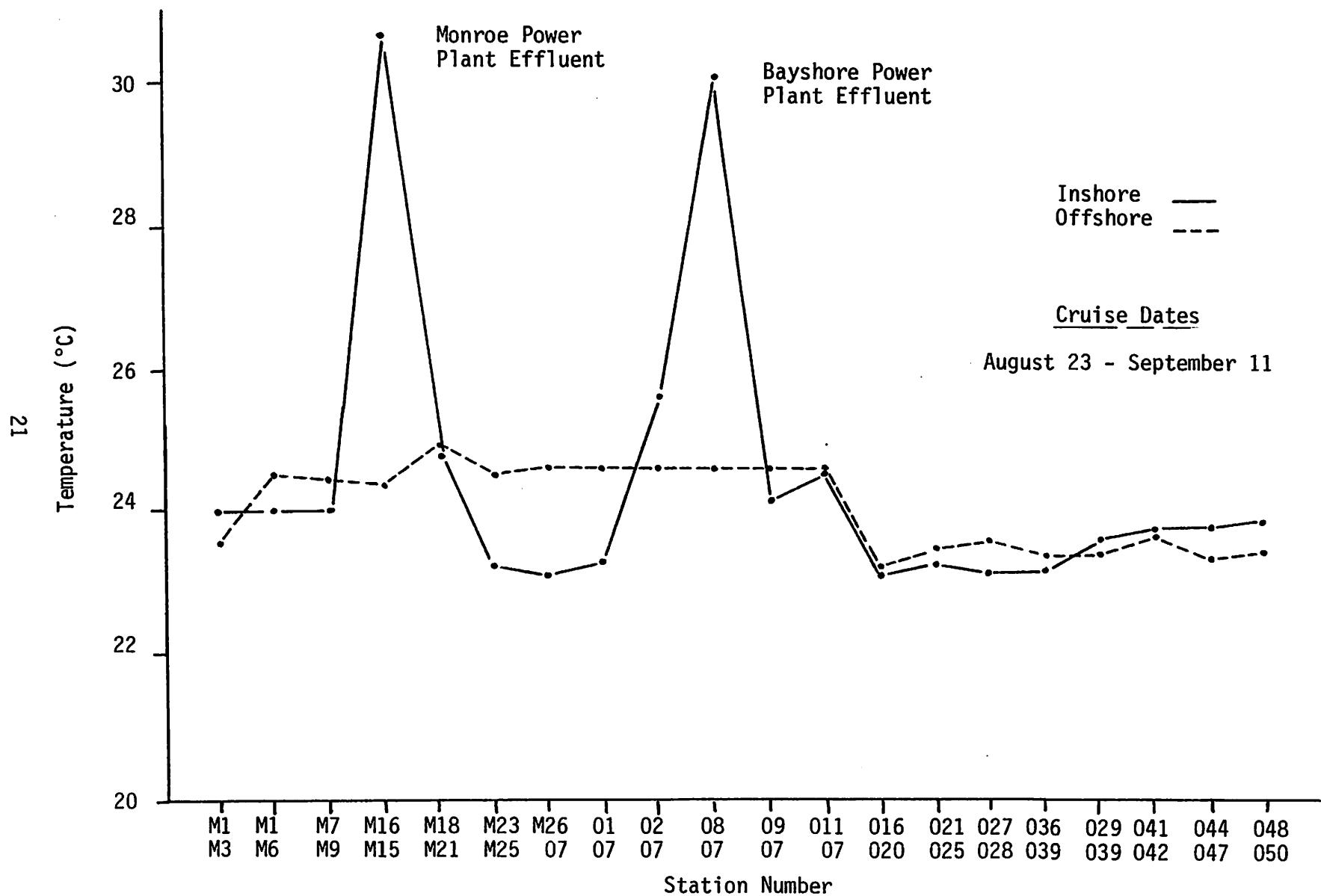


Figure 6. Temperature at Inshore and Offshore Stations for Cruise 3 of 1978.

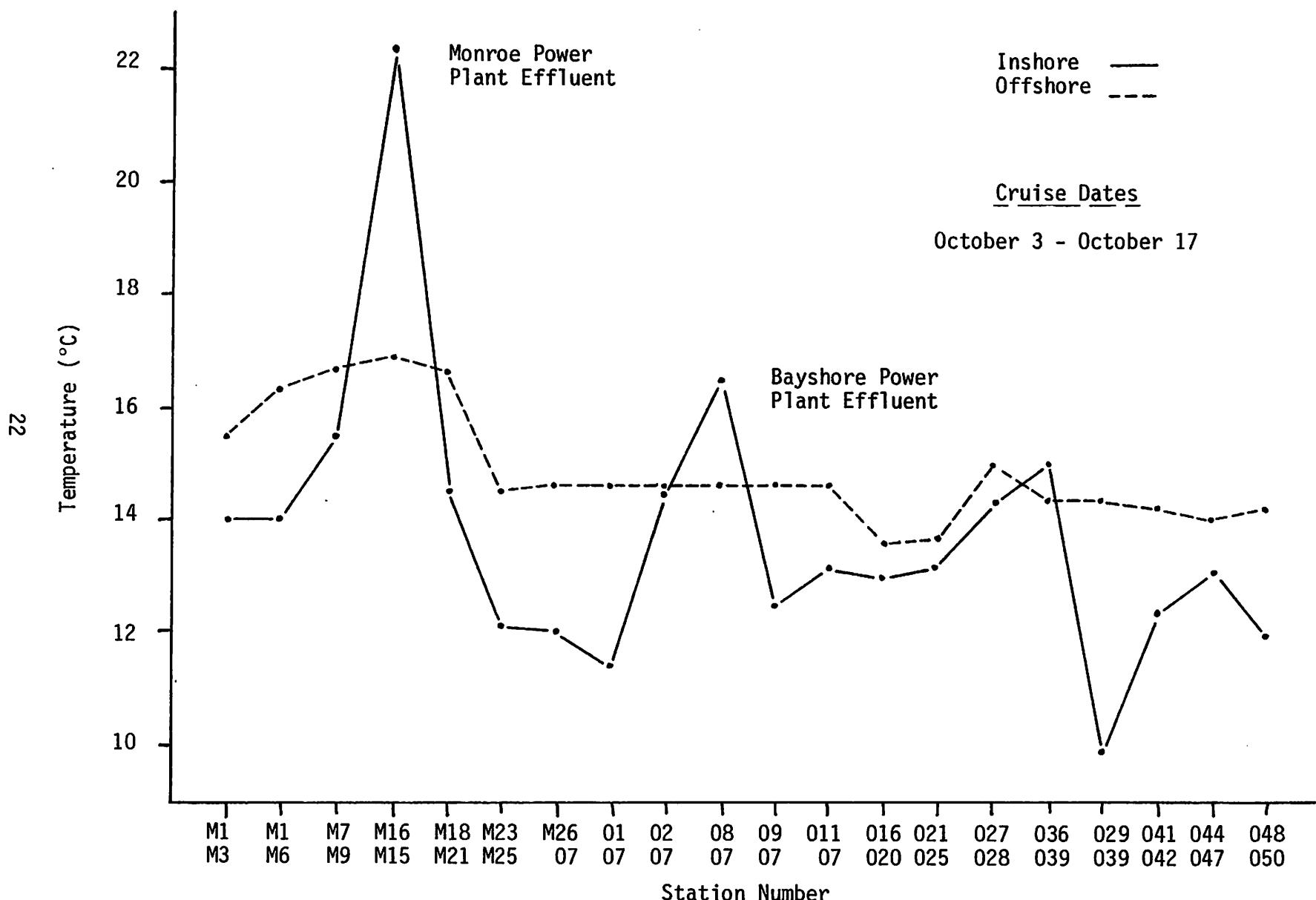


Figure 7. Temperature at Inshore and Offshore Stations for Cruise 4 of 1978.

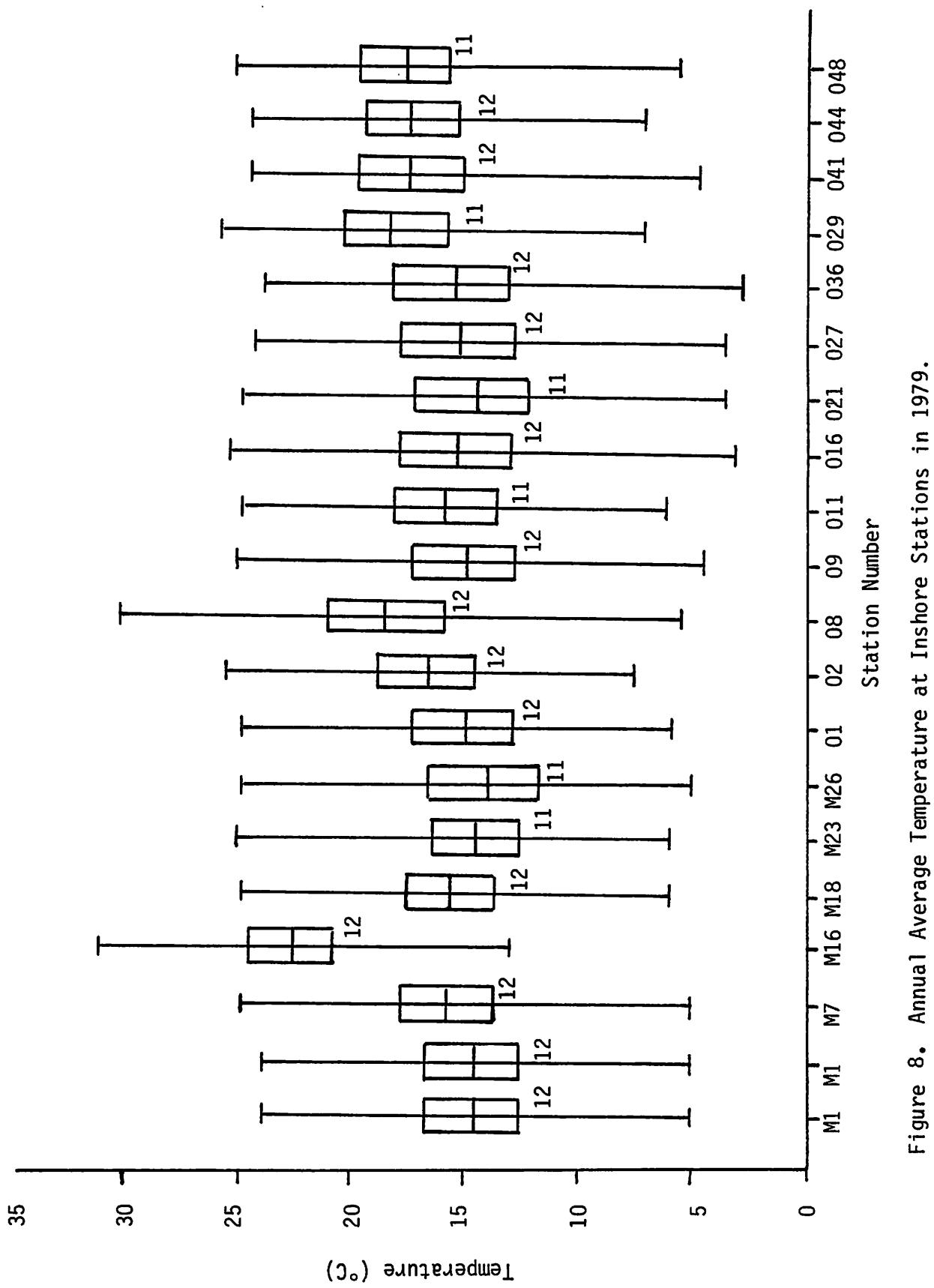


Figure 8. Annual Average Temperature at Inshore Stations in 1979.

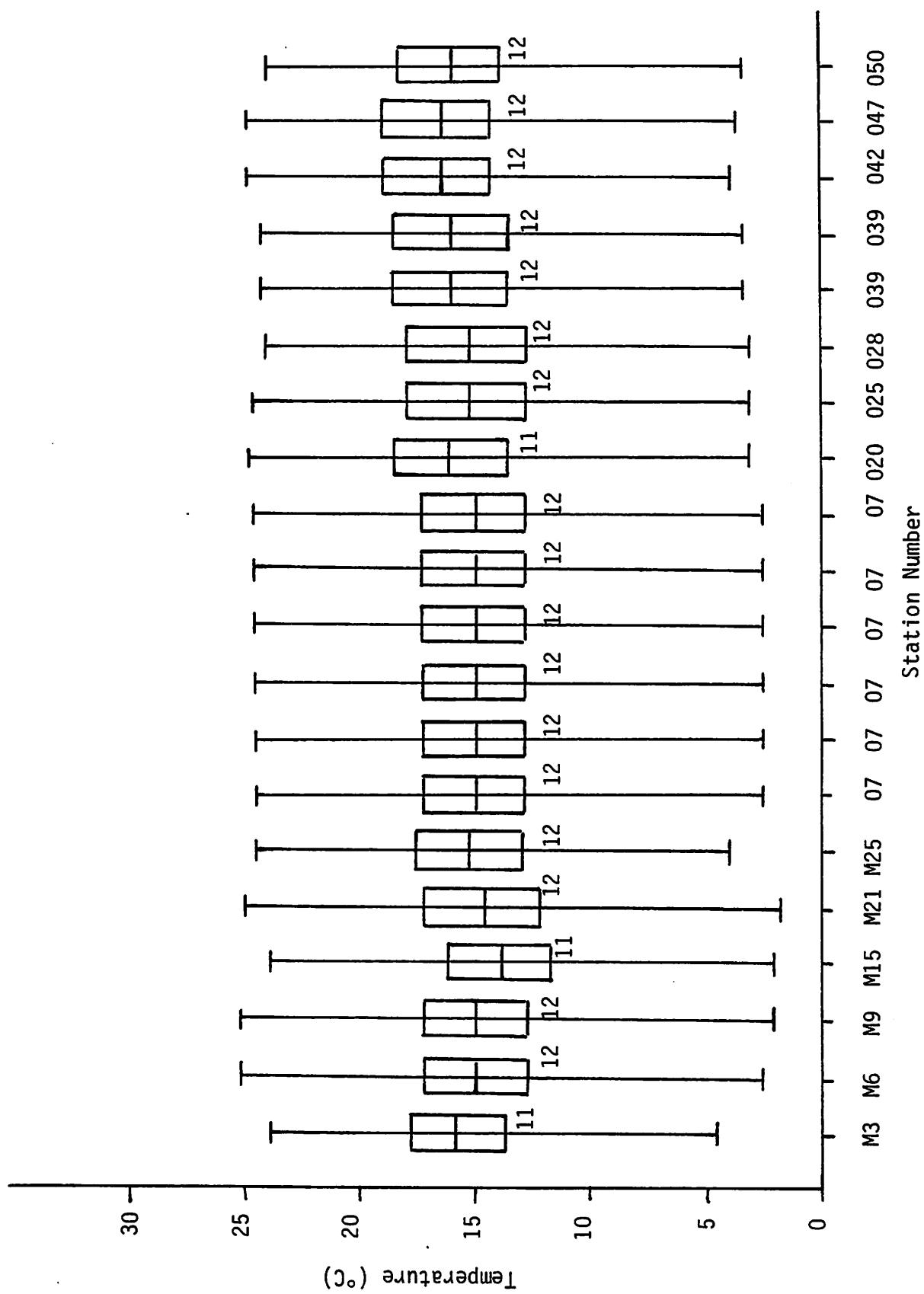


Figure 9. Annual Average Temperature at Offshore Stations in 1979.

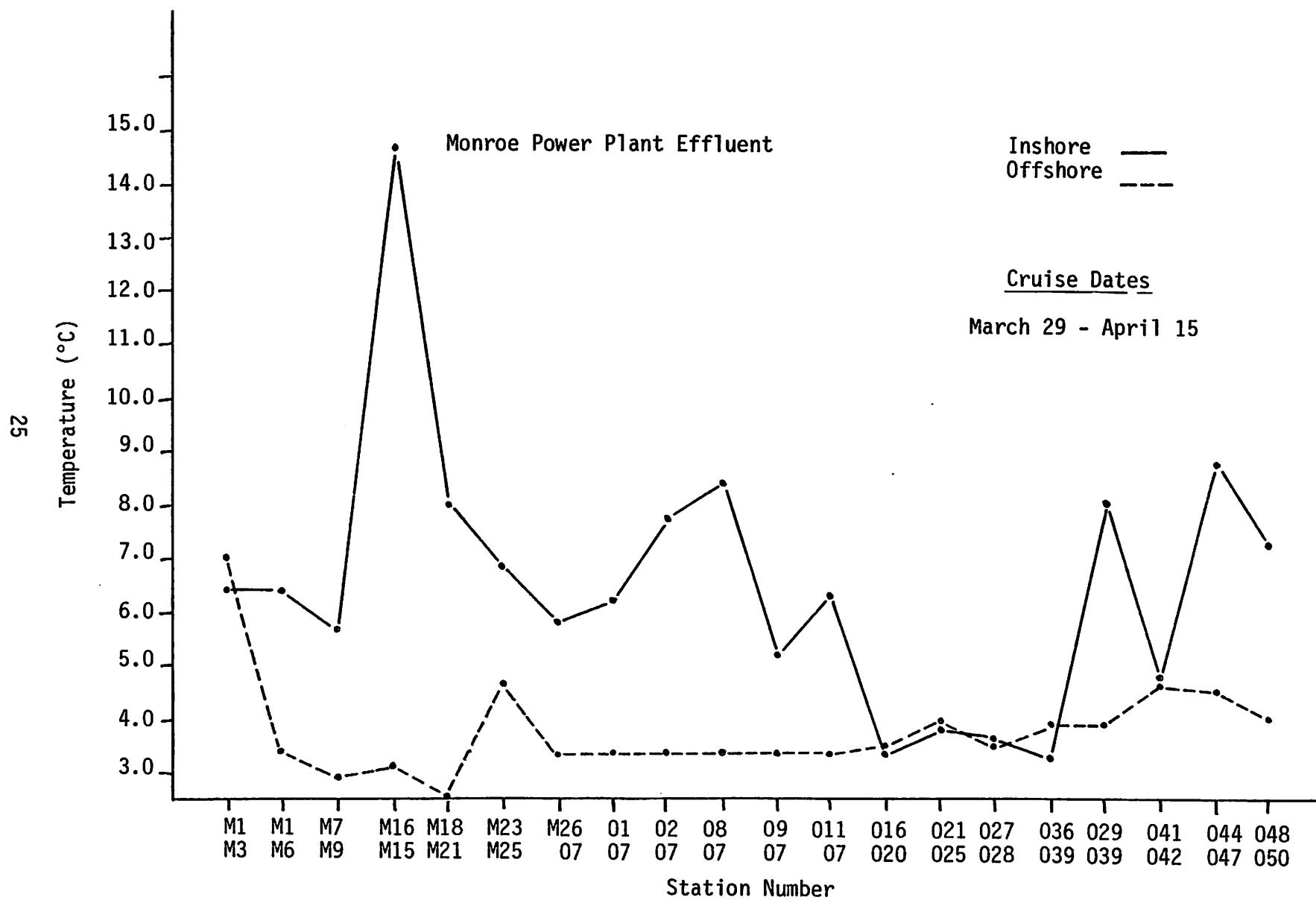


Figure 10. Temperature at Inshore and Offshore Stations for Cruise 1 of 1979.

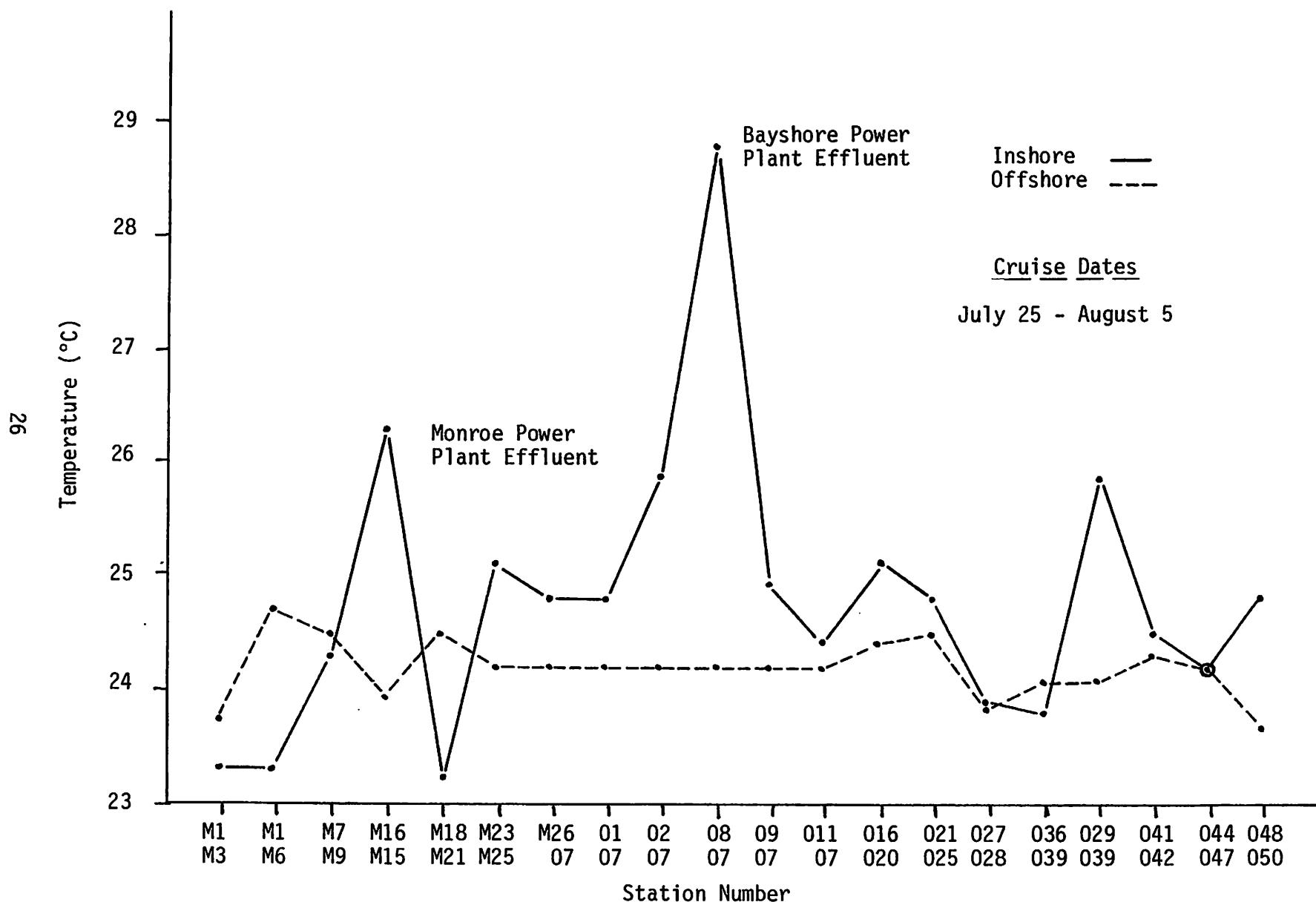


Figure 11. Temperature at Inshore and Offshore Stations for Cruise 2 of 1979.

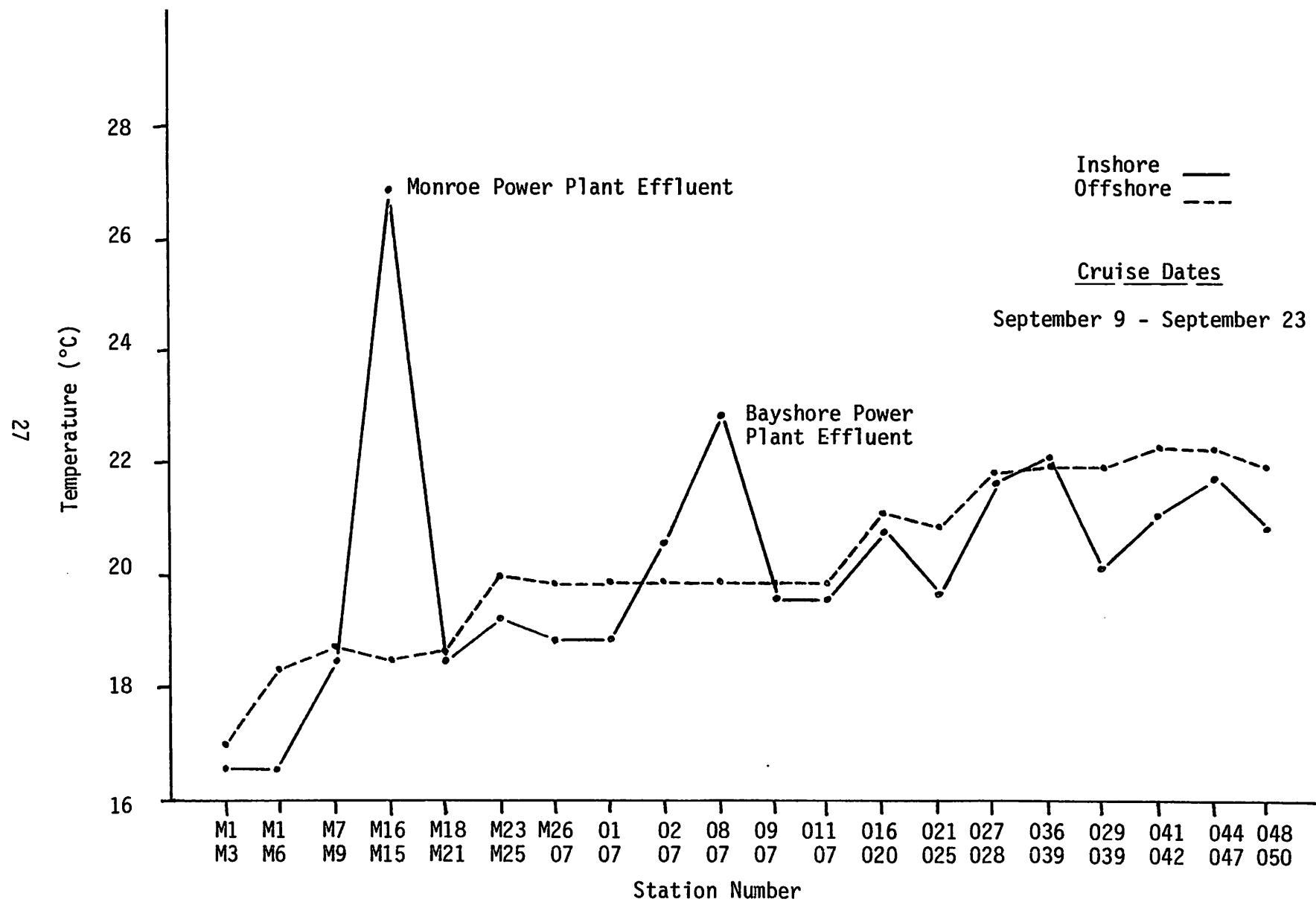


Figure 12. Temperature at Inshore and Offshore Stations for Cruise 3 of 1979.

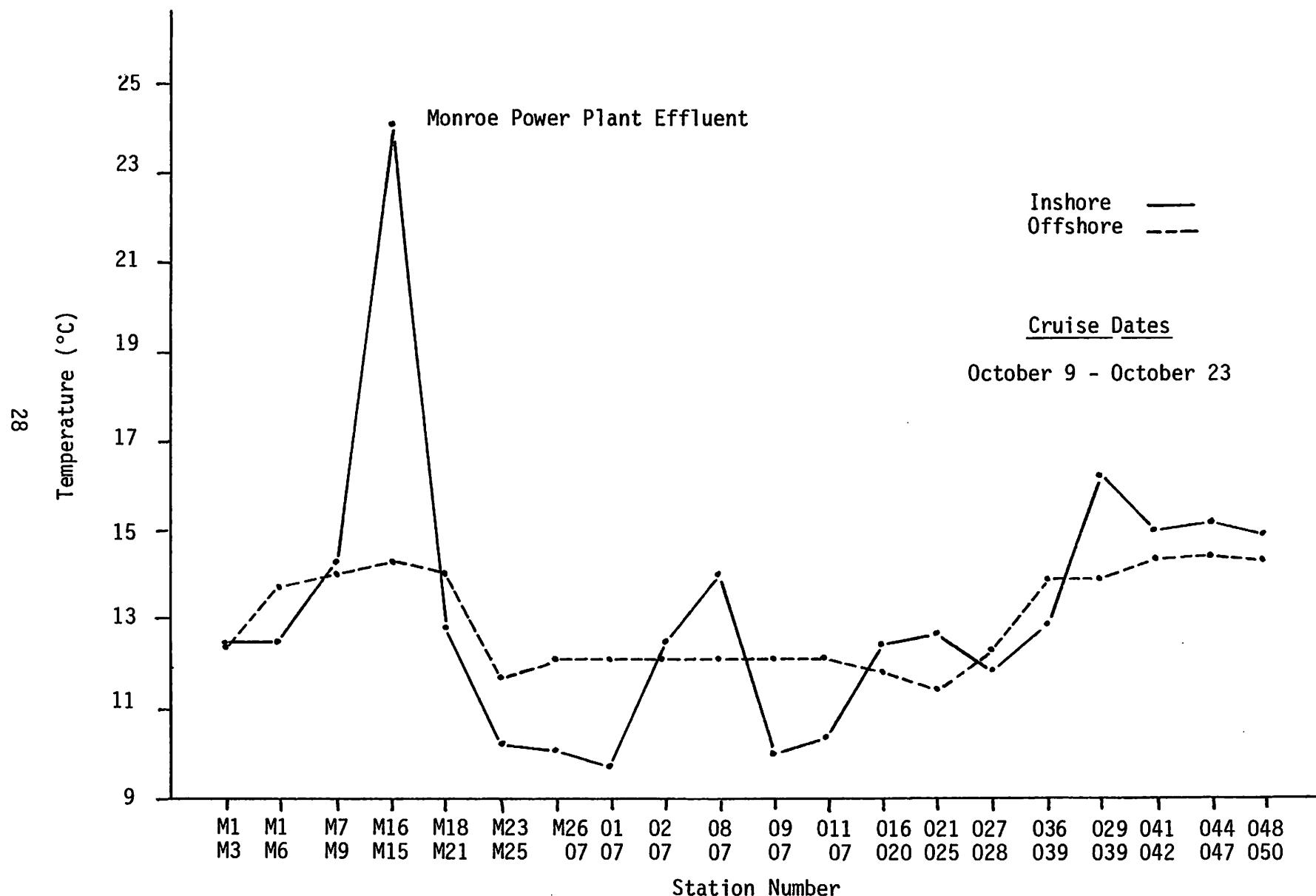


Figure 13. Temperature at Inshore and Offshore Stations for Cruise 4 of 1979.

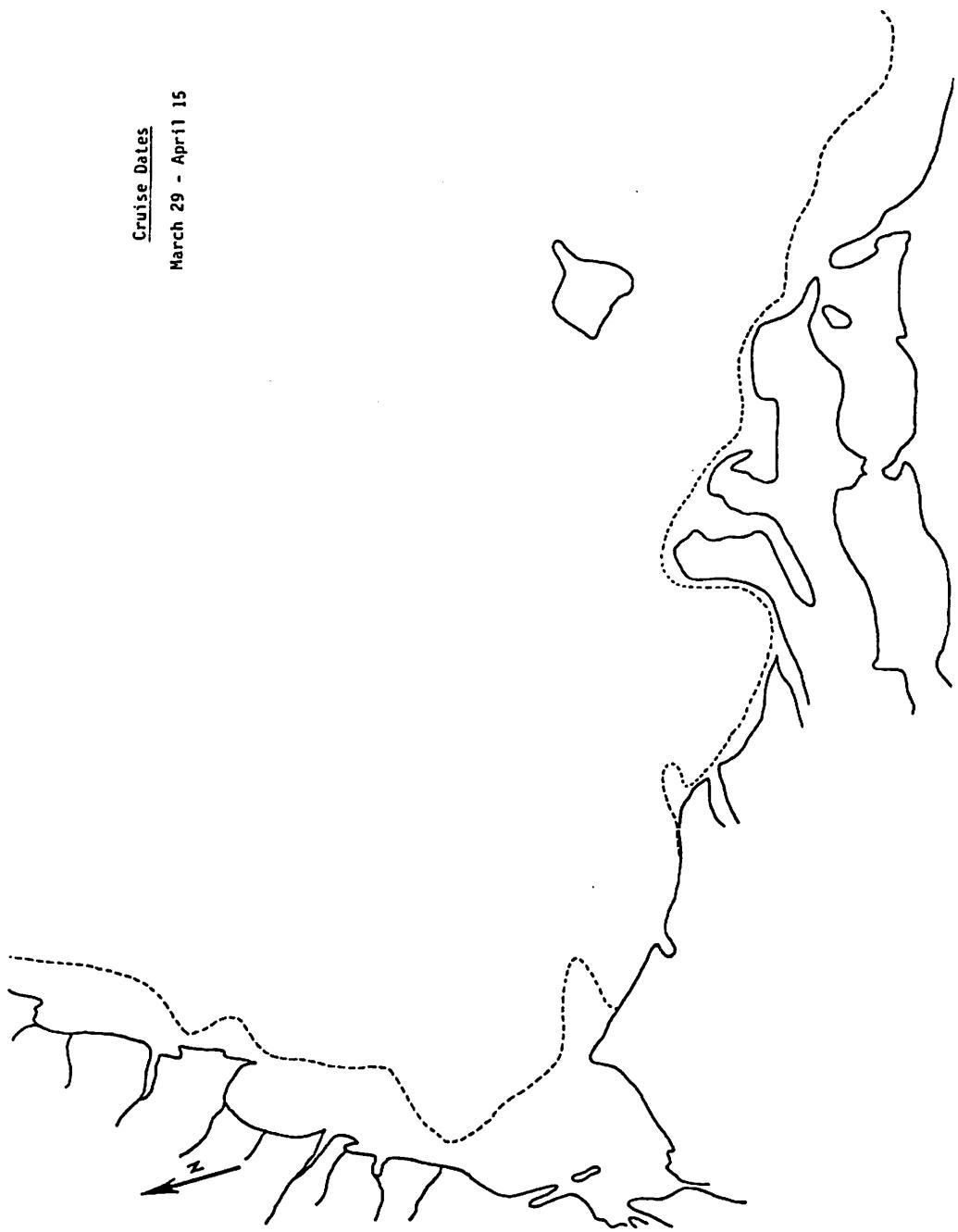


Figure 14. Proposed Thermal Bar as Shown by 4°C Contour for Cruise 1, 1979.

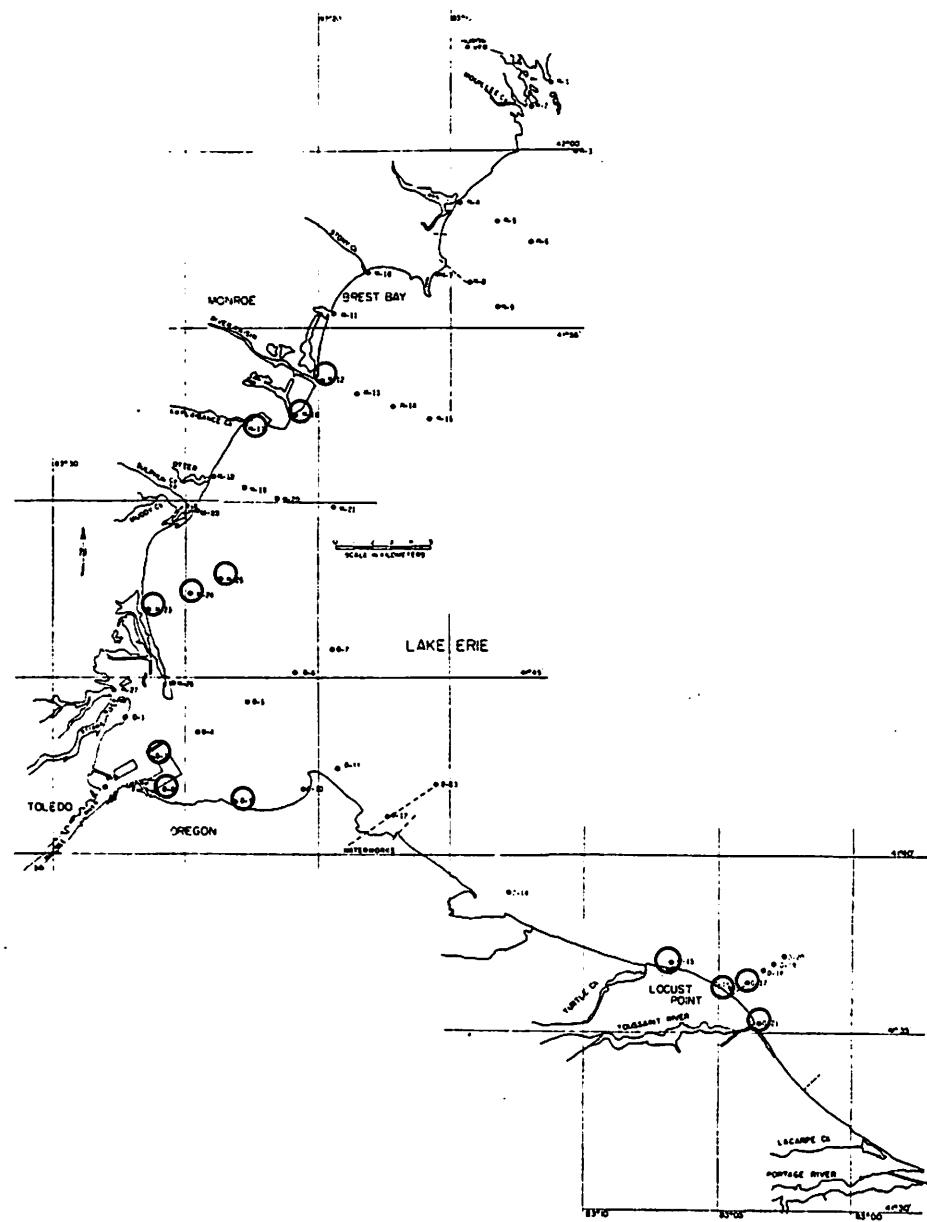


Figure 15. Nearshore Western Basin Stations Analyzed for Power Plant Thermal Effects.

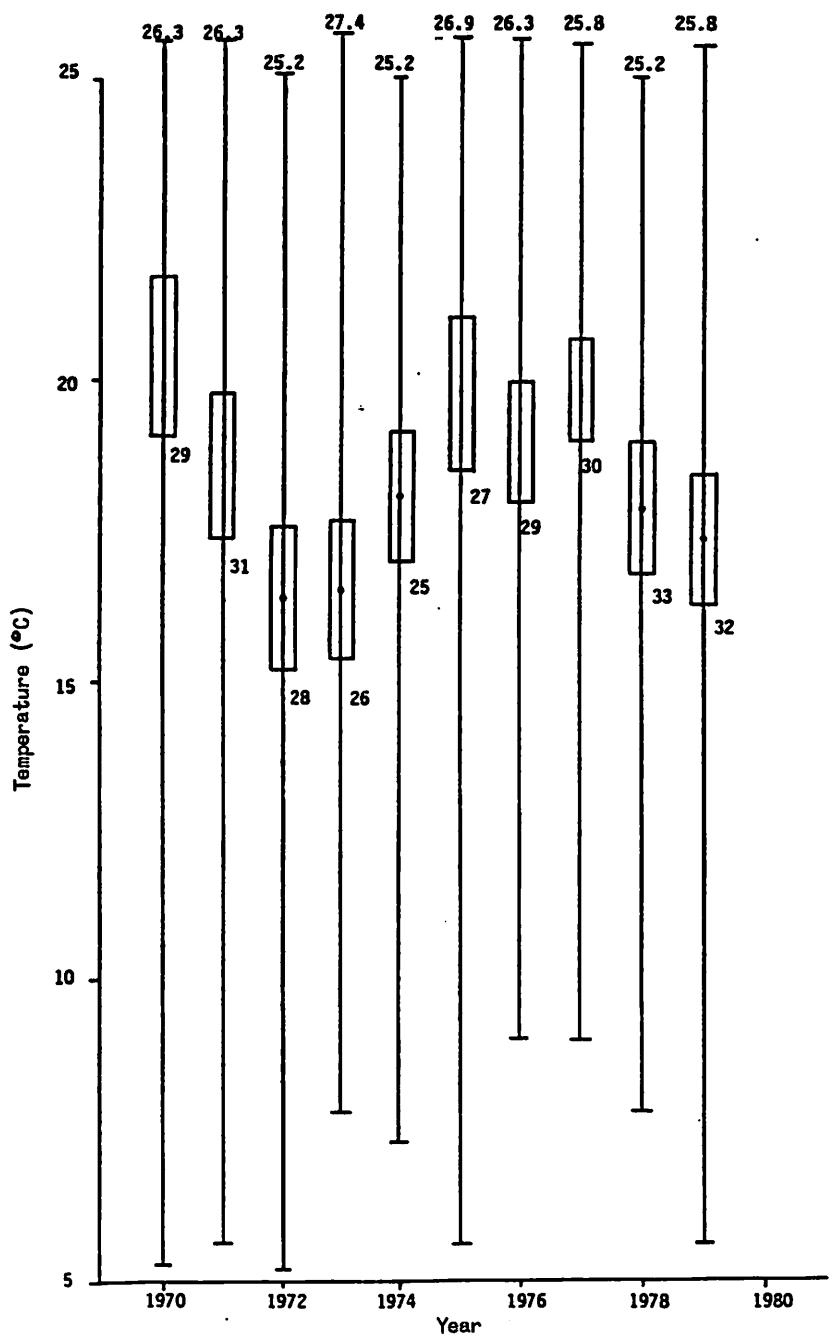


Figure 16. Historical Temperature Data (°C) 1970-1979. Mean, range, standard error and sampling size for April 1 to October 30 Samples from the C&O Dock, Toledo, Ohio.

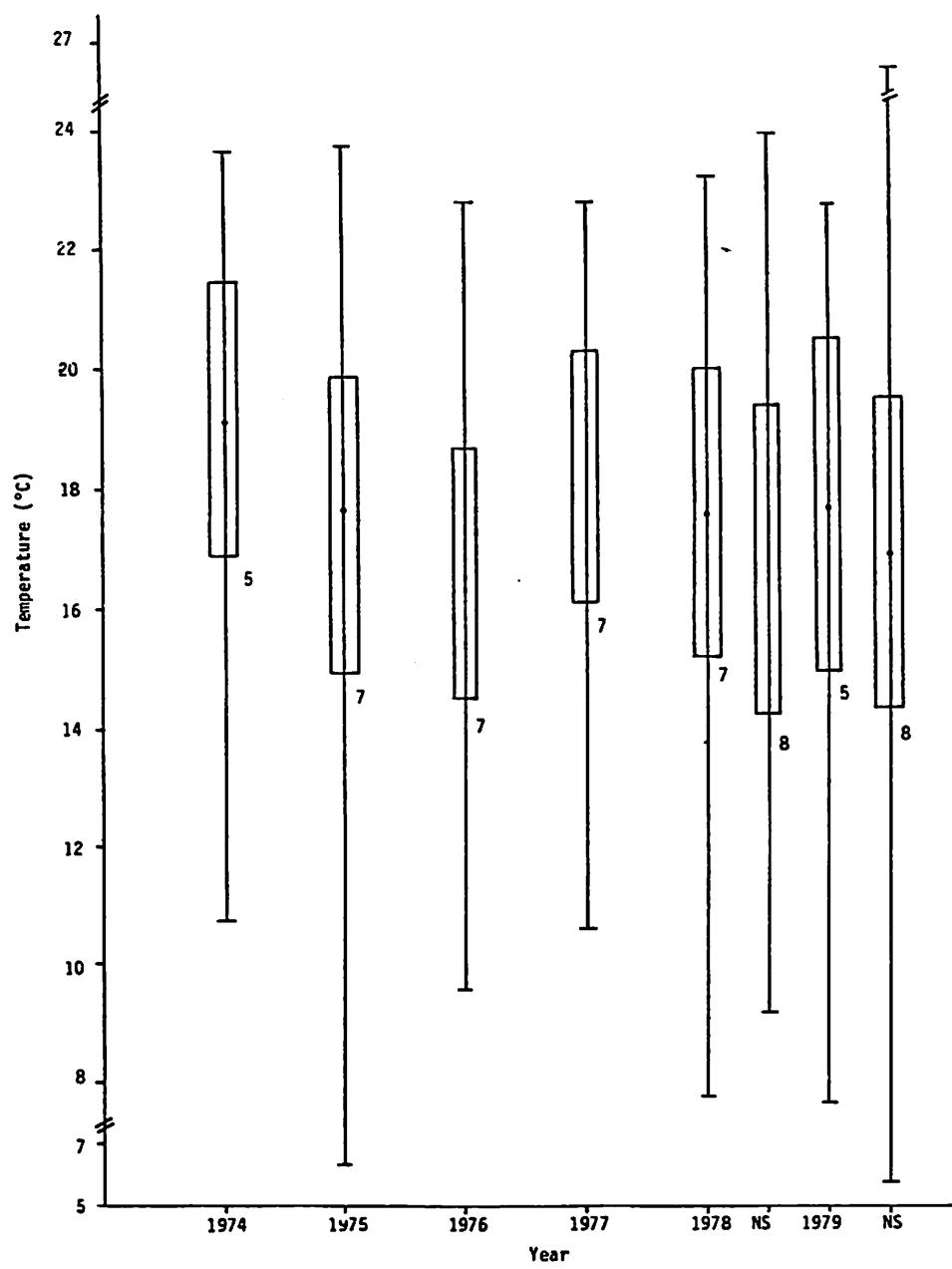


Figure 17. Historical Temperature Data (°C) 1974-1979.
 Mean, Range, Standard Error and Sampling
 Size for Monthly Means (28 samples/month)
 for April to October from the U.S. Gypsum
 Company Intake in Sandusky Bay plus data
 from the Nearshore Study.

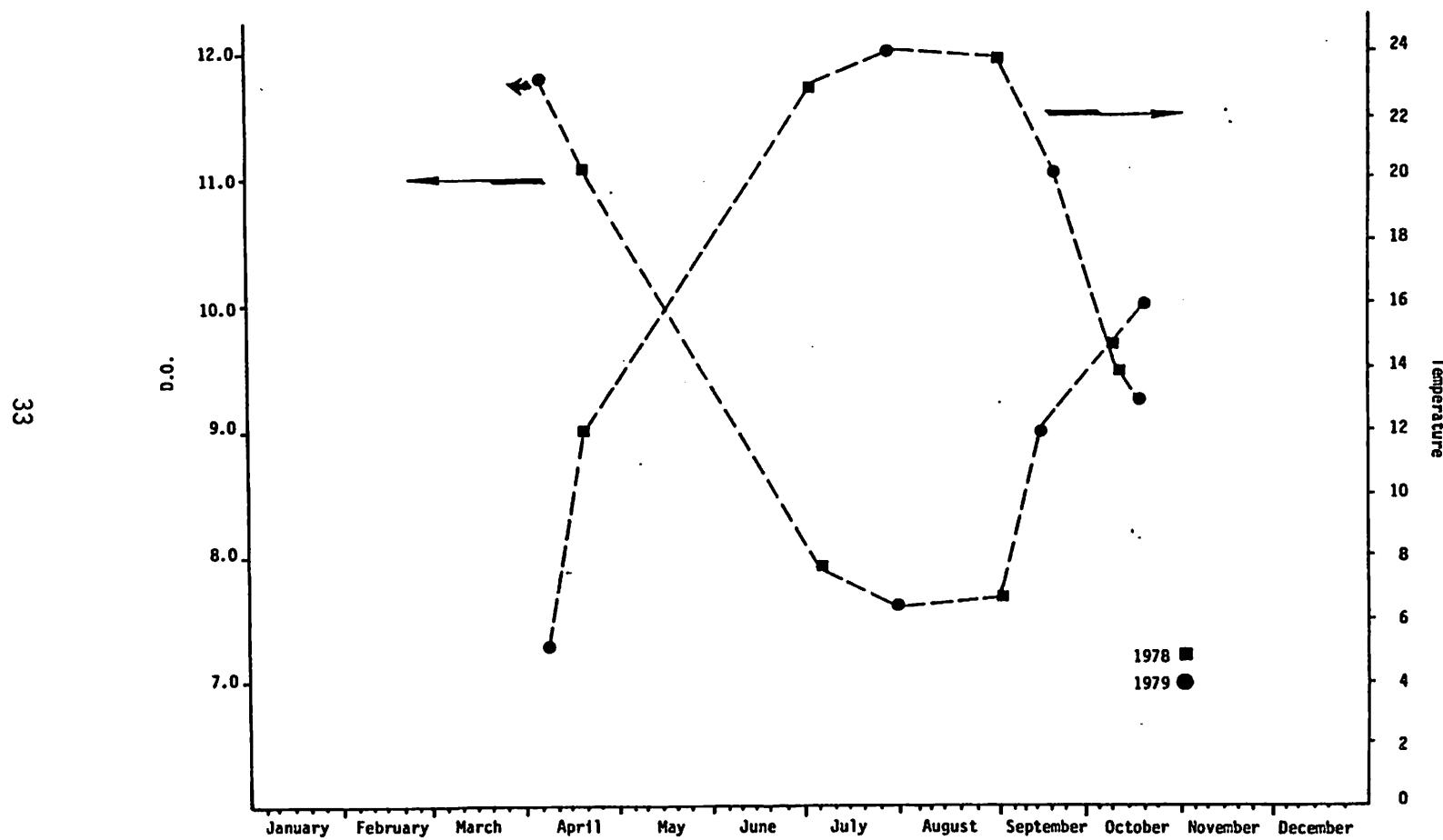


Figure 18. Western Basin Nearshore Cruise Means for Dissolved Oxygen Concentrations (mg/l) and Water Temperature (°C) in 1978 and 1979.

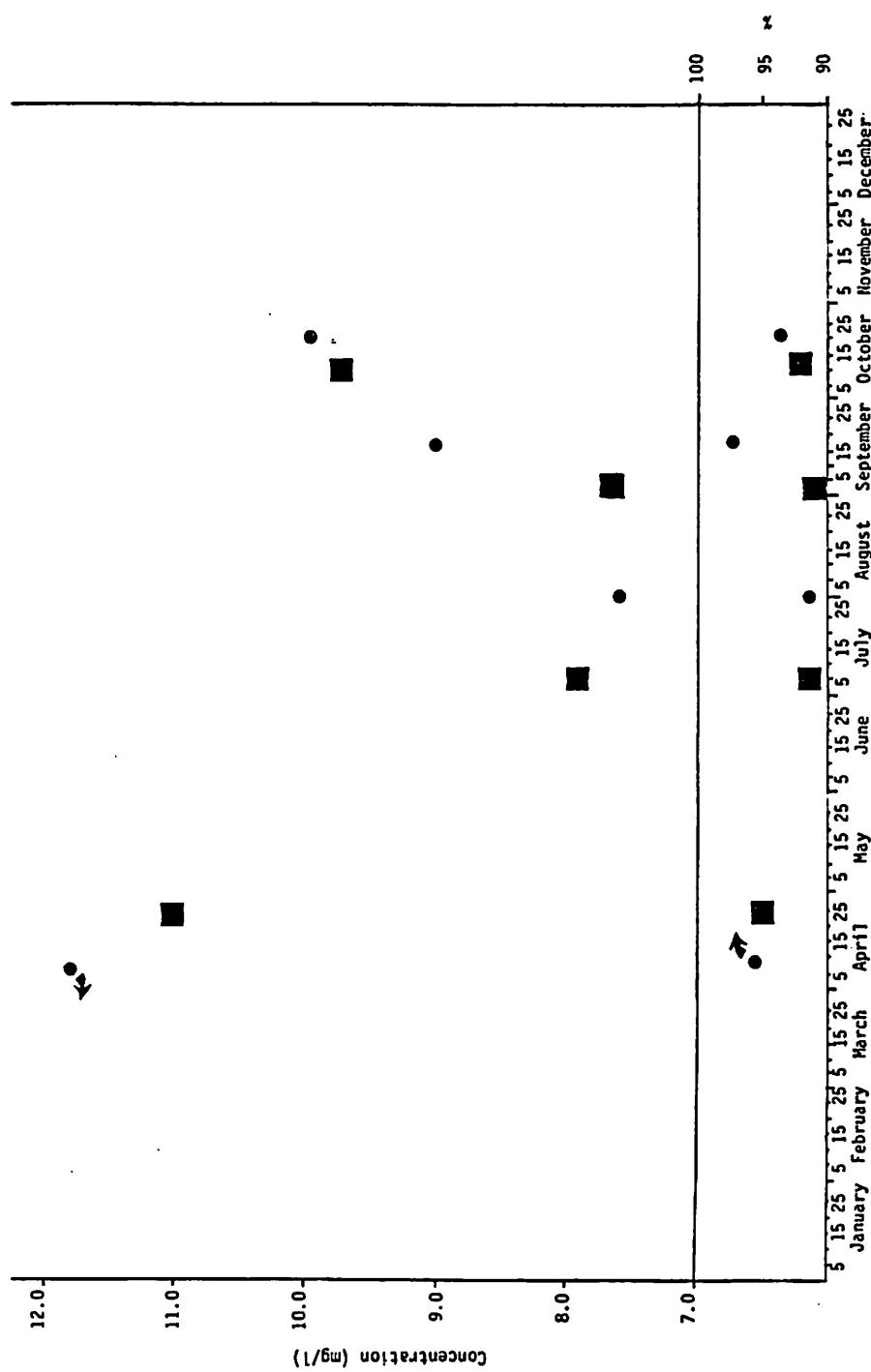


Figure 19. Cruise D.O. Concentrations and Percent Saturations for the Western Basin Nearshore Zone 1978 (■) and 1979 (●).

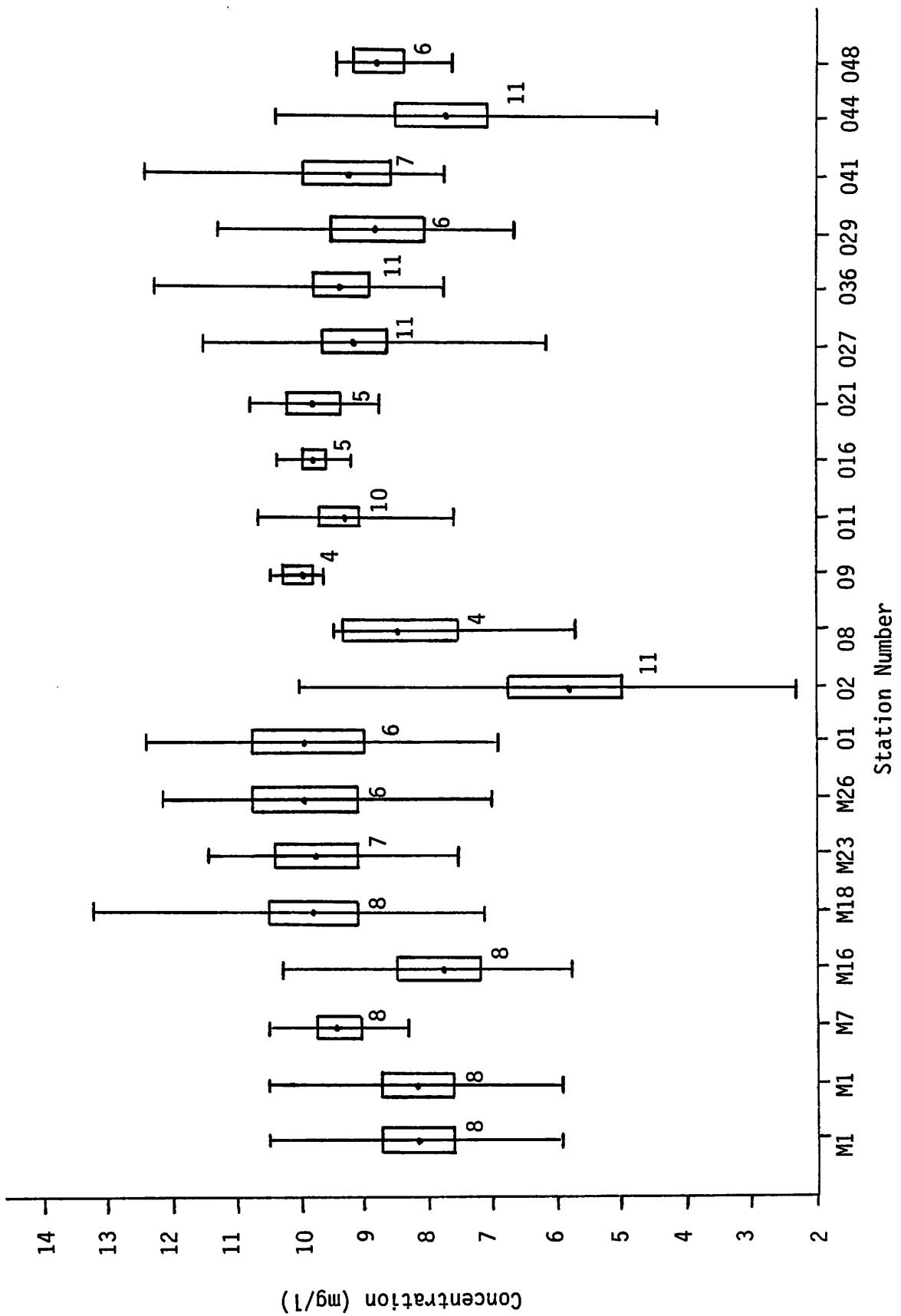


Figure 20. Annual Average Concentration of Dissolved Oxygen at Inshore Stations in 1978.

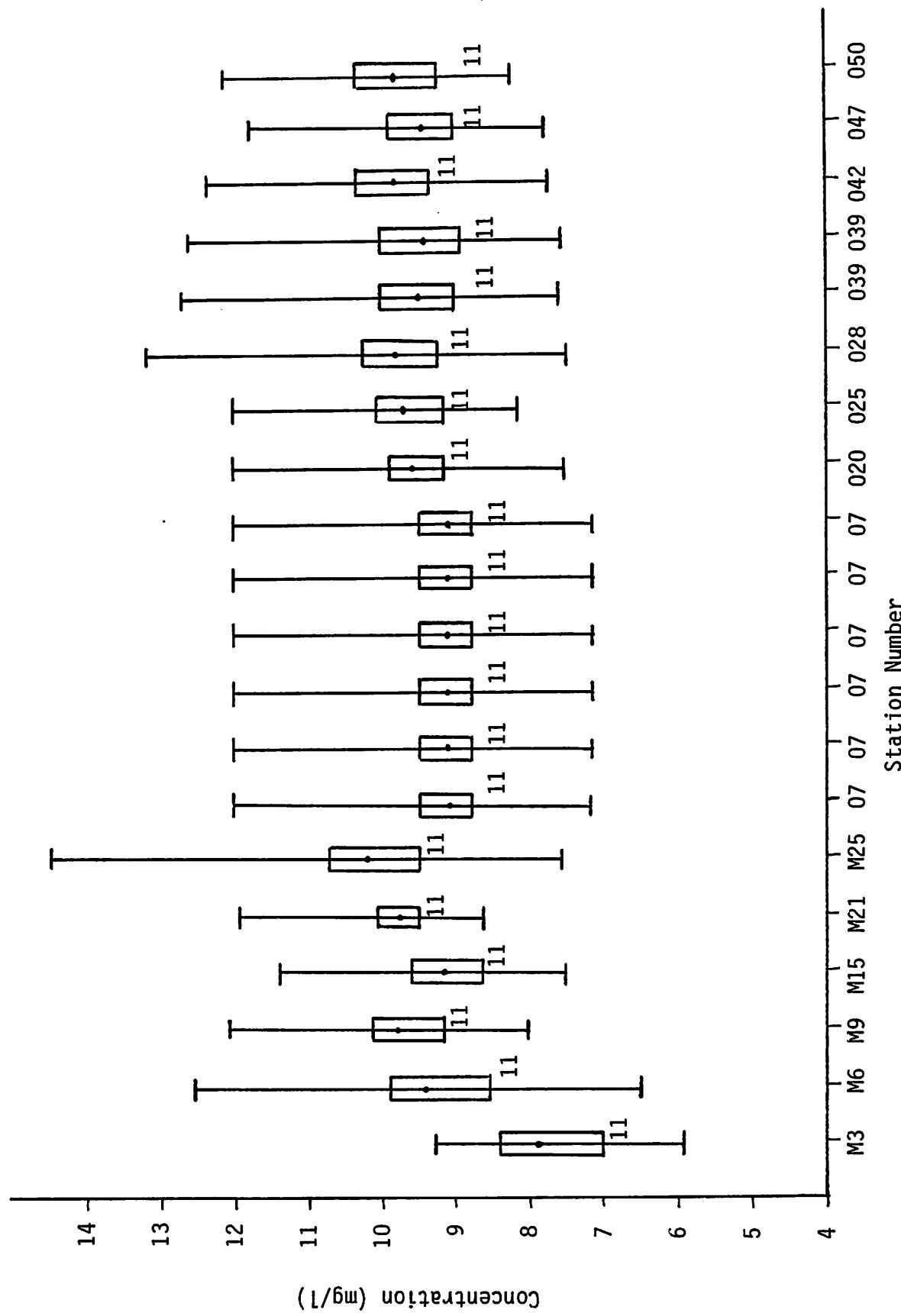


Figure 21. Annual Average Concentration of Dissolved Oxygen at Offshore Stations in 1978.

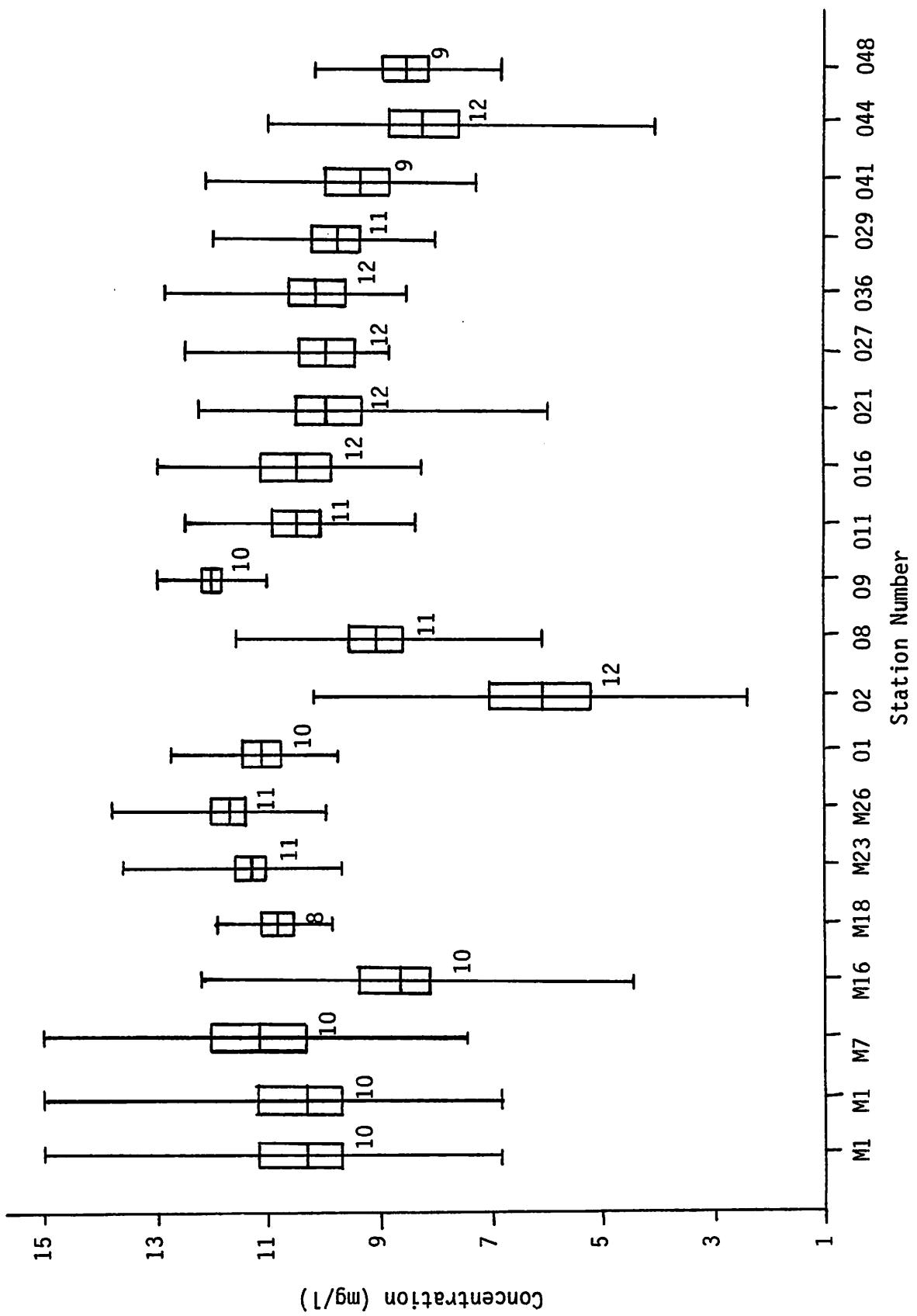


Figure 22. Annual Average Concentration of Dissolved Oxygen at Inshore Stations in 1979.

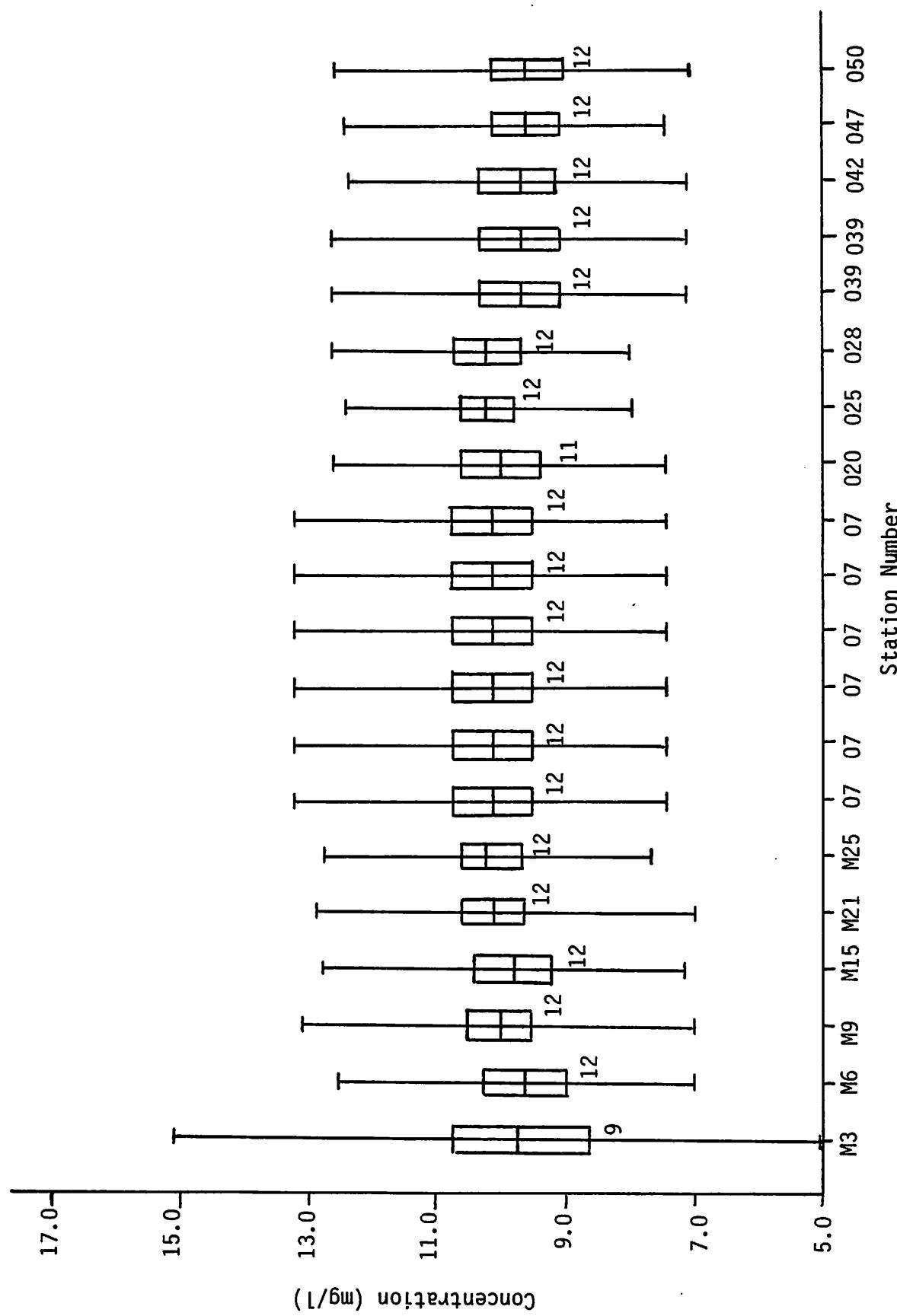


Figure 23. Annual Average Concentration of Dissolved Oxygen at Offshore Stations in 1979.

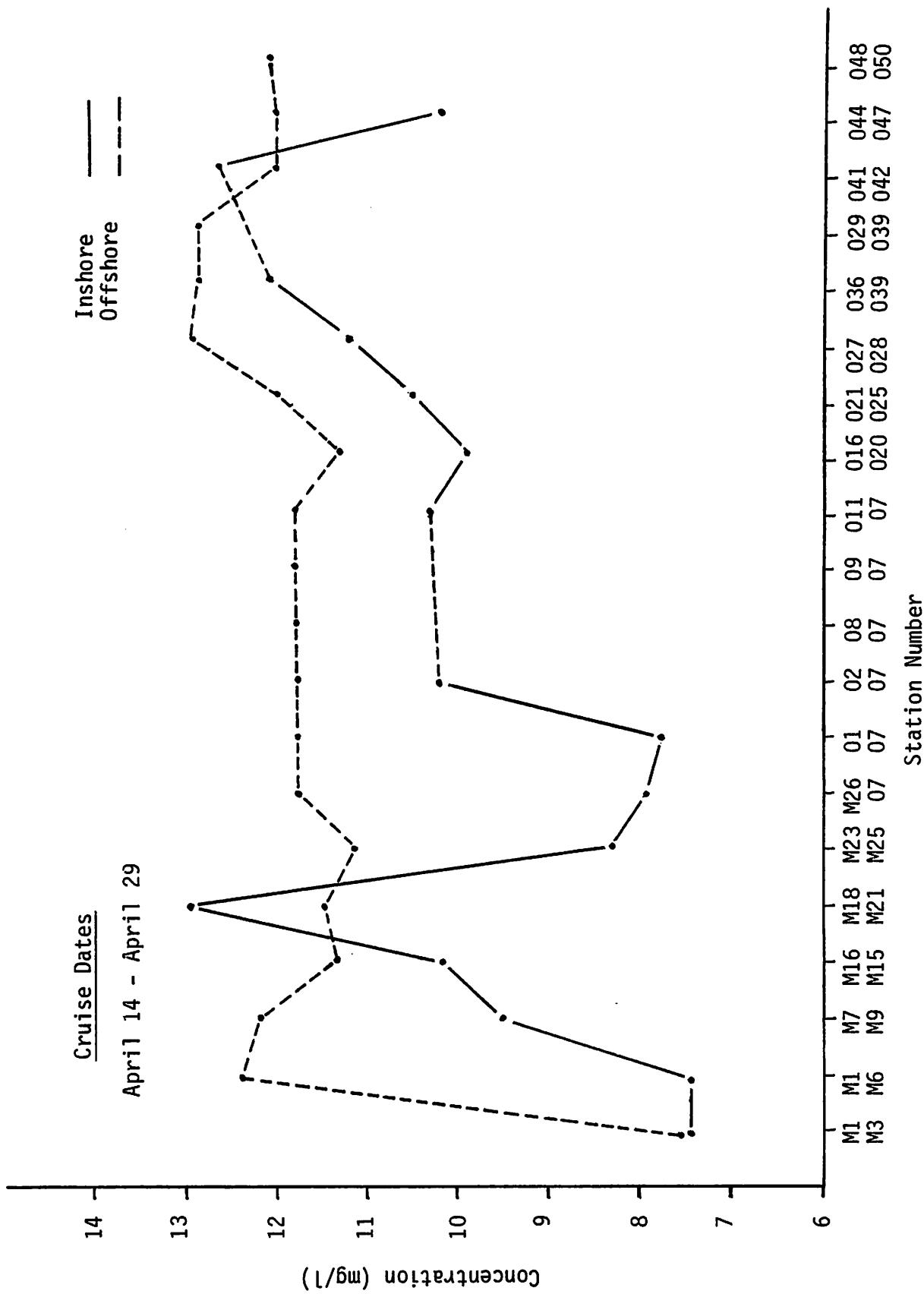


Figure 24. Dissolved Oxygen Concentration at Inshore and Offshore Stations for Cruise 1 of 1978.

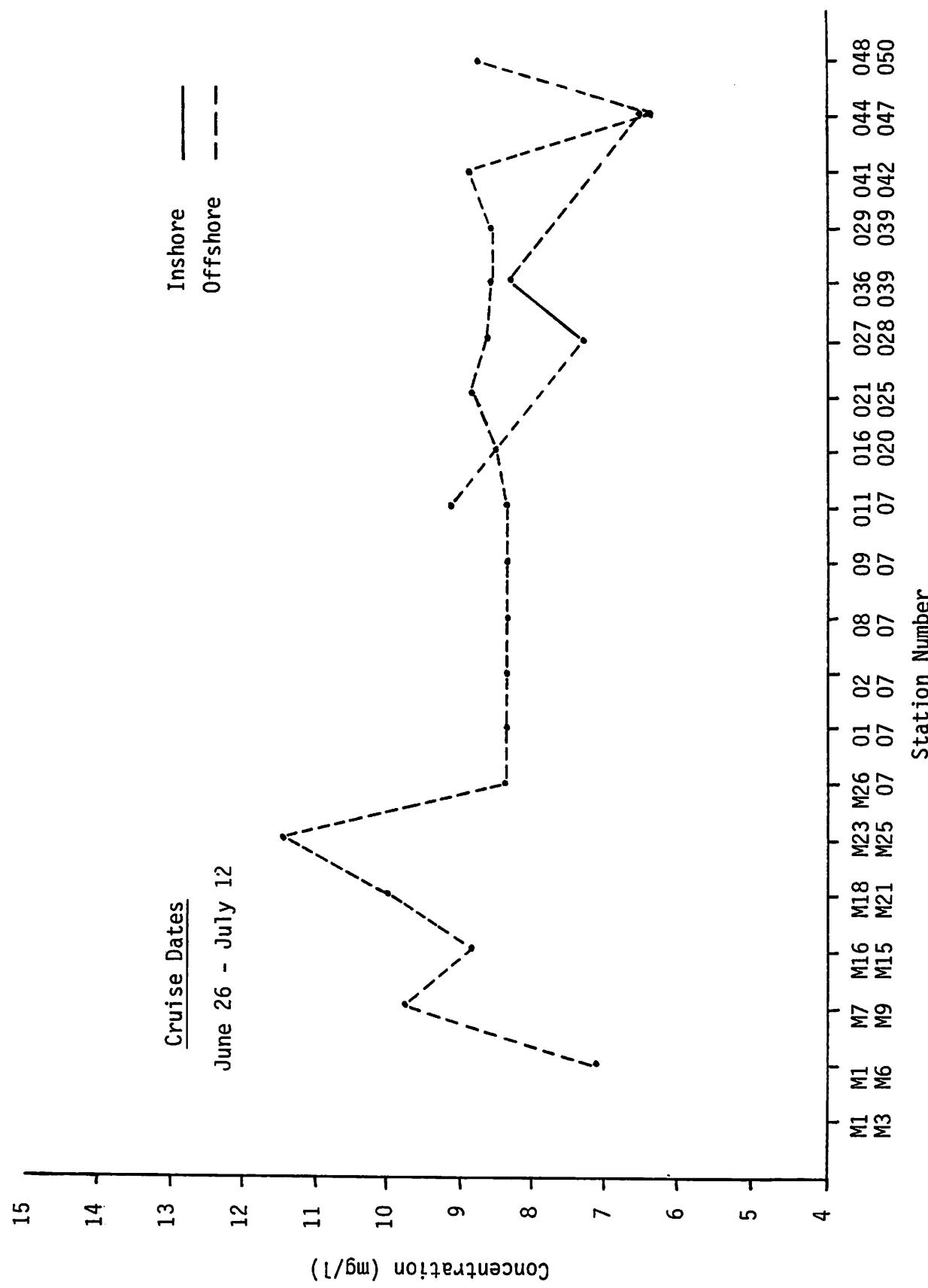


Figure 25. Dissolved Oxygen Concentration at Inshore and Offshore Stations for Cruise 2 of 1978.

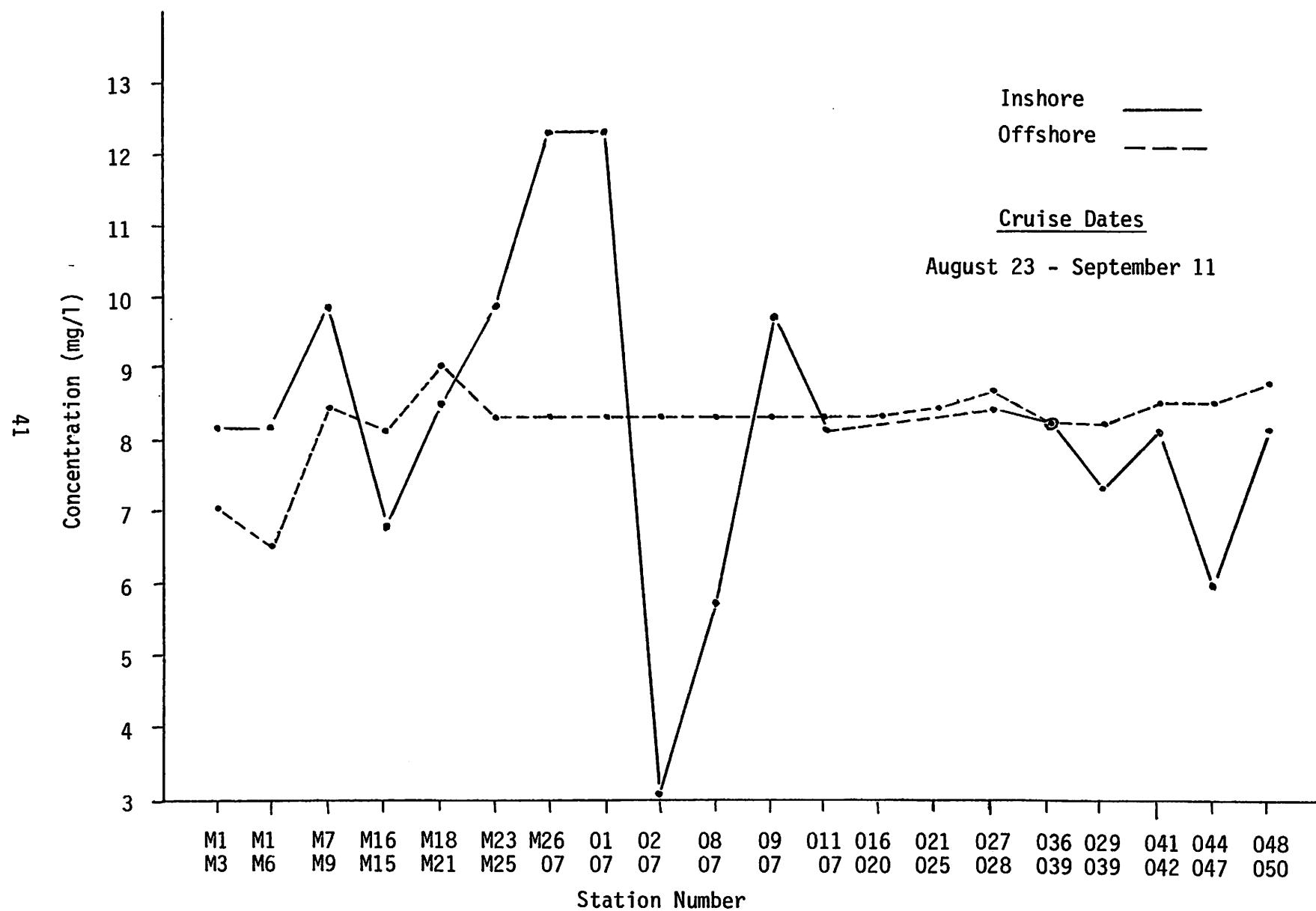


Figure 26. Dissolved Oxygen Concentration at Inshore and Offshore Stations for Cruise 3 of 1978.

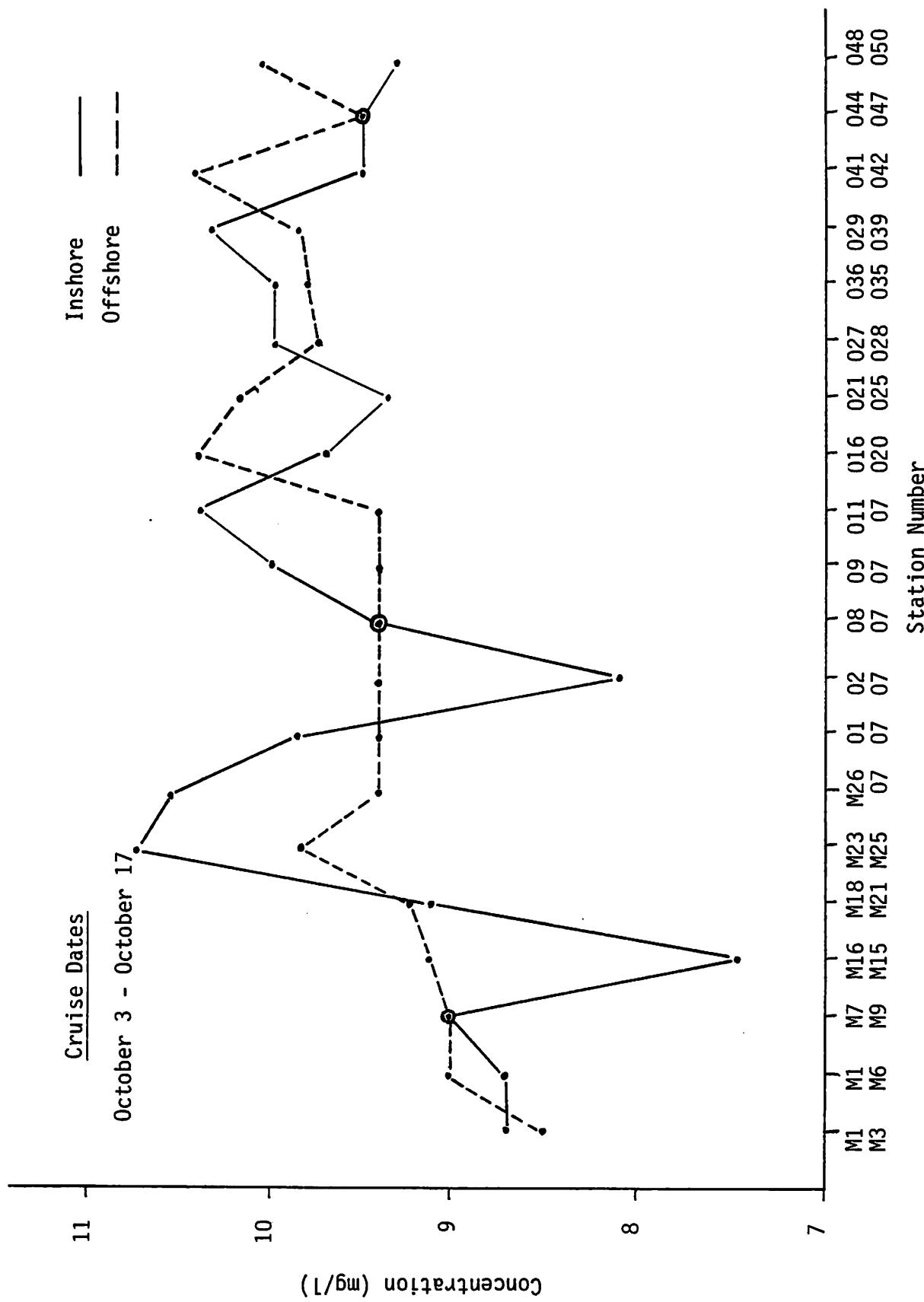


Figure 27. Dissolved Oxygen Concentration at Inshore and Offshore Stations for Cruise 4 of 1978.

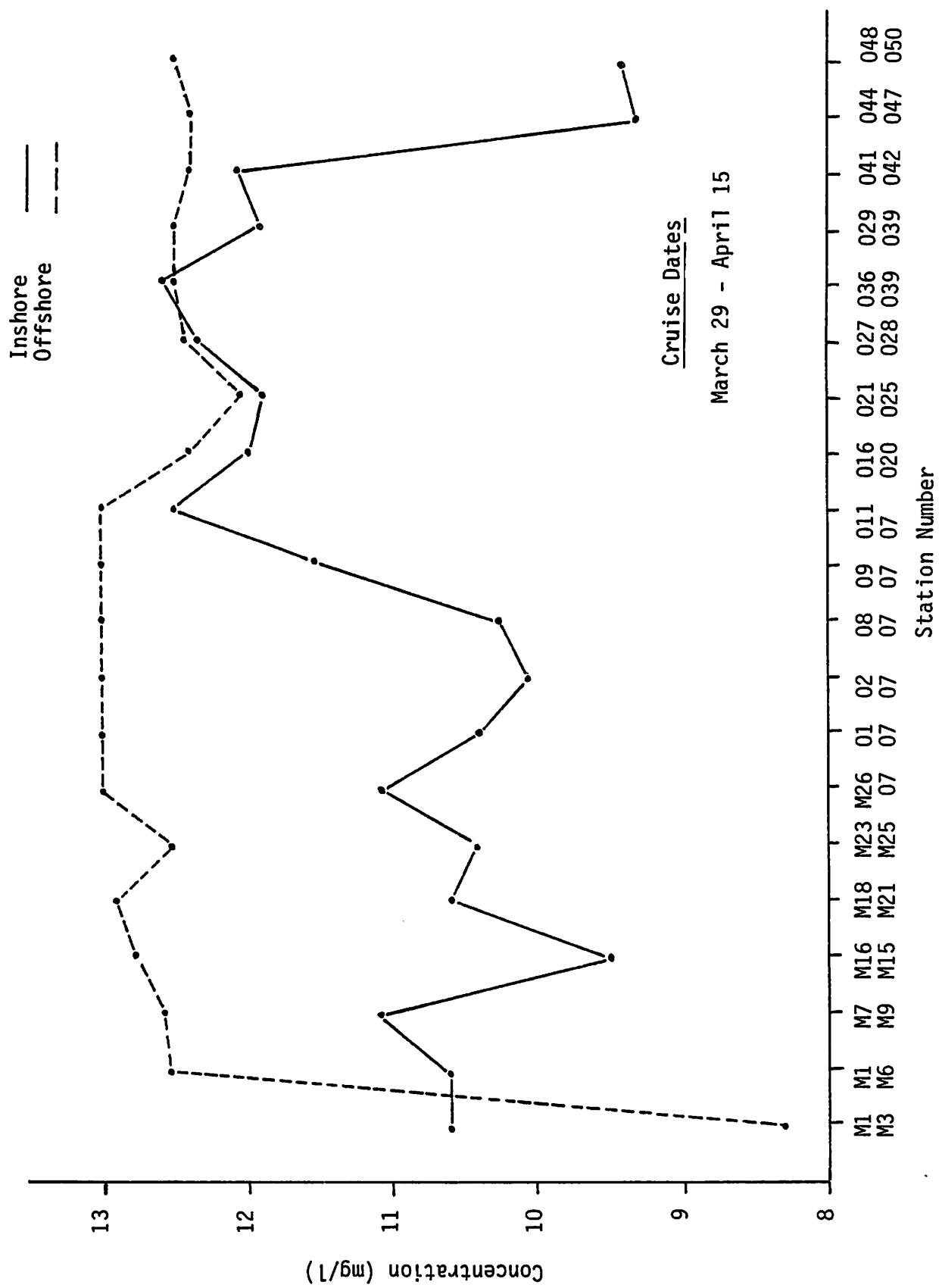


Figure 28. Dissolved Oxygen Concentration at Inshore and Offshore Stations for Cruise 1 of 1979.

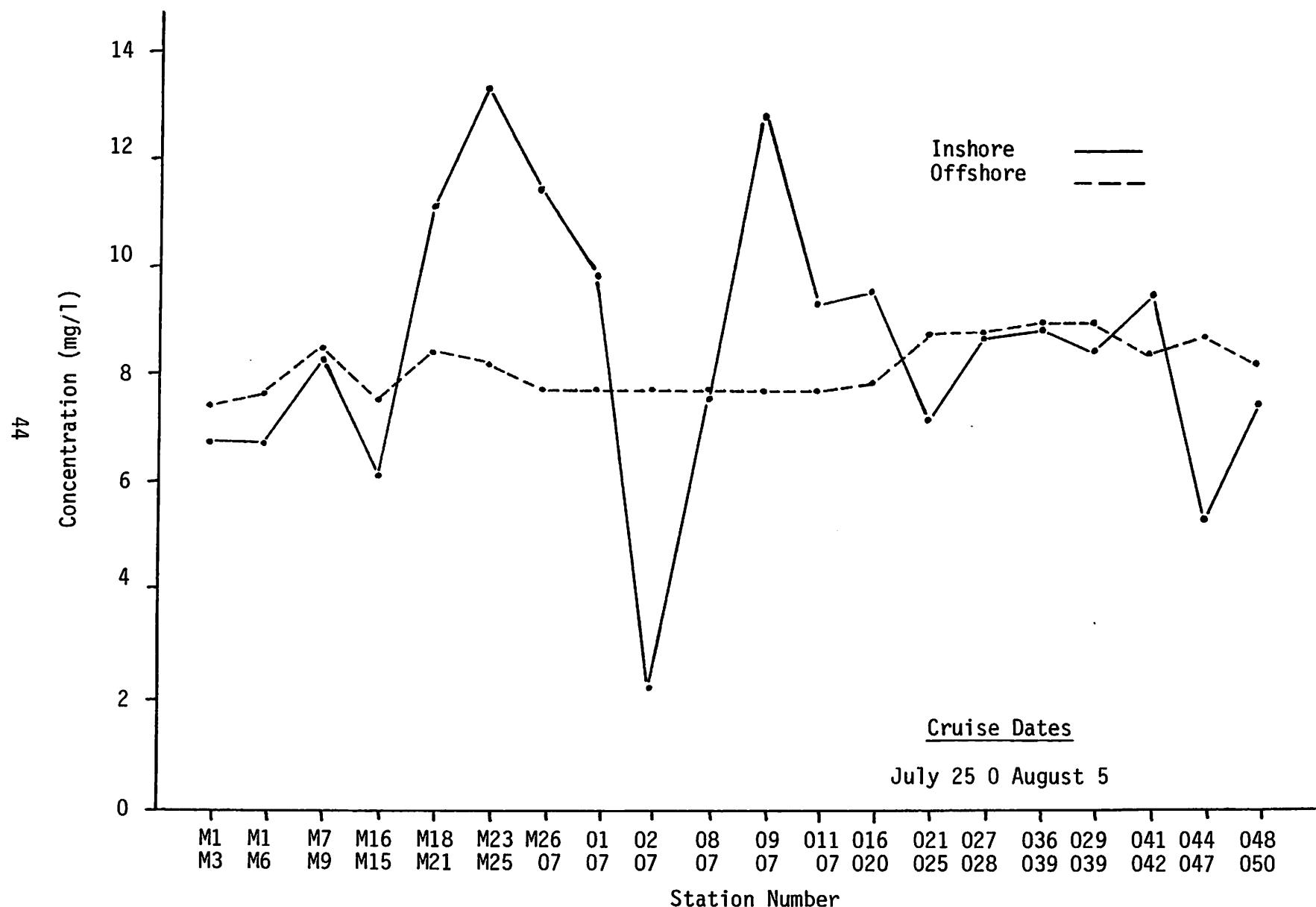


Figure 29. Dissolved Oxygen Concentration at Inshore and Offshore Stations for Cruise 2 of 1979.

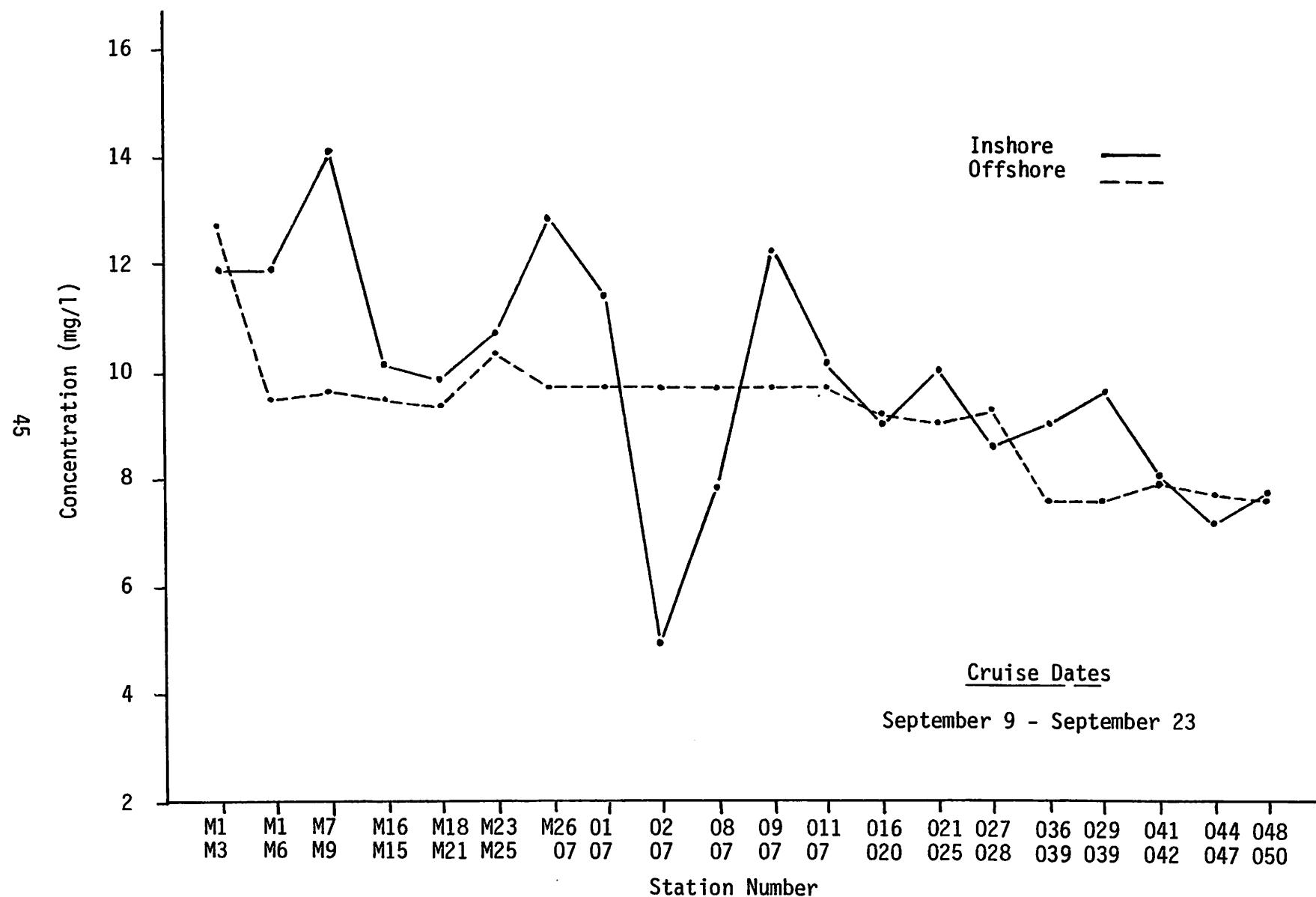


Figure 30. Dissolved Oxygen Concentration at Inshore and Offshore Stations for Cruise 3 of 1979.

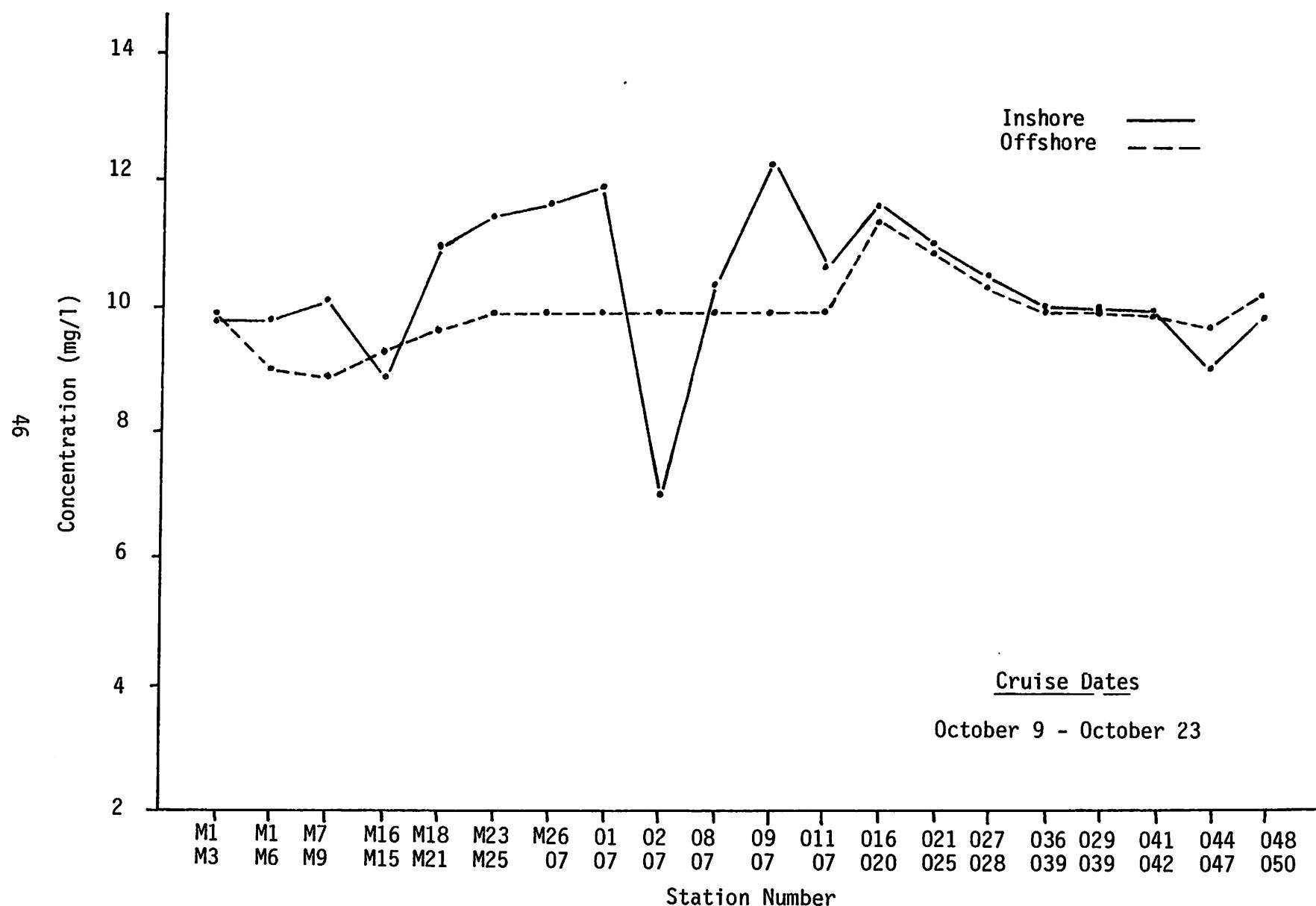


Figure 31. Dissolved Oxygen Concentration at Inshore and Offshore Stations for Cruise 4 of 1979.