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Historical Hydrographic Data from Goose Bay, Lake Melville and Groswater Bay, Labrador: 1950-1997

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Abstract

Goose Bay, Lake Melville and Groswater Bay make up the Hamilton Inlet in Labrador. This is the largest inlet along the Labrador coast. There are 4 major rivers which discharge into the Inlet the largest is the Churchill River. A hydroelectrical project was completed in 1974 at Churchill Falls in Upper Churchill River therefore the flow from the Churchill River is regulated. This report is a summary and presentation of the historical hydrographic data from the Hamilton Inlet and offshore from Groswater Bay collected from several sources between the dates of 1950 and 1997. Included are temperature, salinity, oxygen, phosphorus, nitrate, silicate and chlorophyll profiles. The data was analysed using MATLAB, and sample locations were plotted.

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Introduction

Goose Bay, Lake Melville and Groswater Bay make up the Hamilton Inlet, Labrador. This is the largest inlet along the Labrador coast shown in figure 1. Open to the ocean is Groswater Bay which is about 55 km in length and constricts into a narrow shallow area about 2.8 km in width, 30m in depth and 22 km long, called The Narrows. The lake is approximately170 km long with a maximum width of 35 km and with an average depth of 86m. Lake Melville forms an estuary environment and is a fjord due to The Narrows which creates a sill between the lake and Groswater Bay and due to the lakes deep basin. There are 4 major rivers which discharge into the lake the largest is the Churchill River (Bobbit and Akenhead, 1982).

The historical hydrographic data from the Hamilton Inlet and offshore from Groswater Bay was collected from several sources between the dates of 1950 and 1997 (Tables 1-10). The majority of the existing data was collected by the vessel the **Blue Dolphin** expeditions between 1949 and 1953. These expeditions were supported by the Arctic Institute of North America with funds provided by the U.S. and Canadian Government and private sources. Temperature, salinity oxygen and phosphorus measurements were taken throughout the Hamilton Inlet and offshore during the periods July and August 1950 and 1951; June, July and August 1952; and March 1953. The purpose of the **Blue Dolphin** expeditions was as a general biological and physical study of the coastal waters of Labrador because of the oceanographic and economic importance of the area. Also the natural resources of the area are fundamental for the support of the native population. Observations of temperature and salinity were made using Nansen bottles and reversing thermometers and after 1952 a salinity-temperature-depth recorder (STD) was also used. Dissolved oxygen, inorganic phosphate and salinity were determined aboard the vessel using the standard Kunsen Method, colorimetery for phosphate and the Winkler method for oxygen. However in 1950 salinities and total phosphates were determined at Woods Hole Oceanographic Institute.

Other explorations were carried out by the Fisheries Research Board of Canada aboard the vessel the **Investigator II** during October 1952 and September 1953. The purpose of this expedition was to obtain scientific data particularly of the fishery in Newfoundland. Temperature and salinity measurements were taken from Lake Melville, Groswater Bay and offshore from Groswater Bay.

More recent data was collected in response to the hydroelectric project on Churchill River completed in 1971, located at Churchill Falls. The northern Atlantic cod fishery severely declined in Groswater Bay and Sandwich Bay at about the same time as the Churchill hydro project changed the flow of the Churchill River into Lake Melville. Fishers have expressed concern about hydroelectric development on the Churchill River since the Churchill hydro project was completed (Saunders, 1981). Currently Newfoundland and Labrador Hydro has proposed further construction of hydroelectric stations in the lower Churchill River and this has renewed fishers concerns and initiated a study by the Department of Fisheries and Oceans (DFO) to investigate the effects of the controlled hydro discharge upon the water properties of Groswater Bay. Therefore, a field trip was conducted in August 1981, temperature and salinity measurements were taken from Lake Melville and Groswater Bay aboard the vessel the **Burin Bay**, a fisheries patrol vessel.

The hydro potential of Labrador initiated other studies since the development of power sources along with the natural resources in Labrador attracted industrial development close to the source. Lake Melville was considered an ideal location however a significantly extended shipping season was required. One study was initiated by Memorial University to study the evolution and characteristics of ice on Lake Melville in order to determine the location and method of keeping an extended shipping channel open from Labrador Sea to Goose Bay. Temperature and salinity were measured throughout the lake during January, April, May, and November 1973 and December 1972 aboard the vessel the **CCGS Sir J.A. MacDonald,** the **CCGS Sir Humphrey Gilbert** (icebreakers) and the **Prima Vista**. Another study to determine the feasibility of winter navigation was completed by FENCO Ltd. commissioned by the Government of Newfoundland through the Department of Industry Development. Two ice breaking probes were used aboard the vessel the **CCGS Sir John Franklin** during January and December 1980. Temperature and salinity measurements were obtained using an Applied Microsystem Conductivity, Temperature and Depth recording instrument deployed from a helicopter and through holes in the ice. Raw data was collected using a digiprinter.

Another important resource of Labrador is oil and gas. An Offshore Labrador Biological Studies Program (OLABS) was initiated by Department of Energy, Mines and Resources in 1978. The study was a three-year program that involved industry, communities and government. OLABS collected baseline biological, meteorological and oceanographic data on shoreline sensitivities, fish and the fishery, zooplankton, phytoplankton, marine mammals and seabirds for coastal Labrador. The petroleum industry, Petro-Canada funded the studies and a committee made up of several governments departments and the petroleum industry directed OLABS. OLABS funded the Offshore Labrador Initial Environmental Assessment. The OLABS program produced 30 studies one such study contained salinity, temperature, nitrate, silicate, chlorophyll and phosphorus data which were measured from Groswater Bay and offshore during July and September 1979. Temperature was obtained using reversing thermometers and salinity was obtained by samples in triple rinsed polyethylene bottles. Nutrient samples were obtained with Niskin bottles, sub samples were immediately drawn into double rinsed opaque polyethylene bottles. One litre from each sample was filtered with a Millipore HAWP 47 filter (0.45um pore size). The filtrate was stored in polyethylene bottles, preserved and frozen. Nutrient analysis was conducted by the Water Analysis Facility of Memorial University using a Technicon Autoanalyzer II.

Most of the above data collected was obtained directly from the reports referenced or the Department of Fisheries and Oceans (DFO) website, except for the **Blue Dolphin** expeditions which was obtained directly from the DFO data base (courtesy of K. Drinkwater, DFO). From this database other temperature, salinity, oxygen and phosphorus data was obtained during the periods August 1958, June 1963, and October 1983 throughout the Hamilton Inlet and offshore.

Summary of data collection

The hydrographic data for Goose Bay in Figures 2 - 9, was collected by the **Blue Dolphin** expeditions from 5 hydrographic samples throughout Goose Bay.

The hydrographic data for Lake Melville in Figures 10 - 22, was collected throughout the lake by the vessel the **Blue Dolphin** expeditions from approximately 26 hydrographic stations; the vessel the **Investigator II** from 4 stations in October 1952; from the DFO report aboard the vessel the **Burin Bay** from 6 stations; from the FENCO study aboard the vessel the **CCGS Sir John Franklin** from 17 stations; and from the Memorial University study aboard the vessels the **CCGS Sir J.A. MacDonald,** the **CCGS Sir Humphrey Gilbert** and the **Prima Vista** from 5 stations. More recent temperature data from 1991 was obtained from the DFO ocean sciences database available on their website. Data was collected from 3 stations in September and October 1991.

The hydrographic data for The Narrows in Figures 23 - 31, was collected by the vessel the **Blue Dolphin** expeditions from 7 stations. More recent temperature data from 1984 and 1985 was obtained from the DFO ocean sciences database. Samples were collected from 1 station from January to December.

The hydrographic data for Groswater Bay in Figures 32 – 47, was collected by the vessel the **Blue Dolphin** expeditions from approximately 19 stations; by the vessel the **Investigator II** from 1 station in October 1952; by the vessel **CCGS Sir John Franklin** for the FENCO study from 4 stations; and by the vessel the **Burin Bay** for the DFO report from 3 stations throughout the bay. Further data was collected from OLABS program from 1 hydrographic station in the bay in September 1979.

The hydrographic data offshore of Groswater Bay in Figures 48 – 60, was collected on the **Blue Dolphin** expeditions from 7 samples, by the vessel the **Investigator II** from 22 stations in September 1953 and OLABS study from 5 samples in July 1979. The most recent temperature data from 1978 to 1997 was obtained from the DFO ocean sciences database. Samples were collected from numerous stations from January to December.

Data Processing

The data was analysed and plotted using Matlab. The data was divided into pre and post 1970, this is due to the fact that construction for the hydroelectric project on Churchill River began in 1970. This allows comparison between water properties before and after regulation of flow from the hydroelectric project. The data was further divided into the 5 major areas, Goose Bay, Lake Melville, The Narrows, Groswater Bay and Offshore. Each water property was plotted separately by month pre and post 1970. The mean and standard deviations were determined when possible also using MatLab. Each plot includes a scatter of all the data points shown as circles, a solid line for the mean and deviation bars for those data points in which more than one data point existed for the given depth. The locations of all the samples collected are also plotted.

Data Interpretation

Most of the data collected was temperature and salinity measurements. The temperature and salinity data was consistently collected in all 5 areas for both pre and post 1970 in the month of July, August and October. The temperature near the surface in July and August pre 1970 was higher in Goose Bay and gradually decreased towards Groswater Bay. The surface salinity in July and August pre 1970 in Goose Bay and Lake

Melville was quite low between 0 and 10 and increased from the Narrows to offshore as expected due to the freshwater influence from river discharge. The salinity below 50 m gradually increased from Goose Bay to offshore from approximately 21, 22 to 33, 34 in Groswater Bay and offshore. Post 1970 temperature and salinity data was collected in all 5 areas for the month of October. As expected the same trends in salinity are apparent for the pre and post 1970 data however, the temperature was more variable. In August, the post 1970 data show higher surface temperatures in Lake Melville with a maximum of approximately 15^{o}C and the lowest temperature in the Narrows and Groswater Bay with a maximum of approximately 6.5^{o}C. Offshore the temperature was highly variable in August with a maximum of approximately 16^{o}C but lows below 0^{o}C. The temperatures in August below 80m were less variable and similar in all areas, for both pre and post 1970 data, close to 0^{o}C.

Oxygen levels were only collected by the Blue Dolphin expeditions and phosphorus was collected by Blue Dolphin expeditions and OLABS study. The least amount of data was found for nitrate, silicate and chlorophyll levels which were only recorded in Groswater Bay and offshore by the OLABS study. For the pre 1970 data oxygen and phosphorus data was consistently collected in all 5 areas in the month of July and August except for offshore and the Narrows where phosphorus was only collected in August. Surface oxygen values in August, pre 1970 are approximately 300 μM in all areas with slightly higher values in Groswater Bay and offshore. Oxygen levels increases with depth in all areas except Goose Bay. Fewer phosphate data was found and it was highly variable especially near the surface. Phosphorus values in August, pre 1970 near the surface were between 0 and 1 μM varying slightly with depth in all areas. For post 1970 data no nutrient data was found for Goose Bay, and only oxygen concentrations were found in October for Lake Melville and the Narrows. For Groswater Bay oxygen concentrations were found in October and phosphorus, nitrate, silicate and chlorophyll in September. For offshore only phosphorus, nitrate, silicate and chlorophyll concentrations were found in July. Near the surface nitrate concentrations were much lower in offshore between 0 and 1.5 μM in July as compared to Groswater Bay between 2.2 and 2.5 μM in September. However at 50m the concentrations were similar. The similar pattern is seen with silicate concentrations with near surface values in Groswater bay at 14.2 μM and offshore between 0.7 and 2.1 μM. In Groswater Bay silicate concentrations decrease with depth and offshore they do the opposite, therefore at 50m the concentrations are again similar. Comparing phosphorus concentrations they were similar in both Groswater Bay and offshore with a slight higher concentration near the surface in Groswater Bay.

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Tables

Table 1: Goose Bay-temperature and salinity

Reference	Data	Expedition	Month	Year	Station numbers
DFO Canada database	T S	BD (Blue Dolphin)	July	1950	62, 73
			July	1951	62, 72, 73
			July	1952	62, 73
			Aug	1951	62, 72, 73
			Aug	1952	62, 73
			Oct	1983	34, 73
Coachman, L. 1953. River Flow and Winter Hydrologic Structure of the Hamilton Inlet-Lake Melville Estuary of Labrador.	T S	BD (Blue Dolphin)	Mar	1953	34, 62, 113

Table 2: Goose Bay-nutrients

Reference	Data	Expedition	Month	Year	Station numbers
DFO Canada database	P	BD (Blue Dolphin)	July	1950	62, 73
			July	1951	62, 72, 73
			July	1952	62, 73
			Aug	1951	62, 72, 73
			Aug	1952	62, 73
	O	BD (Blue Dolphin)	July	1950	62, 73
			July	1951	62, 72, 73
			July	1952	62, 73
			Aug	1951	62, 72, 73
			Aug	1952	62, 73
			Oct	1983	34, 73

Legend: T- Temperature, S- Salinity, P- Phosphorus, O- Oxygen

Table 3: Lake Melville-temperature and salinity

Reference	Data	Expedition	Month	Year	Station numbers
DFO Canada database	T S	BD (Blue Dolphin)	July	1950	38, 46, 39, 45, 40, 44, 42, 43, 47, 48, 49, 50, 51
			July	1951	71, 38, 39, 40, 47, 48, 49
			July	1952	38, 40, 47, 49
			Aug	1950	
			Aug	1951	38, 39, 40, 47, 48, 49
			Aug	1952	38, 40, 47, 49
			Aug	1958	71
			Oct	1983	
Bobbit, J. and Akenhead, S. 1982. Influence of Controlled Discharge from the Churchill River on the Oceanography of Groswater Bay, Labrador.	T S	BB (Burin Bay)	Aug	1981	1, 2, 3, 4, 5, 6
		In (Investiga-tor II)	Oct	1952	1, 2, 3, 4
Coachman, L. 1953. River Flow and Winter Hydrologic Structure of the Hamilton Inlet-Lake Melville Estuary of Labrador	T S	BD (Blue Dolphin)	Mar	1953	38, 47, 40, 49, 50
DFO Canada http://www.mar.dfo-mpo.gc.ca/science/ocean/home.html	T		Sept	1991	
			Oct	1991	
Fenco Newfoundland Limited 1981. Lake Melville/offshore Labrador winter navigation study 1979-1980: final report. Department of Industrial Development report.	T	CCGS Sir John Franklin	Jan	1980	
Fenco Newfoundland Limited 1981. Lake Melville freeze up study 1980: final report. Newfoundland and Labrador Department of Industrial Development report.	T	CCGS Sir John Franklin	Dec	1980	1,2,3,4,5,6,7,8,9,10, 11,12,13,14,15
	S		Dec	1980	3,6,8,10,11,12,13
Memorial University of Newfoundland, Faculty of Engineering and Applied Science 1974. Lake Melville ice research, 1973-1974, report no. III and Appendices	T S	Prima Vista, CCGS Sir Humphrey Gilbert and CCGS Sir J.A MacDonald	Jan	1973	A-1
			April	1973	A, A-1
			May	1973	D
			Nov	1973	A, B, C, D
			Dec	1972	A, B, C, D

Legend: T- Temperature, S- Salinity

Table 4: Lake Melville-nutrients

Reference	Data	Expedition	Month	Year	Station numbers
DFO Canada database	P	BD (Blue Dolphin)	July	1950	38, 46, 39, 45, 40, 44, 42, 43, 47, 48, 49, 50, 51
			July	1951	71, 38, 39, 40, 47, 48, 49
			July	1952	38, 40, 47, 49
			Aug	1950	
			Aug	1951	38, 39, 40, 47, 48, 49
			Aug	1952	38, 40, 47, 49
			Aug	1958	71
	O	BD (Blue Dolphin)	July	1950	38, 46, 39, 45, 40, 44, 42, 43, 47, 48, 49, 50, 51
			July	1951	71, 38, 39, 40, 47, 48, 49
			July	1952	38, 40, 47, 49
			Aug	1950	
			Aug	1951	38, 39, 40, 47, 48, 49
			Aug	1952	38, 40, 47, 49
			Aug	1958	71
			Oct	1983	

Table 5: Narrows-temperature and salinity

Reference	Data	Expedition	Month	Year	Station numbers
DFO Canada database	T S	BD (Blue Dolphin)	July	1950	61
			July	1952	104, 105, 107
			Aug	1952	107, 104
			Oct	1983	
DFO Canada http://www.mar.dfo-mpo.gc.ca/science/ocean/home.html	T		Jan	1984	
			Feb	1984	
			Mar	1984	
			April	1984	
			May	1984	
			June	1984	
			July	1984	
			August	1984	
			Sept	1984	
			Oct	1983	
			Nov	1983	
			Dec	1983	

Legend: T- Temperature, S- Salinity, P- Phosphorus, O- Oxygen.

Table 6: Narrows-nutrients

Reference	Data	Expedition	Month	Year	Station numbers
DFO Canada database	P	BD (Blue Dolphin)	Aug	1952	107, 104
	O	BD (Blue Dolphin)	July	1950	61
			July	1952	104, 105, 107
			Aug	1952	107, 104
			Oct	1983	

Table 7: Groswater Bay-temperature and salinity

Reference	Data	Expedition	Month	Year	Station numbers
DFO Canada database	T S	BD (Blue Dolphin)	June	1952	92, 96, 97, 99, 93
			July	1950	52, 53, 54, 55, 56
			July	1951	70, 54, 55, 56
			July	1952	102, 100, 52
			Aug	1951	55, 56
			Aug	1952	102, 100, 90, 91
			Oct	1983	
Fenco Newfoundland Limited 1981. Lake Melville/offshore Labrador winter navigation study 1979-1980: final report. Department of Industrial Development report.	T	CCGS Sir John Franklin	Jan	1980	
Bobbit, J. and Akenhead, S. 1982. Influence of Controlled Discharge from the Churchill River on the Oceanography of Groswater Bay, Labrador.	T S	BB (Burin Bay)	Aug	1981	7, 8, 9
		In (Investiga-tor II)	Oct	1952	5
Coachman, L. 1953. River Flow and Winter Hydrologic Structure of the Hamilton Inlet-Lake Melville Estuary of Labrador	T S	BD (Blue Dolphin)	Mar	1953	52
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Legend: T- Temperature, S- Salinity, P- Phosphorus, O- Oxygen

Table 8: Groswater Bay-nutrients

Reference	Data	Expedition	Month	Year	Station numbers
DFO Canada database	P	BD (Blue Dolphin)	June	1952	92, 96, 97, 99, 93
			July	1950	52, 53, 54, 55, 56
			July	1951	70, 54, 55, 56
			July	1952	102, 100, 52
			Aug	1951	55, 56
			Aug	1952	102, 100, 90, 91
	O	BD (Blue Dolphin)	June	1952	92, 96, 97, 99, 93
			July	1950	52, 53, 54, 55, 56
			July	1951	70, 54, 55, 56
			July	1952	102, 100, 52
			Aug	1951	55, 56
			Aug	1952	102, 100, 90, 91
			Oct	1983	
Buchanan R.A. and Foy M.S. 1980. Plankton, Nutrients, Chlorophyll, Phytoplankton and Ichthyoplankton. Olabs Program Report: Offshore Labrador Biological study.	N P Chlo Si		Sept	1979	GB-1

Legend: T- Temperature, S- Salinity, P- Phosphorus, O- Oxygen, N- Nitrate, Chl- Chlorophyll, Si- Silicate

Table 9: Offshore-temperature and salinity

Reference	Data	Expe-dition	Month	Year	Station numbers
DFO Canada http://www.mar.dfo-mpo.gc.ca/science/ocean/home.html	T S		Jan	1979, 1984, 1985, 1986, 1987, 1988, 1989, 1991, 1992, 1993	
			Feb	1979, 1984, 1985, 1986, 1987, 1988, 1989, 1991, 1992, 1993	
			March	1979, 1984, 1985, 1986, 1987, 1988, 1989, 1991, 1992, 1993	
			April	1979, 1984, 1985, 1986, 1987, 1988, 1989, 1991, 1992, 1993	
			May	1979, 1984, 1985, 1986, 1987, 1988, 1989, 1991, 1992, 1993	
			June	1979, 1981, 1984, 1985, 1986, 1987, 1988, 1989, 1991, 1992, 1993, 1994, 1995, 1996	
			July	1979, 1980, 1981, 1984, 1985, 1986, 1987, 1988, 1989, 1991, 1992, 1993, 1994, 1995, 1996, 1997	
			August	1979, 1980, 1981, 1984, 1985, 1986, 1987, 1988, 1989, 1991, 1992, 1993, 1994, 1995, 1996, 1997	
			Sept	1979, 1980, 1981, 1984, 1985, 1986, 1987, 1988, 1989, 1991, 1992, 1993, 1994, 1995, 1997	
			Oct	1978, 1979, 1980, 1981, 1984, 1985, 1986, 1987, 1988, 1992, 1995, 1997	
			Nov	1978, 1982, 1983, 1984, 1985, 1986, 1987, 1988, 1992, 1995, 1997	
			Dec	1978, 1982, 1983, 1984, 1985, 1986, 1987, 1988, 1991, 1992,	

Table 9: Offshore-temperature salinity (continued)

Reference	Data	Expe-dition	Month	Year	Station numbers
DFO Canada database	T S	BD (Blue Dolphin)	June	1928	
			June	1952	88, 89
			June	1963	
			July	1980	
			Oct	1983	
Newfoundland Fisheries Research Station 1952, 1953. Report of the Newfoundland Fisheries Research Station for 1951-1955. The Station, 1951-1955, St John's, NF.	T	In (Investiga-tor II)	Sept	1953	
Buchanan R.A. and Foy M.S. 1980. Plankton, Nutrients, Chlorophyll, Phytoplankton and Ichthyoplankton. Olabs Program Report: Offshore Labrador Biological study.	T S		July	1979	LC-1, LC-2, LC-3, LC-4, LC-5

Legend: T- Temperature, S- Salinity

Table 10: Offshore-nutrients

Reference	Data	Expedition	Month	Year	Station numbers
DFO Canada database	P	BD	June	1928	
			June	1952	88, 89
			June	1963	
			August	1952	88
	O	BD	June	1928	
			June	1952	88, 89
			June	1963	
			August	1952	88
Buchanan R.A. and Foy M.S. 1980. Plankton, Nutrients, Chlorophyll, Phytoplankton and Ichthyoplankton. Olabs Program Report: Offshore Labrador Biological study.	N P Chl Si		July	1979	LC-1, LC-2, LC-3, LC-4, LC-5

Legend: P- Phosphorus, O- Oxygen, N- Nitrate, Chl- Chlorophyll, Si- Silicate

Figures

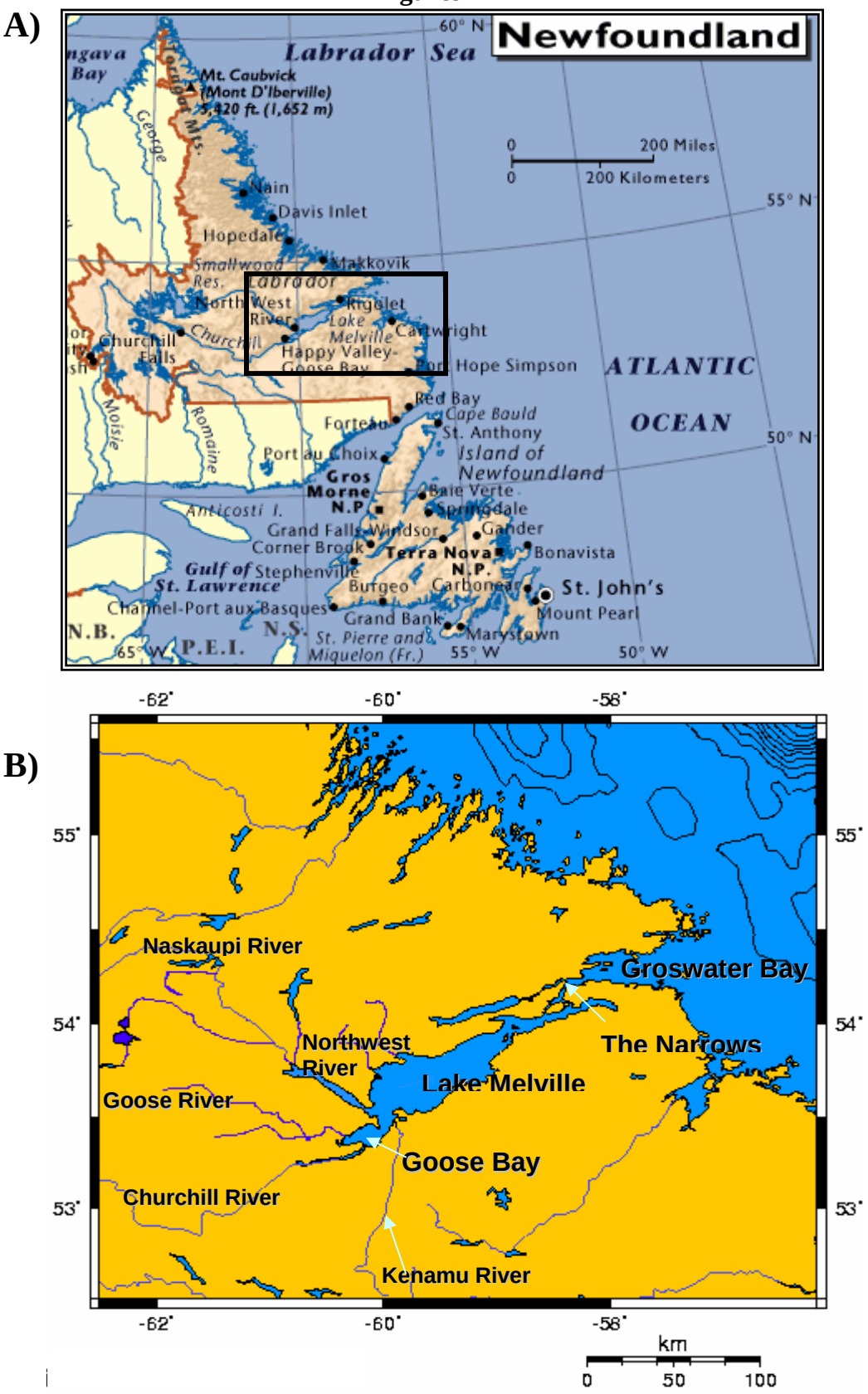


Figure 1: Location of study area, The Hamilton Inlet, Labrador. Figure B shows an enlargement of the boxed area in figure A.

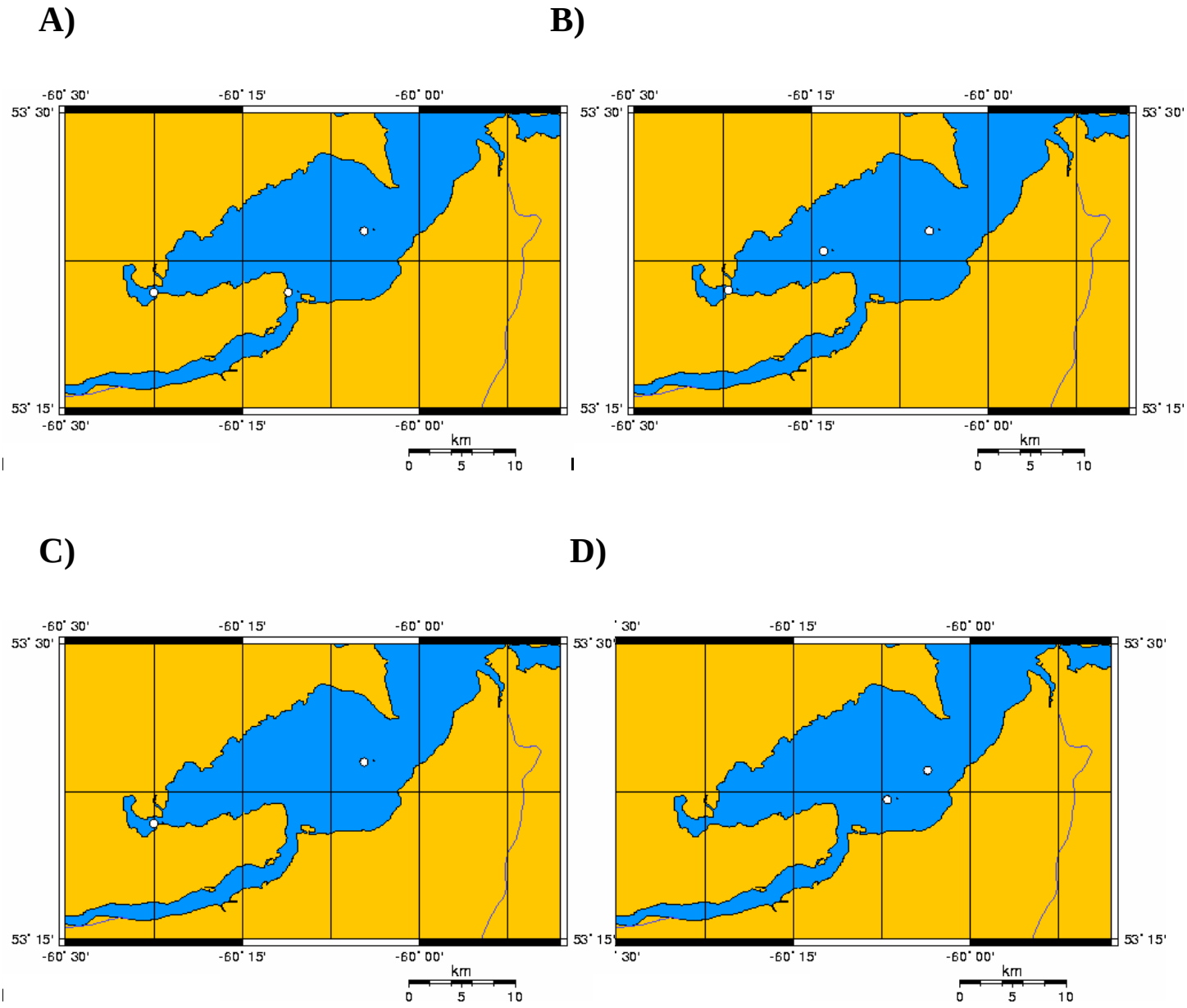


Figure 2: Location of temperature and salinity data collection, Goose Bay.
A) temperature March, Pre 1970, B) temperature/salinity July and August, Pre 1970,
C) salinity March, Pre 1970, D) temperature/salinity October, Post 1970.

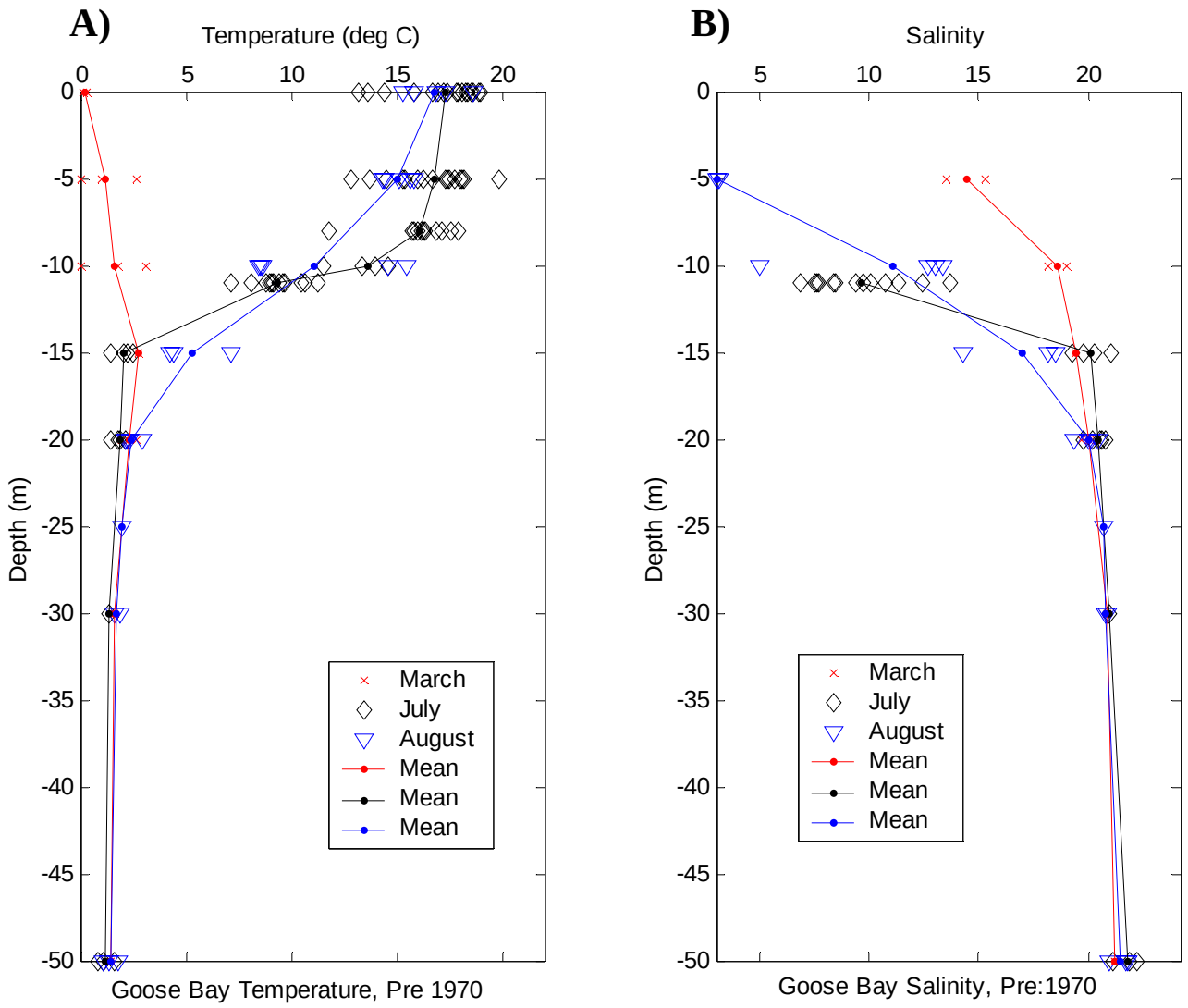


Figure 3: Goose Bay temperature and salinity, pre 1970. A) all temperature data, B) all salinity data.

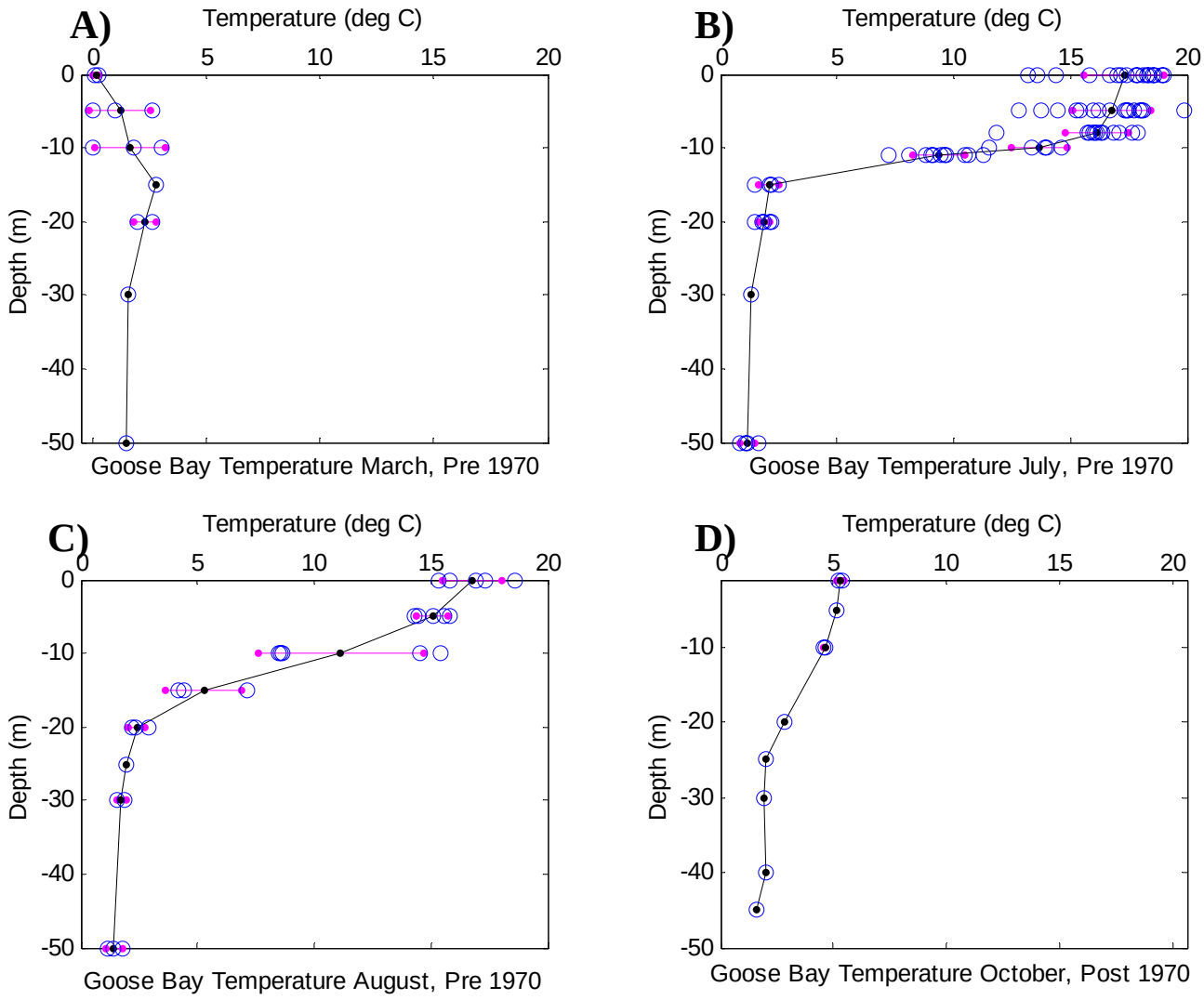


Figure 4: Monthly Goose Bay temperature. The circles represent each data point, the solid line is the mean and the horizontal bars are the standard deviation.
A) March pre 1970, B) July pre 1970, C) August pre 1970, D) October post 1970.

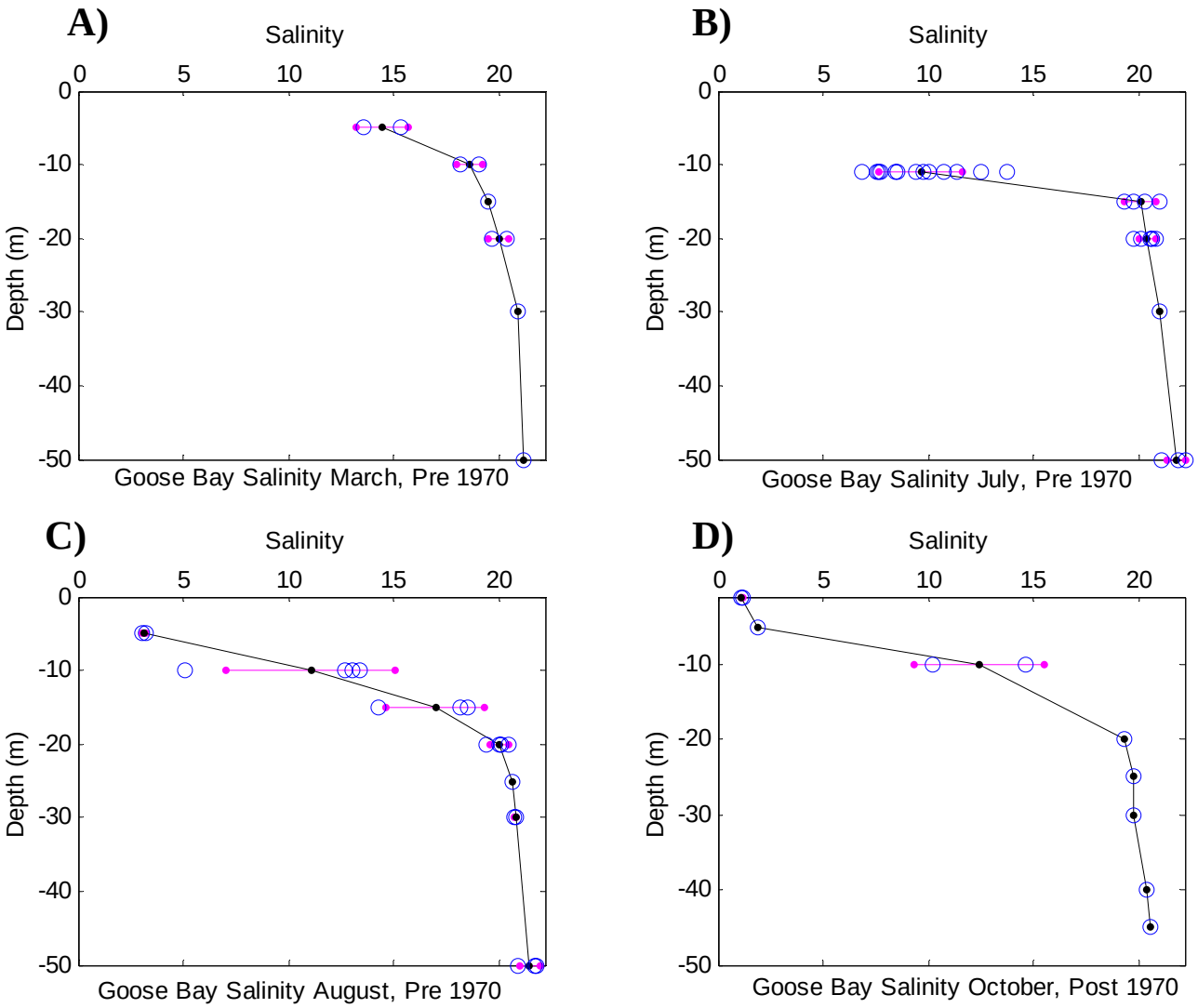
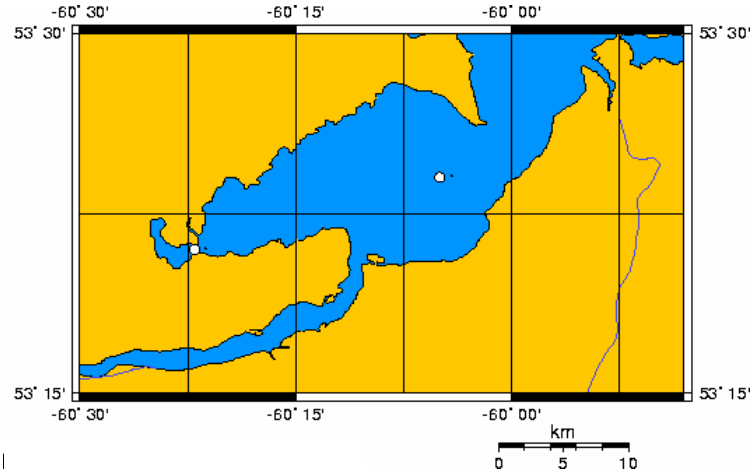
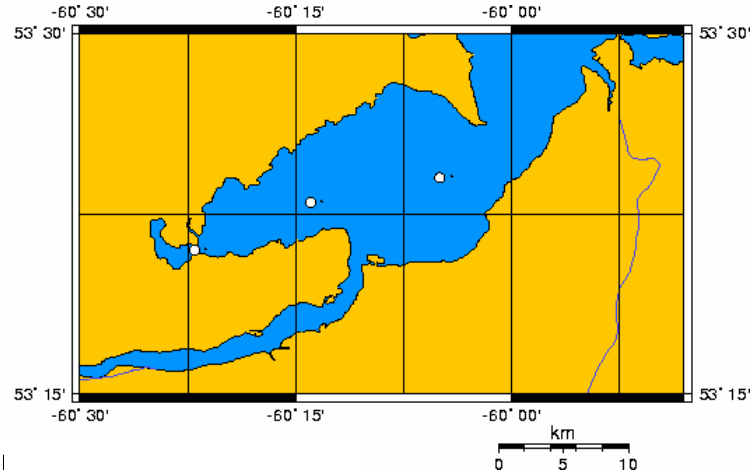


Figure 5: Monthly Goose Bay salinity. The circles represent each data point, the solid line is the mean and the horizontal bars are the standard deviation.
A) March pre 1970, B) July pre 1970, C) August pre 1970, D) October post 1970.

A)



B)



C)

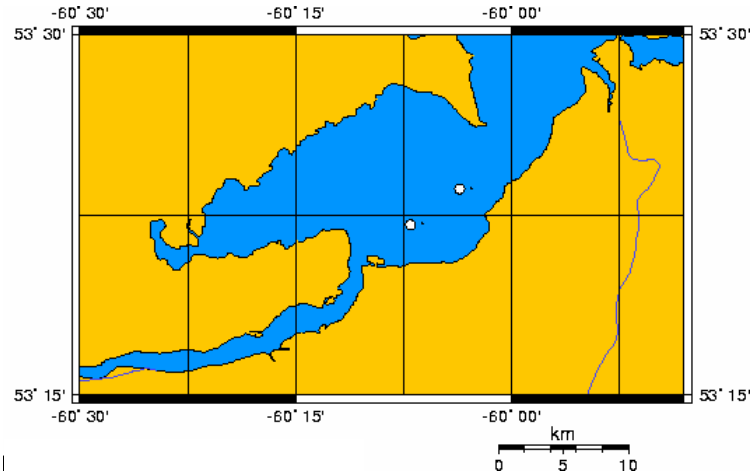


Figure 6: Location of oxygen and phosphorus data collection, Goose Bay.
A) phosphorus July and August, Pre 1970,
B) oxygen July and August, Pre 1970,
C) oxygen October, Post 1970.

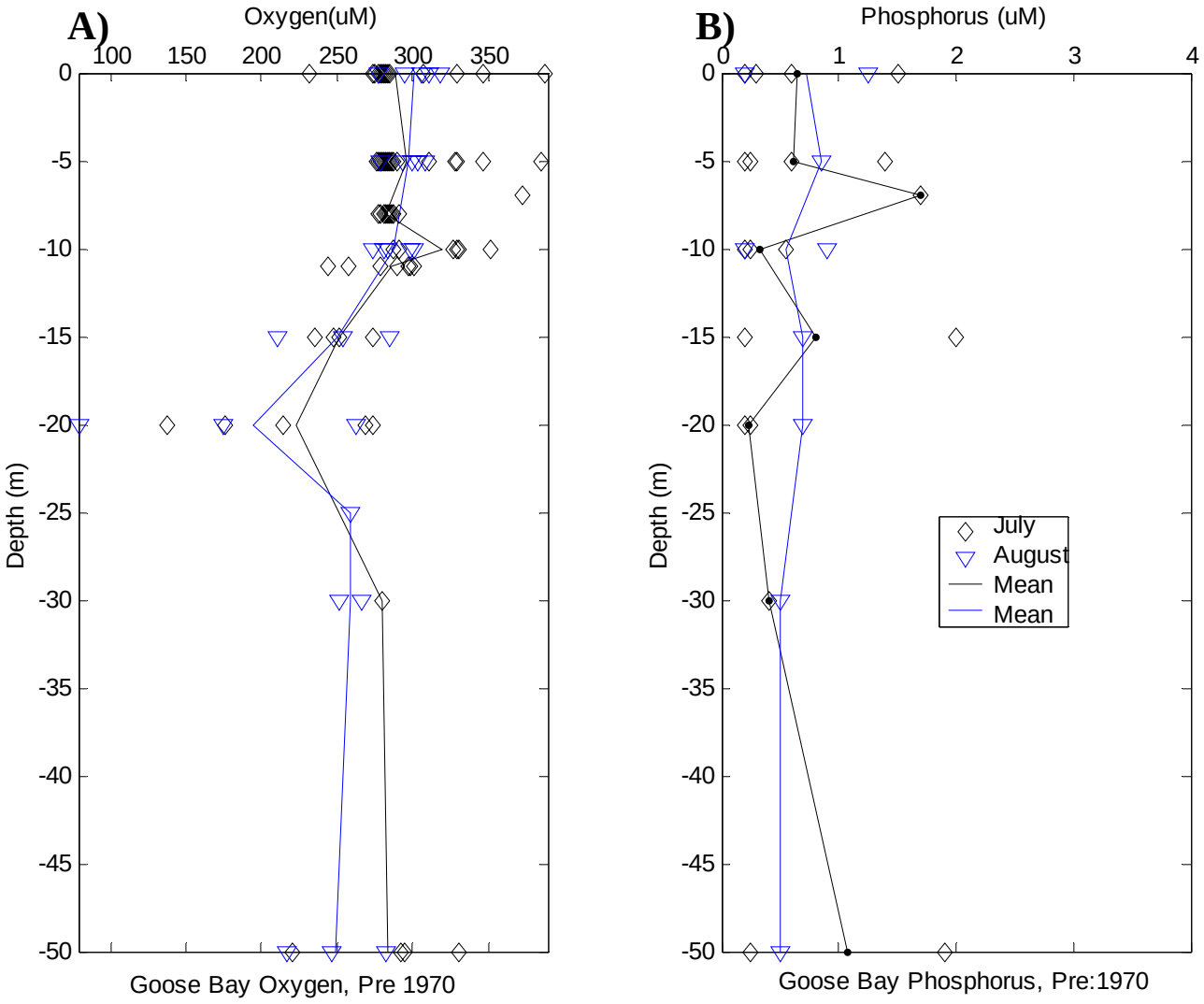


Figure 7: Goose Bay oxygen and phosphorus, pre 1970. A) all oxygen data, B) all phosphorus data.

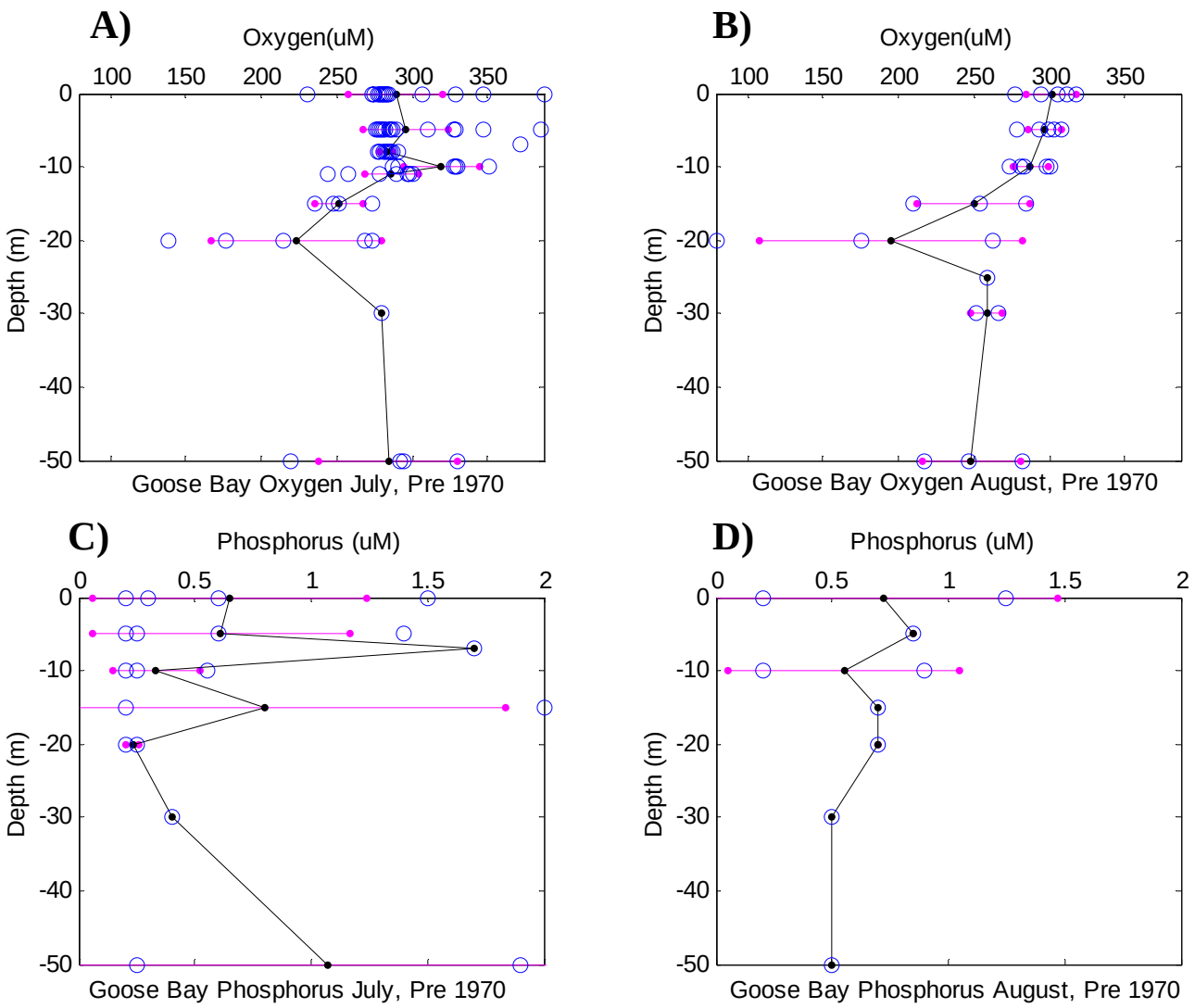


Figure 8: Monthly Goose Bay oxygen and phosphorus, pre 1970. The circles represent each data point, the solid line is the mean and the horizontal bars are the standard deviation. A) oxygen July, B) oxygen August, C) phosphorus July, D) phosphorus August.

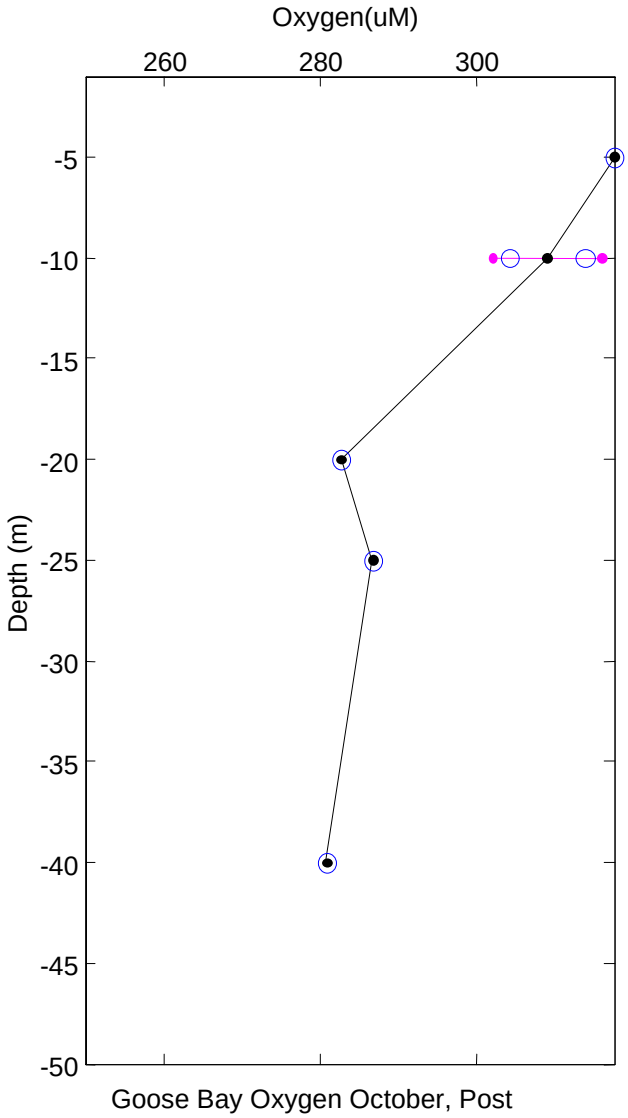


Figure 9: Goose Bay oxygen October, post 1970. The circles represent each data point, the solid line is the mean and the horizontal bars are the standard deviation.

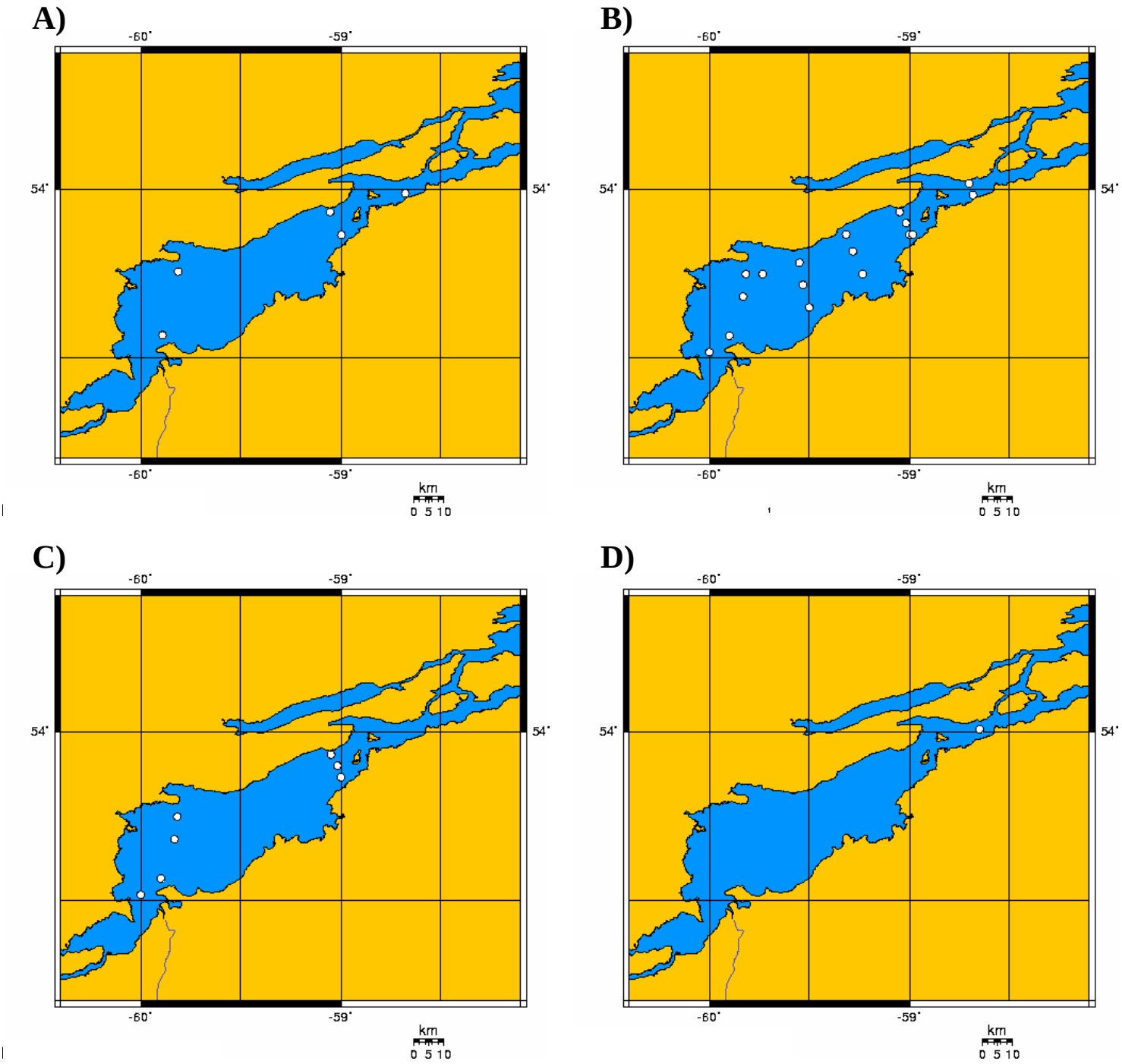


Figure 10: Location of temperature and salinity data collection, Lake Melville.

A) temperature/salinity March, Pre 1970, B) temperature/salinity July, Pre 1970, C) temperature/salinity August, Pre 1970, D) temperature October, Pre 1970.

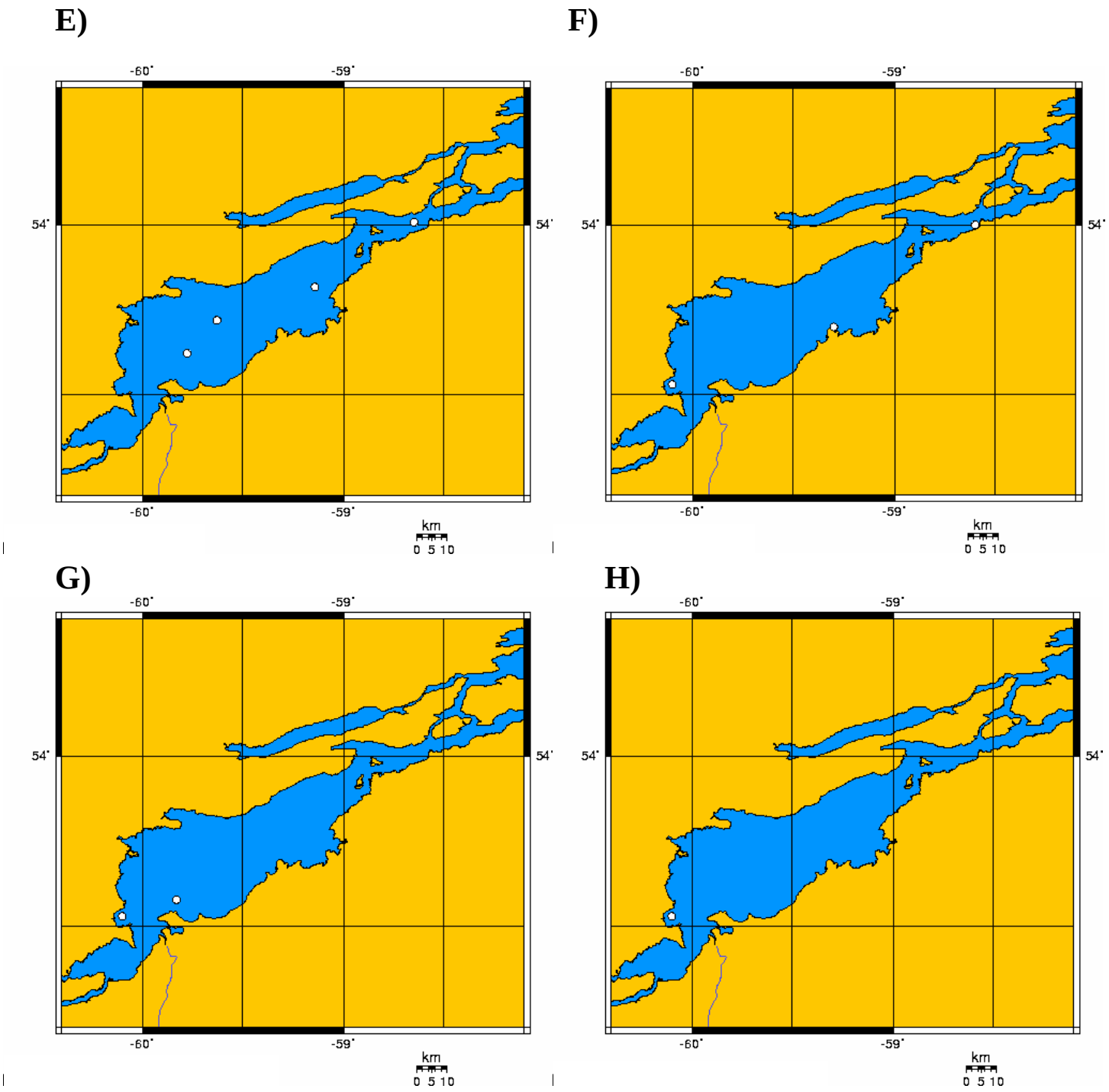


Figure 10: Location of temperature and salinity data collection, Lake Melville.

E) salinity October, Pre 1970, F) temperature January, Post 1970,
G) temperature/salinity April, Post 1970, H) salinity January, Post 1970.

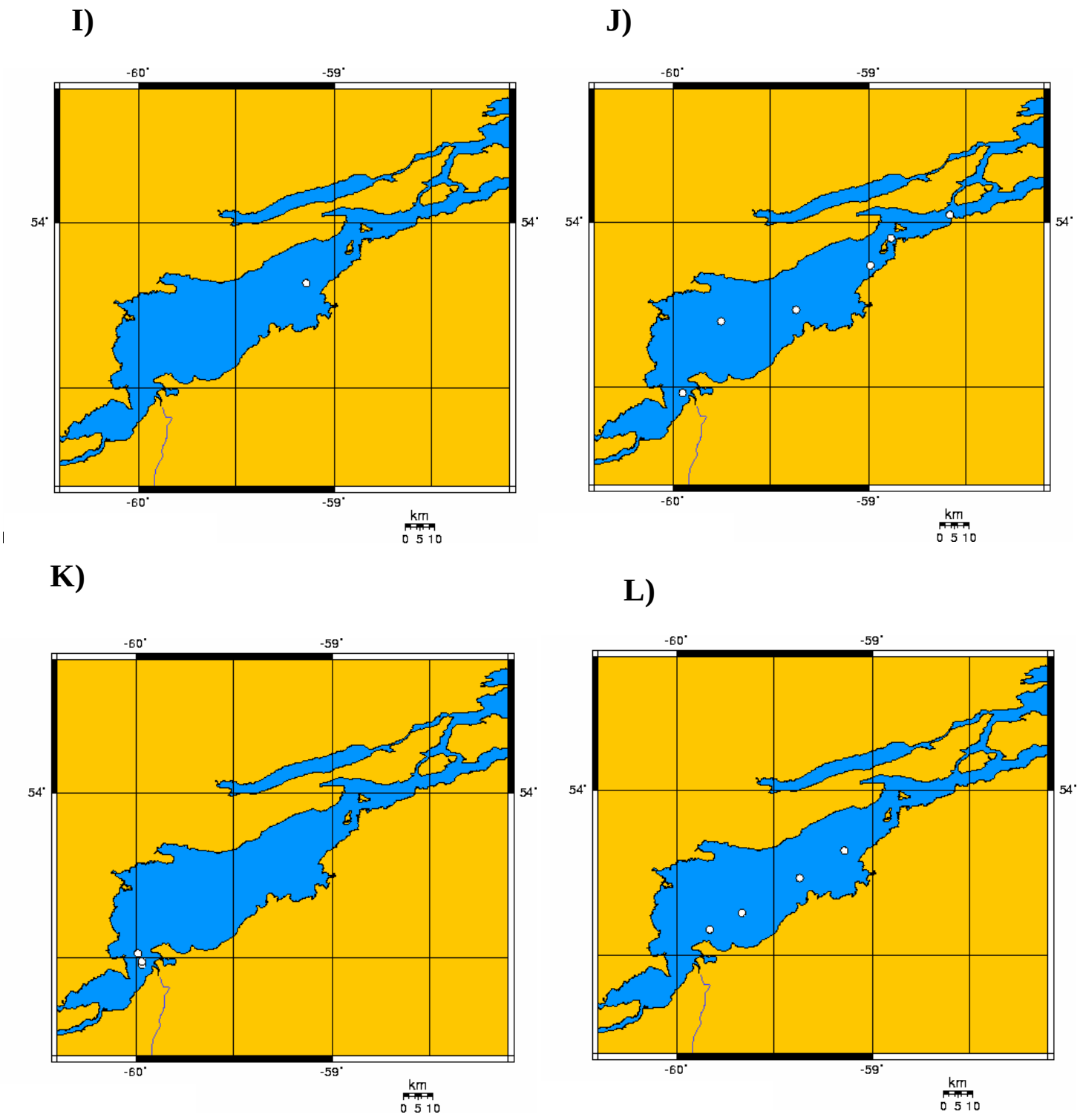


Figure 10: Location of temperature and salinity data collection, Lake Melville.

I) temperature/salinity May, Post 1970, J) temperature/salinity July, Post 1970,
K) temperature September, Post 1970, L) temperature/salinity November, Post 1970.

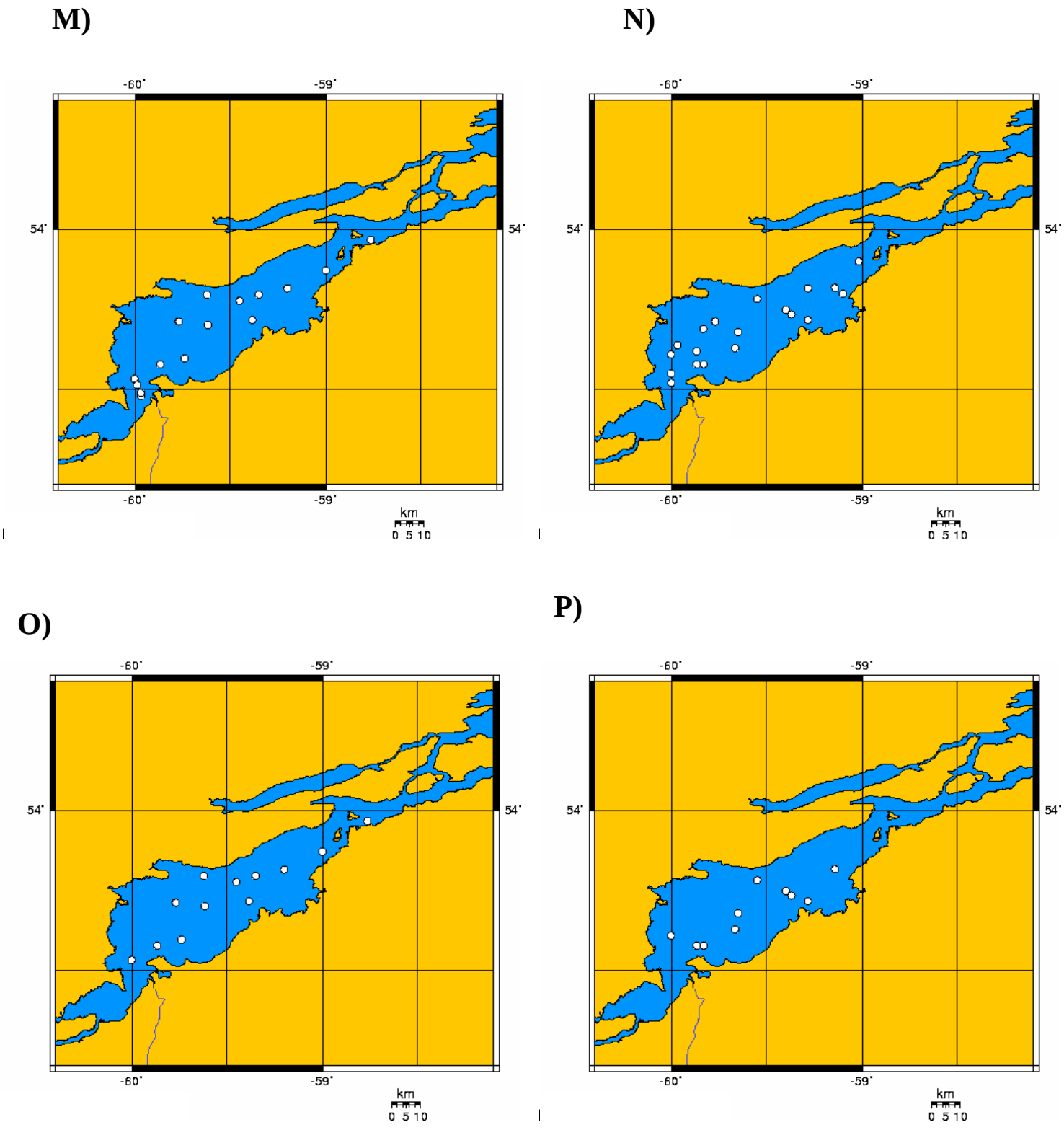


Figure 10: Location of temperature and salinity data collection, Lake Melville.

M) temperature October, Post 1970, N) temperature December, Post 1970,
O) salinity October, Post 1970, P) salinity December, Post 1970.

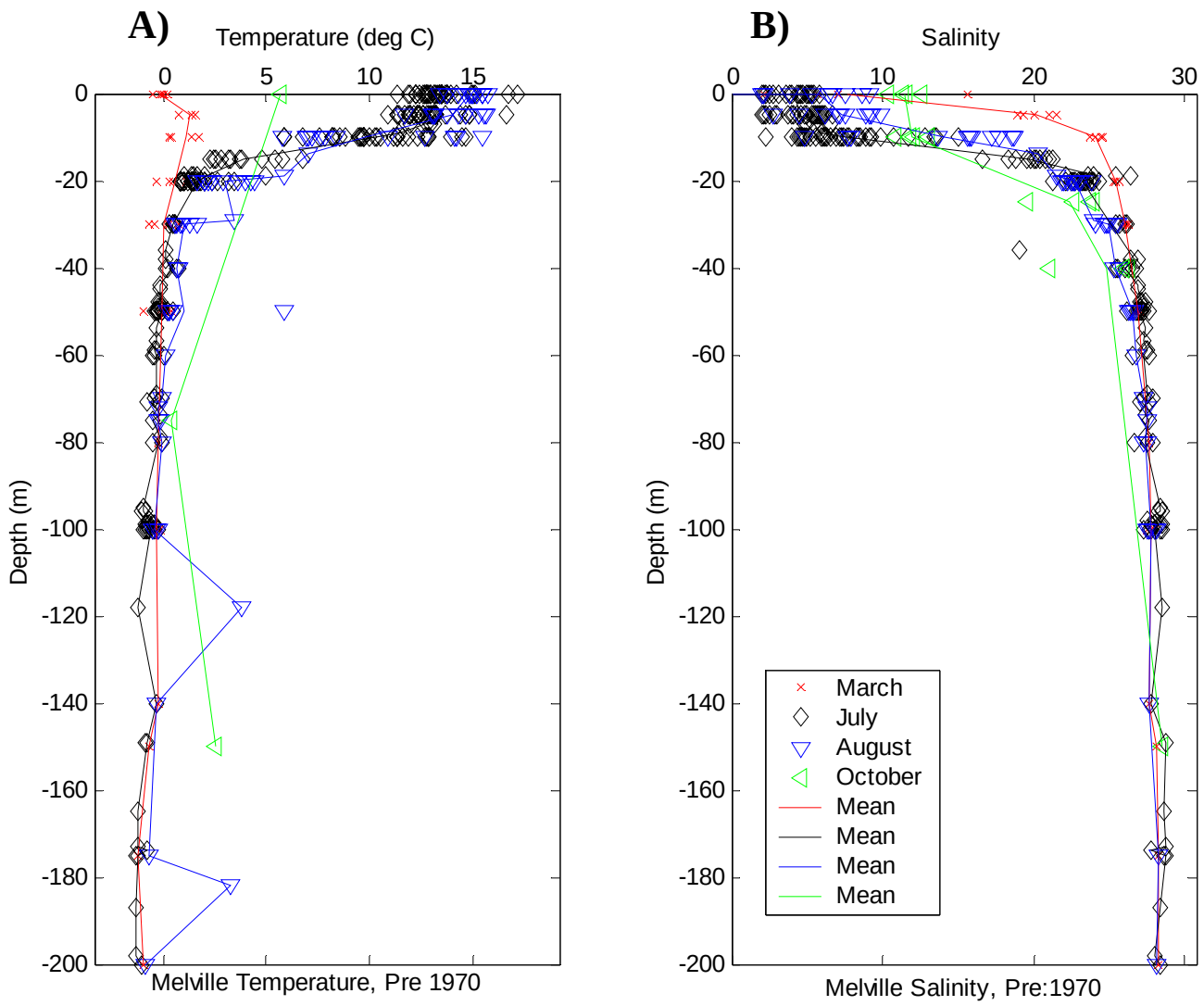


Figure 11: Lake Melville temperature and salinity, pre 1970. A) all temperature data, B) all salinity data.

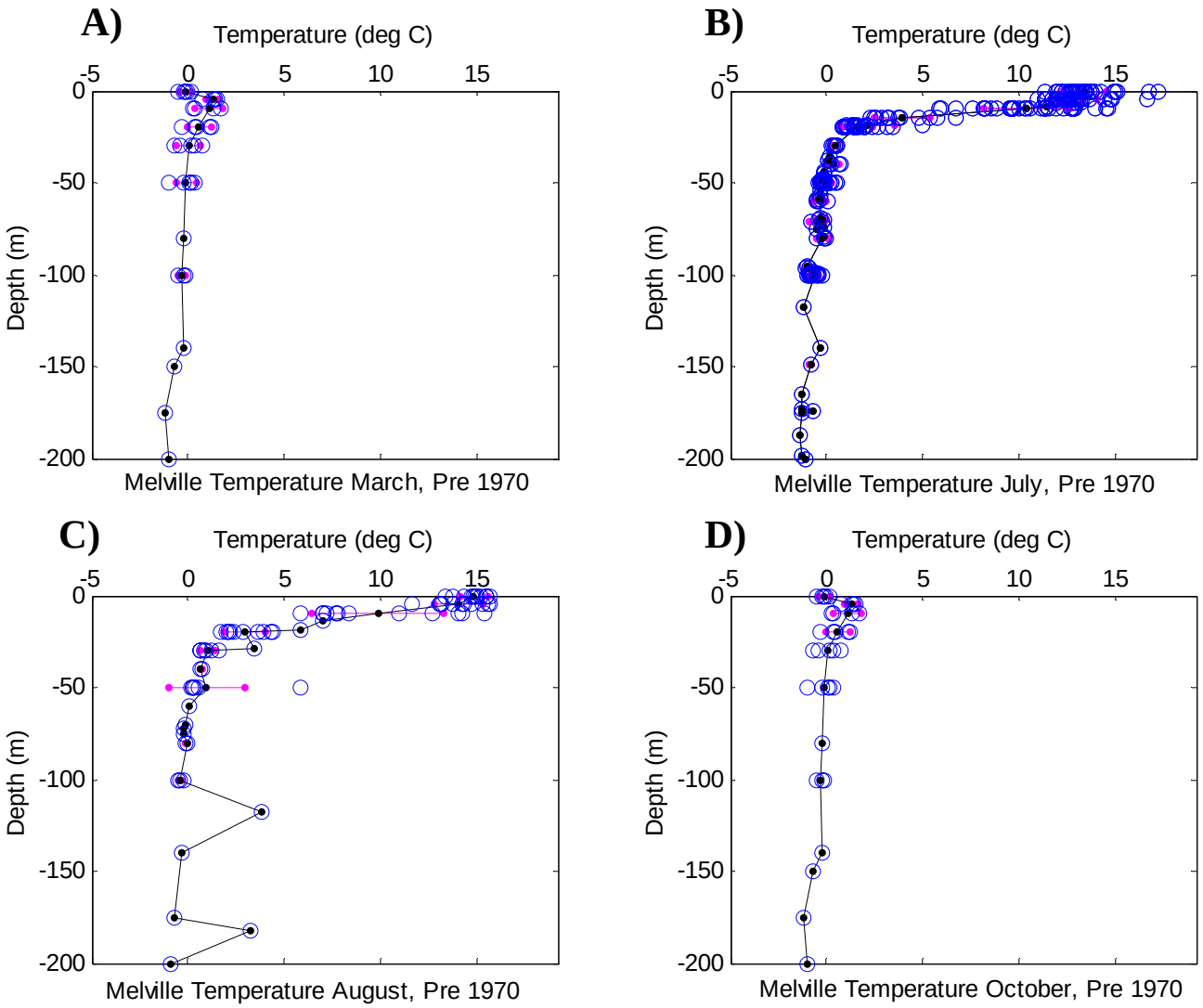


Figure 12: Monthly Lake Melville temperature, pre 1970. The circles represent each data point, the solid line is the mean and the horizontal bars are the standard deviation. A) March, B) July, C) August, D) October.

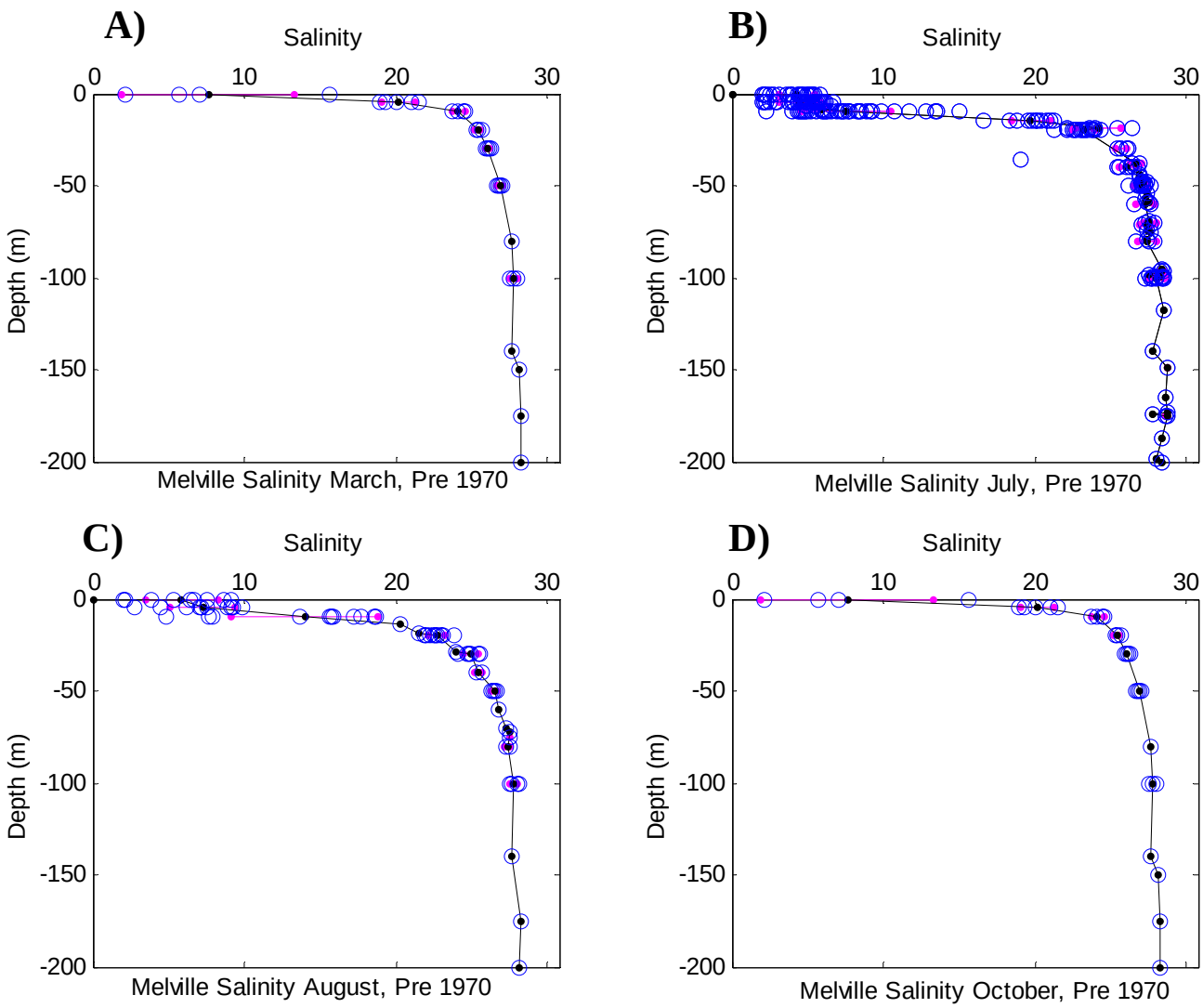


Figure 13: Monthly Lake Melville salinity, pre 1970. The circles represent each data point, the solid line is the mean and the horizontal bars are the standard deviation. A) March, B) July, C) August, D) October.

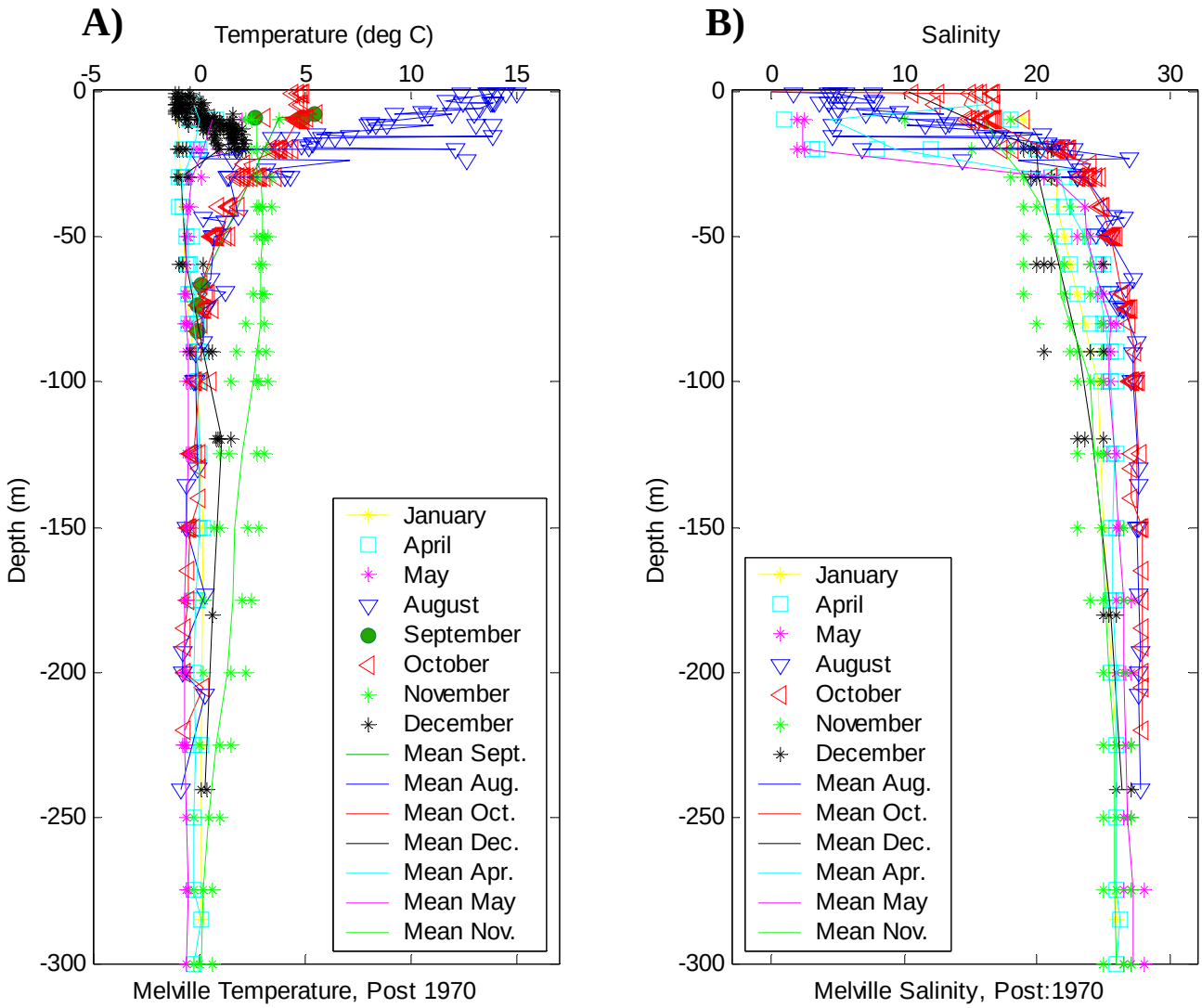


Figure 14: Lake Melville temperature and salinity, post 1970. A) all temperature data, B) all salinity data.

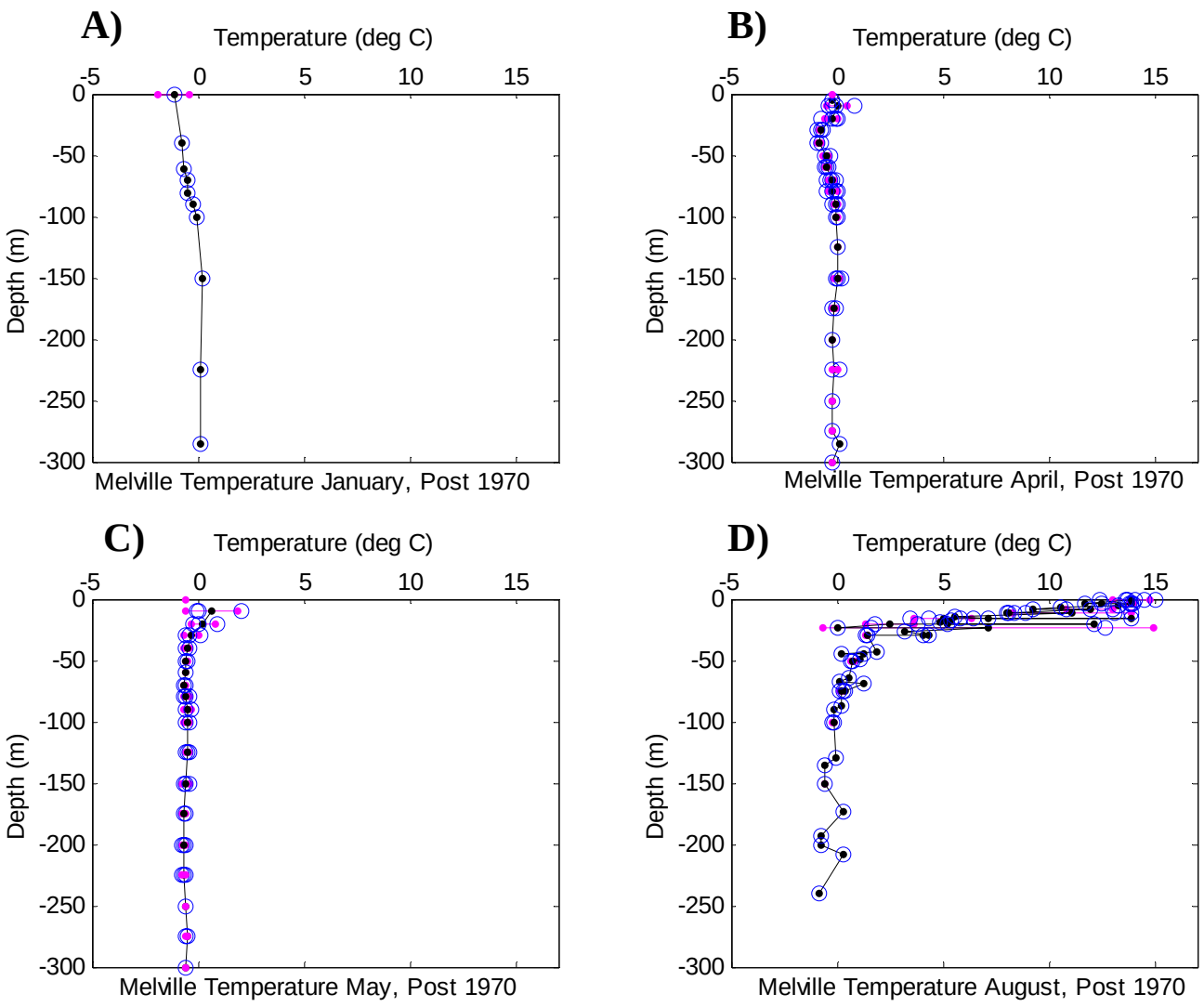


Figure 15: Monthly Lake Melville temperature, post 1970. The circles represent each data point, the solid line is the mean and the horizontal bars are the standard deviation. A) January, B) April, C) May, D) August.

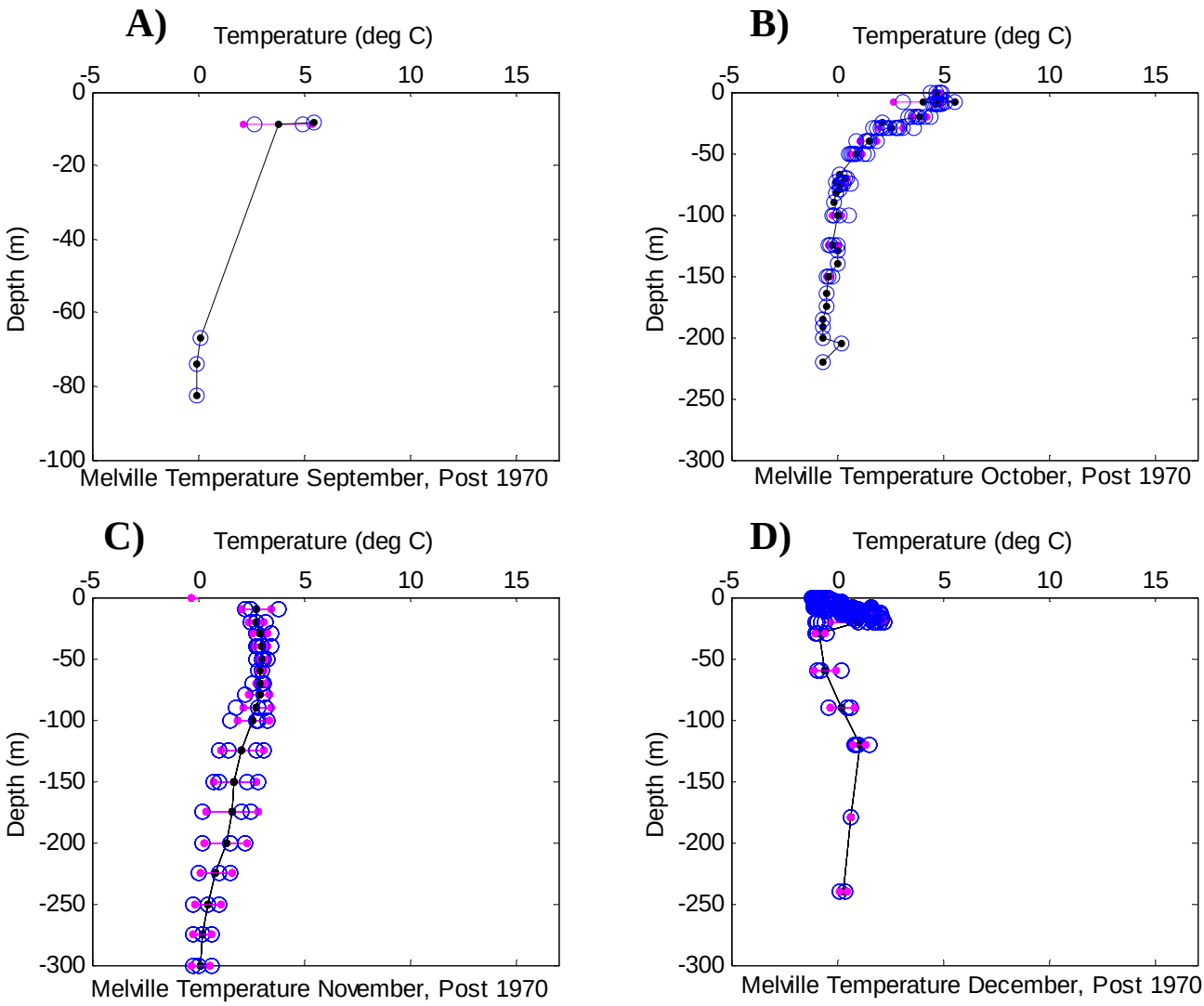


Figure 16: Monthly Lake Melville temperature, post 1970. The circles represent each data point, the solid line is the mean and the horizontal bars are the standard deviation. A) September, B) October, C) November, D) December.

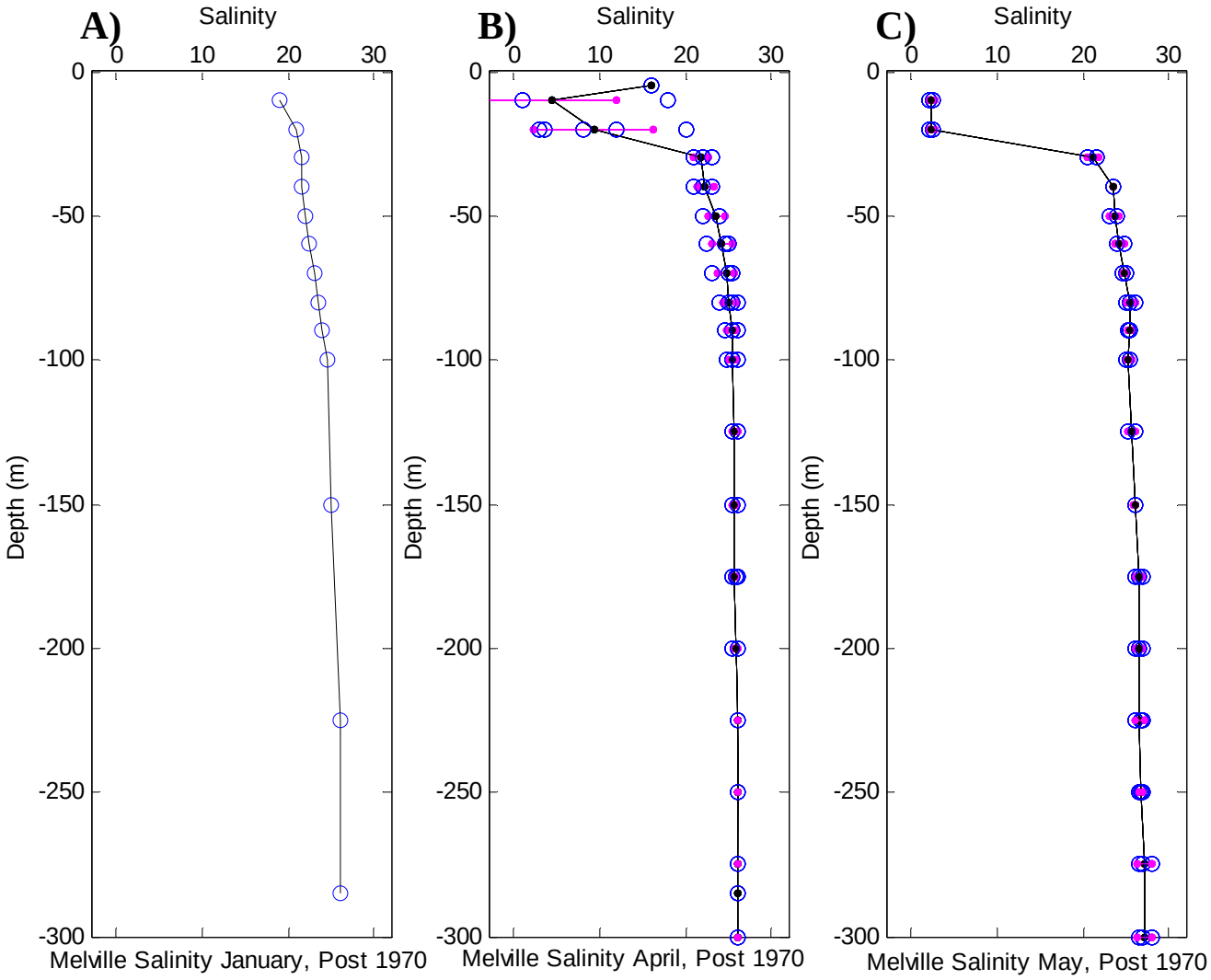


Figure 17: Monthly Lake Melville salinity, post 1970**.** The circles represent each data point, the solid line is the mean and the horizontal bars are the standard deviation. A) January, B) April, C) May**.**

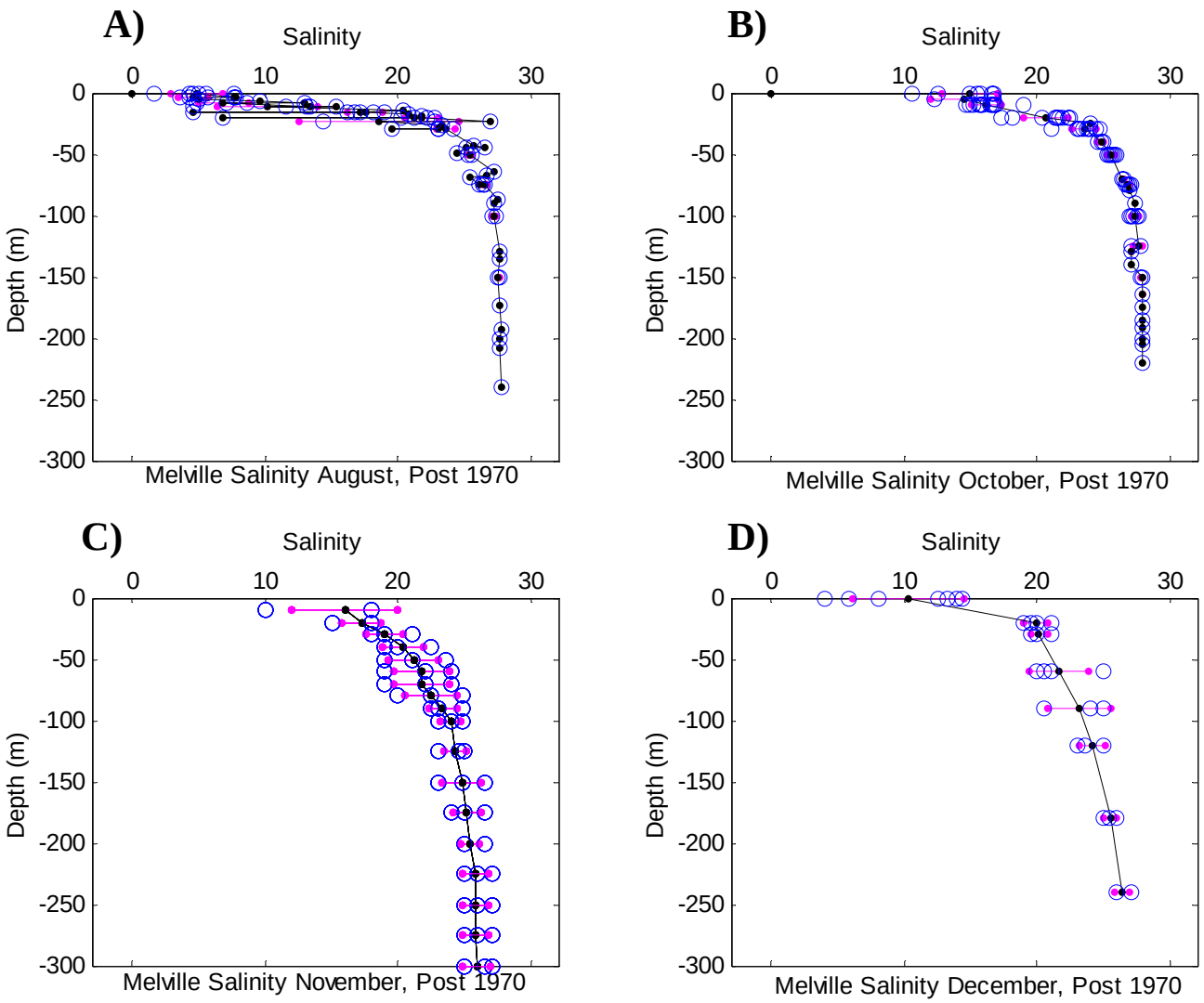


Figure 18: Monthly Lake Melville salinity, post 1970. The circles represent each data point, the solid line is the mean and the horizontal bars are the standard deviation.

A) August, B) October, C) November, D) December.

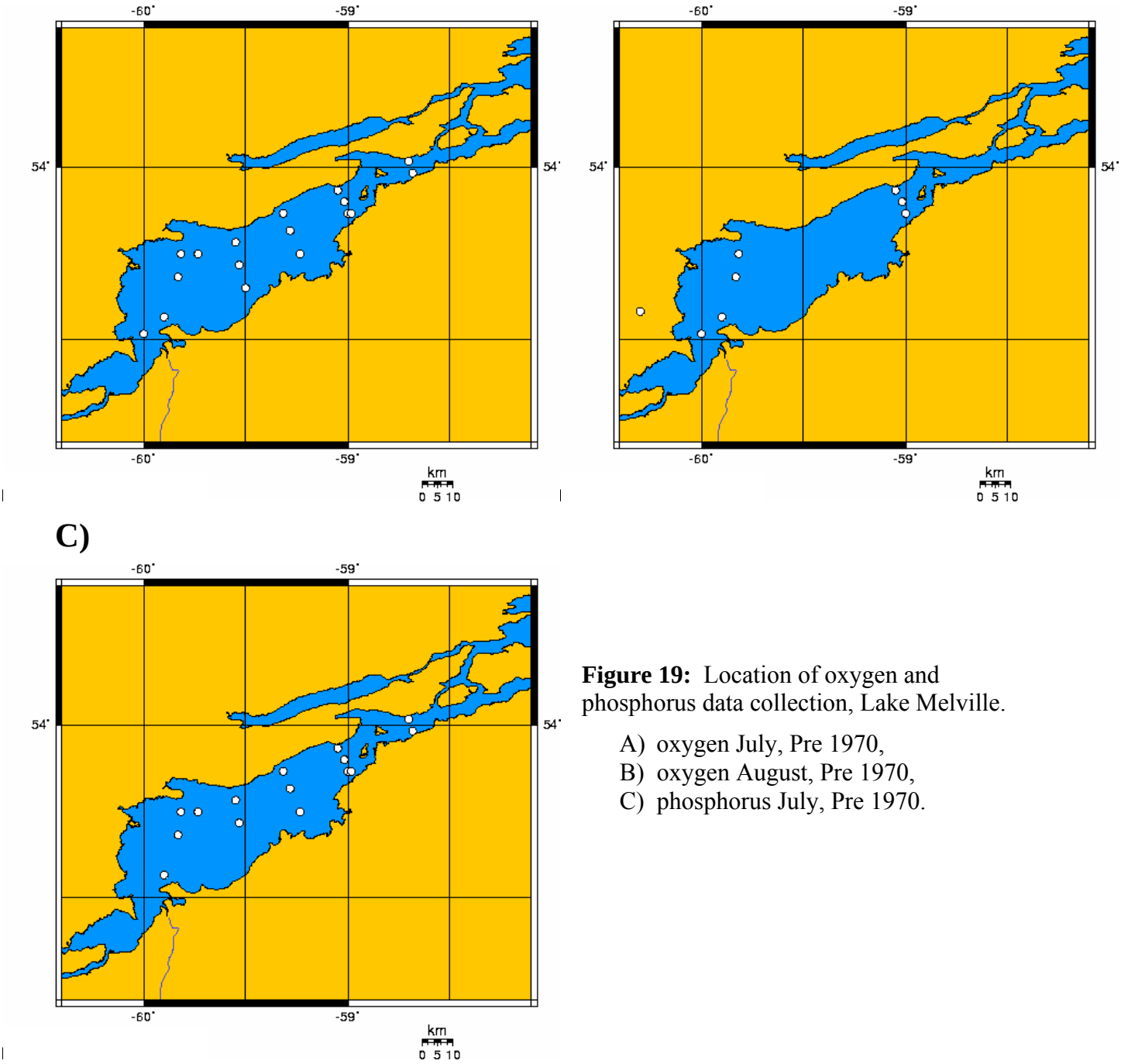
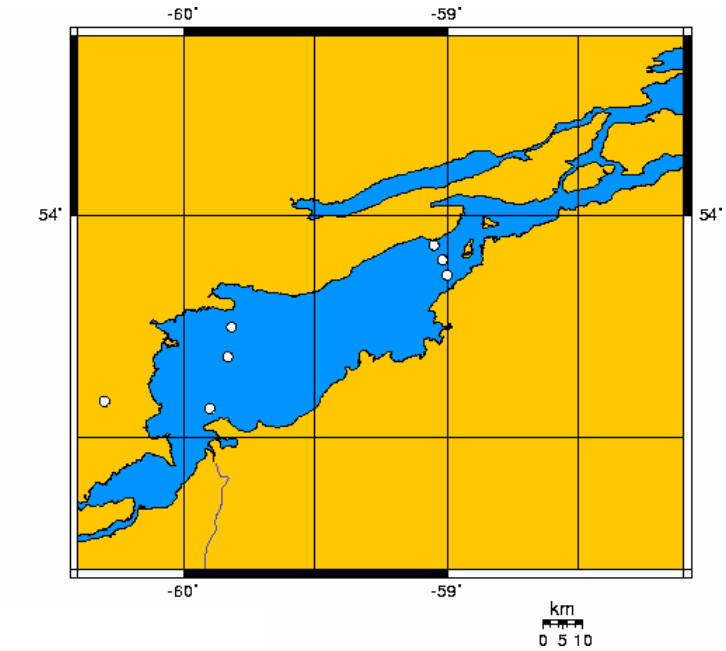


Figure 19: Location of oxygen and phosphorus data collection, Lake Melville.

A) oxygen July, Pre 1970,
B) oxygen August, Pre 1970,
C) phosphorus July, Pre 1970.

D)



E)

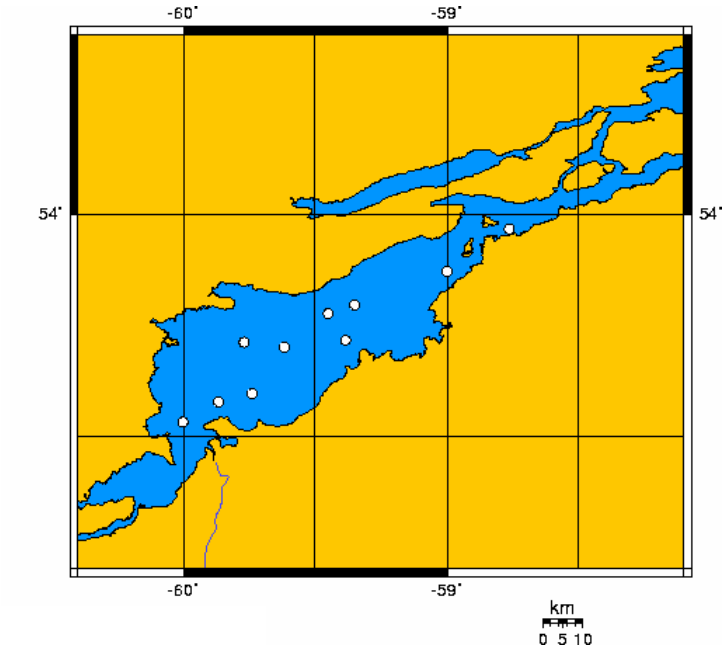


Figure 19: Location of oxygen and phosphorus data collection, Lake Melville. D) phosphorus August, Pre 1970, E) oxygen October, Post 1970.

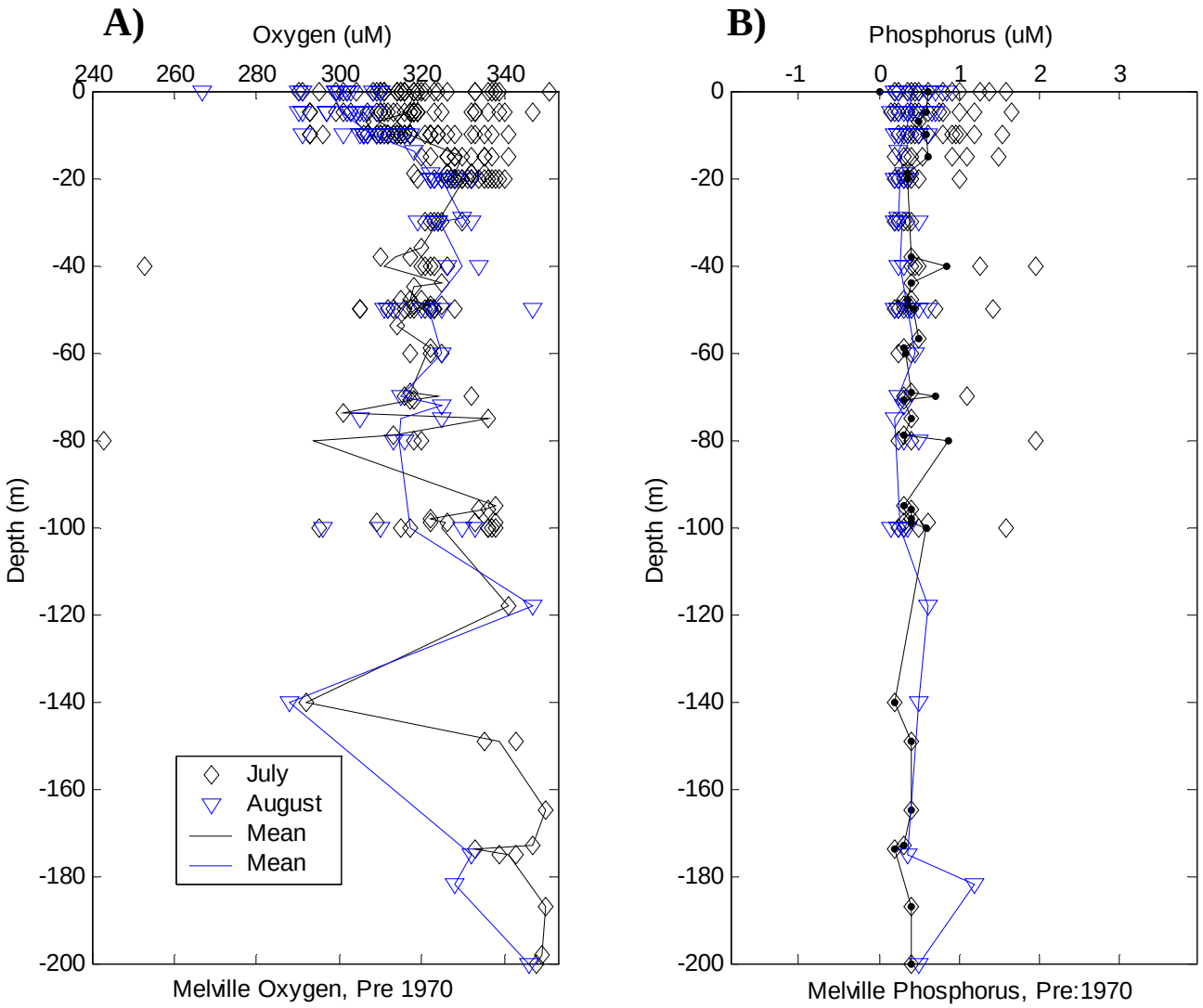


Figure 20: Lake Melville oxygen and phosphorus, pre 1970. A) all oxygen data, B) all phosphorus data.

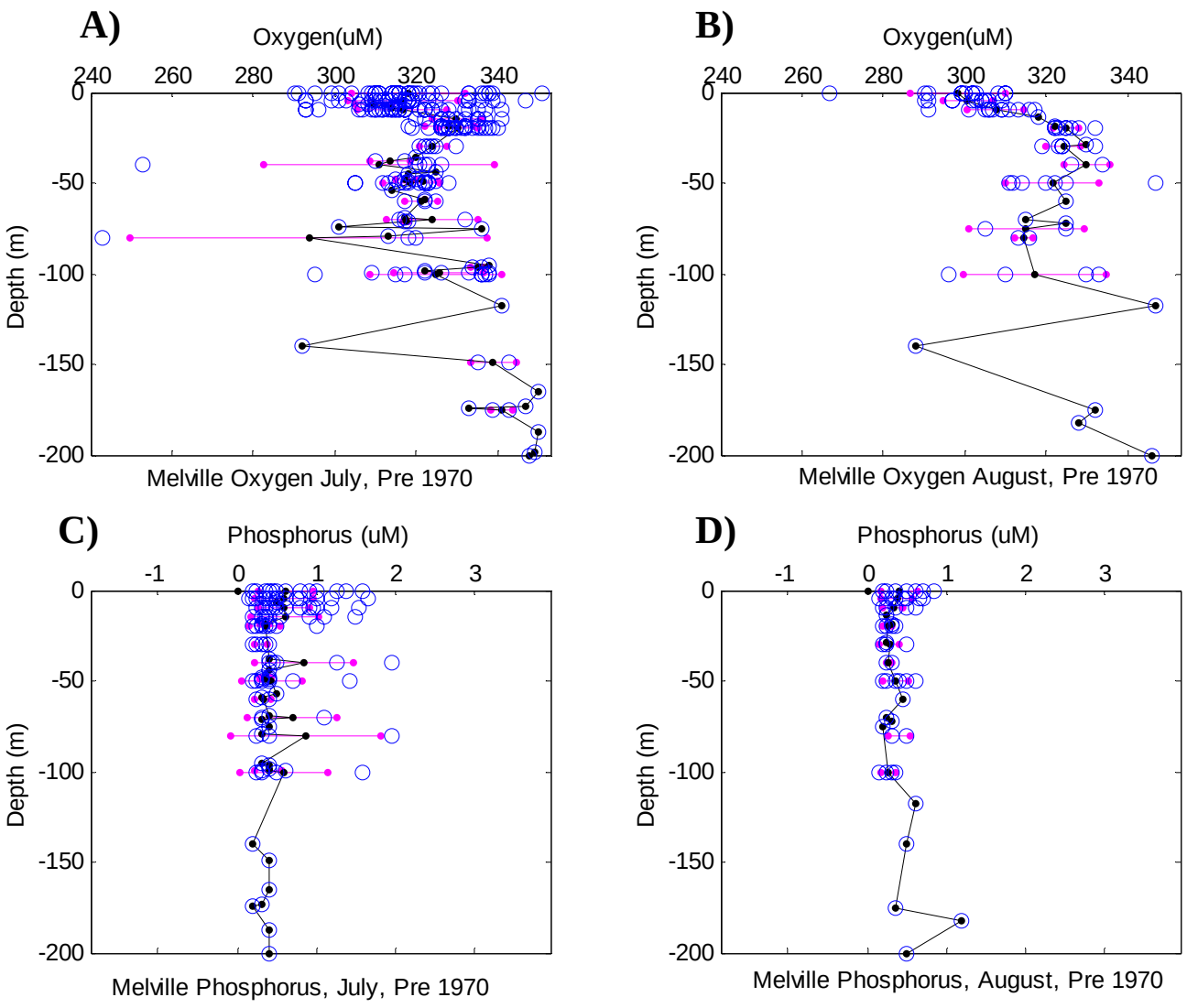


Figure 21: Monthly Lake Melville oxygen and phosphorus, pre 1970. The circles represent each data point, the solid line is the mean and the horizontal bars are the standard deviation. A) oxygen July, B) oxygen August, C) phosphorus July, D) phosphorus August.

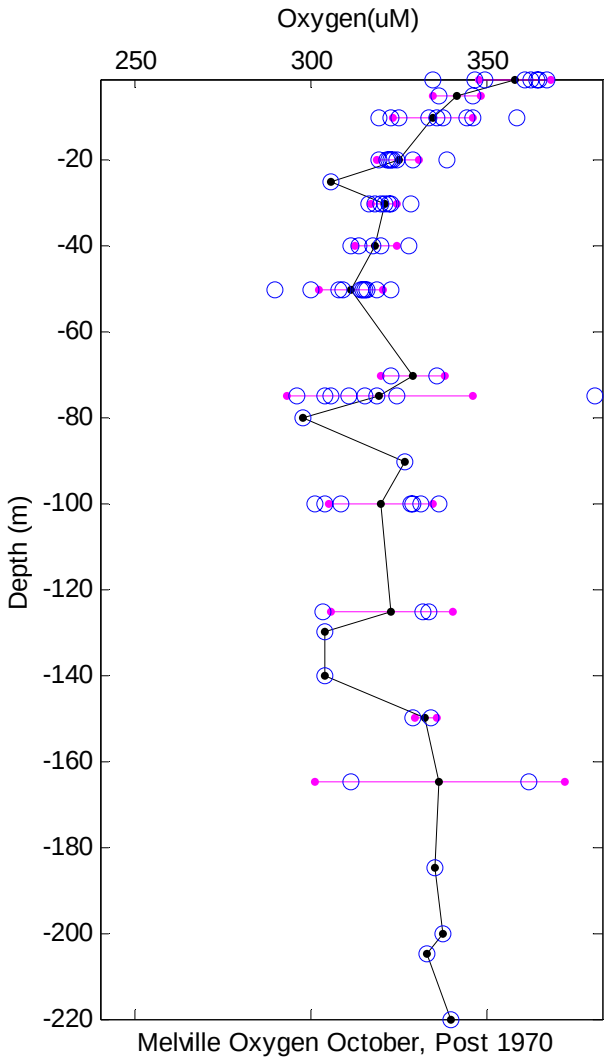


Figure 22: Lake Melville oxygen October, post 1970**.** The circles represent each data point, the solid line is the mean and the horizontal bars are the standard deviation.

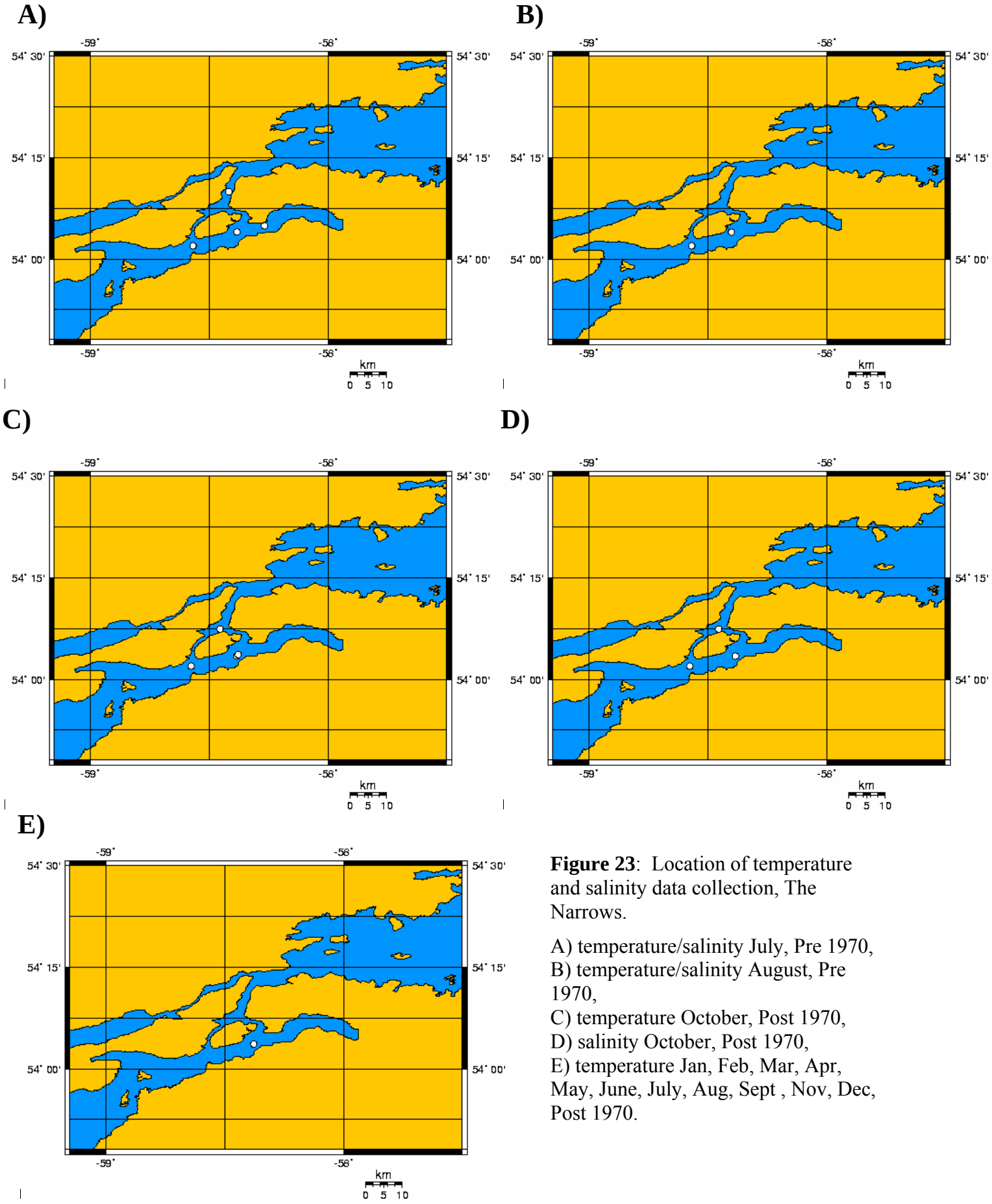


Figure 23: Location of temperature and salinity data collection, The Narrows.

A) temperature/salinity July, Pre 1970,
B) temperature/salinity August, Pre 1970,
C) temperature October, Post 1970,
D) salinity October, Post 1970,
E) temperature Jan, Feb, Mar, Apr, May, June, July, Aug, Sept , Nov, Dec, Post 1970.

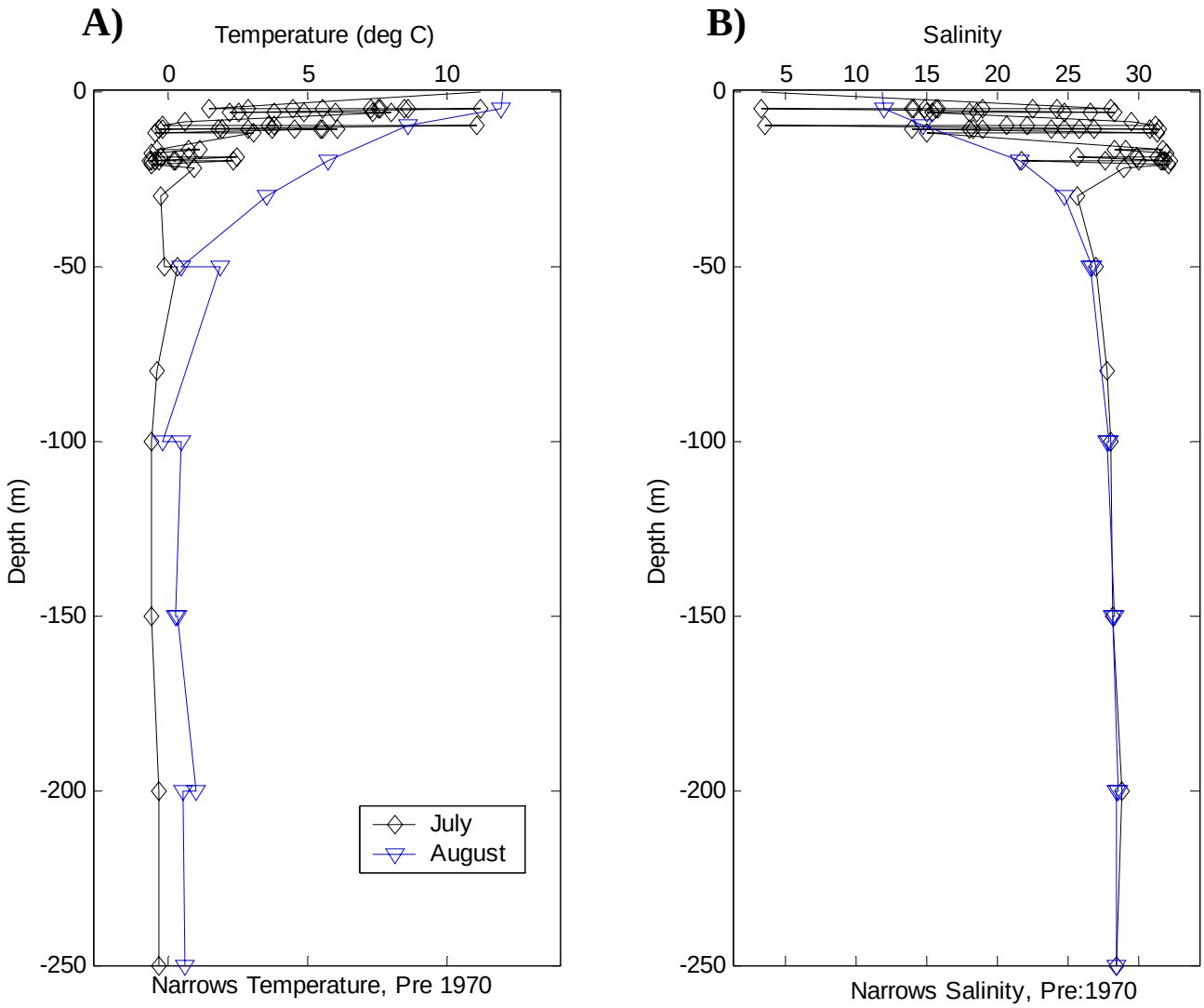


Figure 24: The Narrows temperature and salinity, pre 1970. A) all temperature data, B) all salinity data.

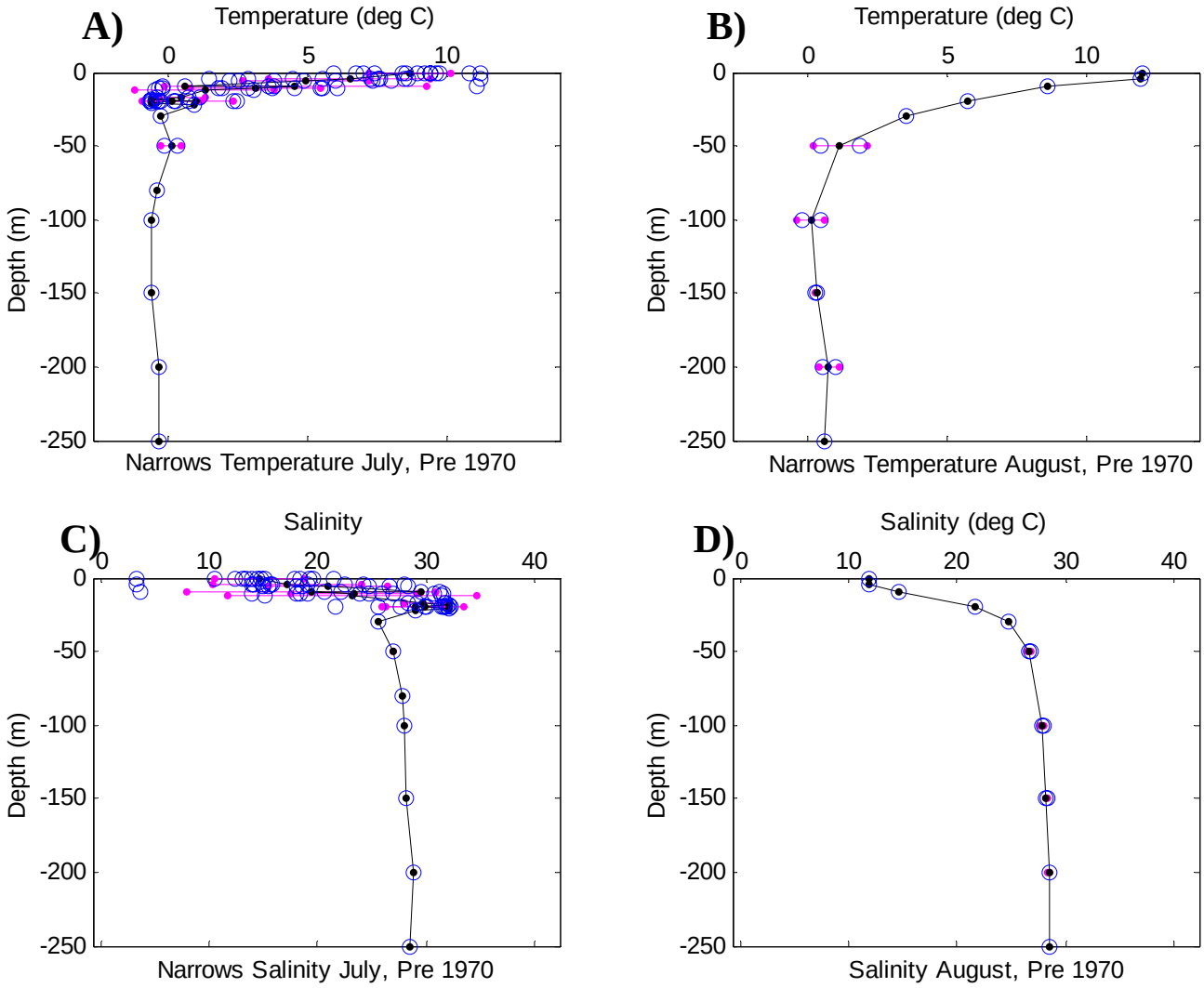


Figure 25: Monthly The Narrows temperature and salinity, pre 1970. The circles represent each data point, the solid line is the mean and the horizontal bars are the standard deviation. A) temperature July, B) temperature August, C) salinity July, D) salinity August.

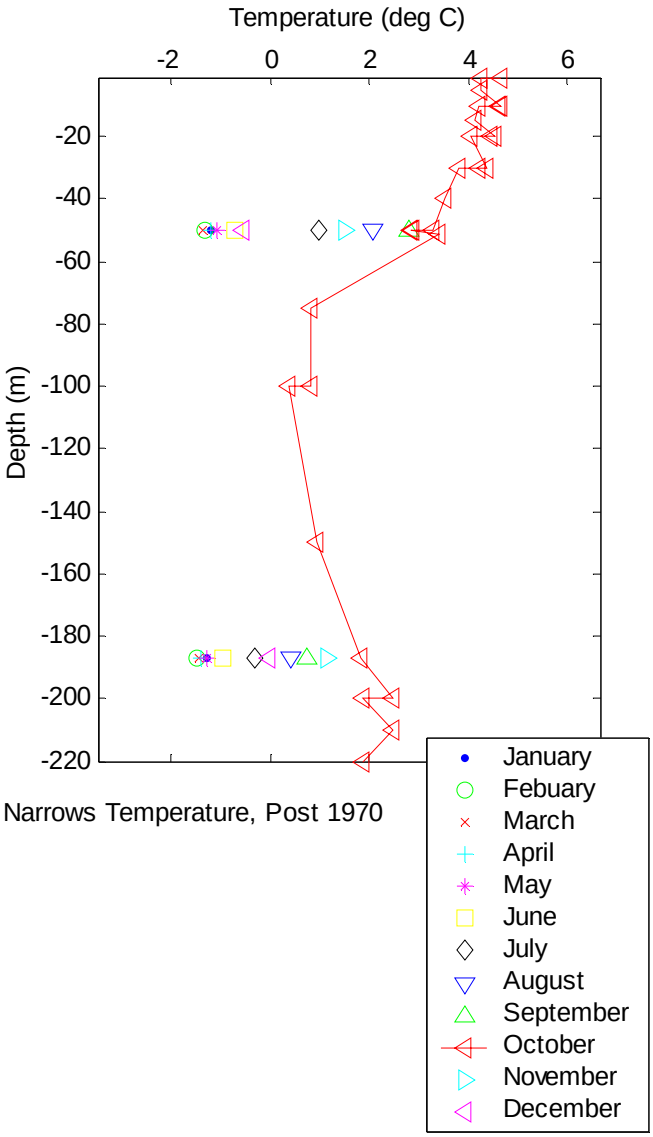


Figure 26: The Narrows temperature, post 1970.

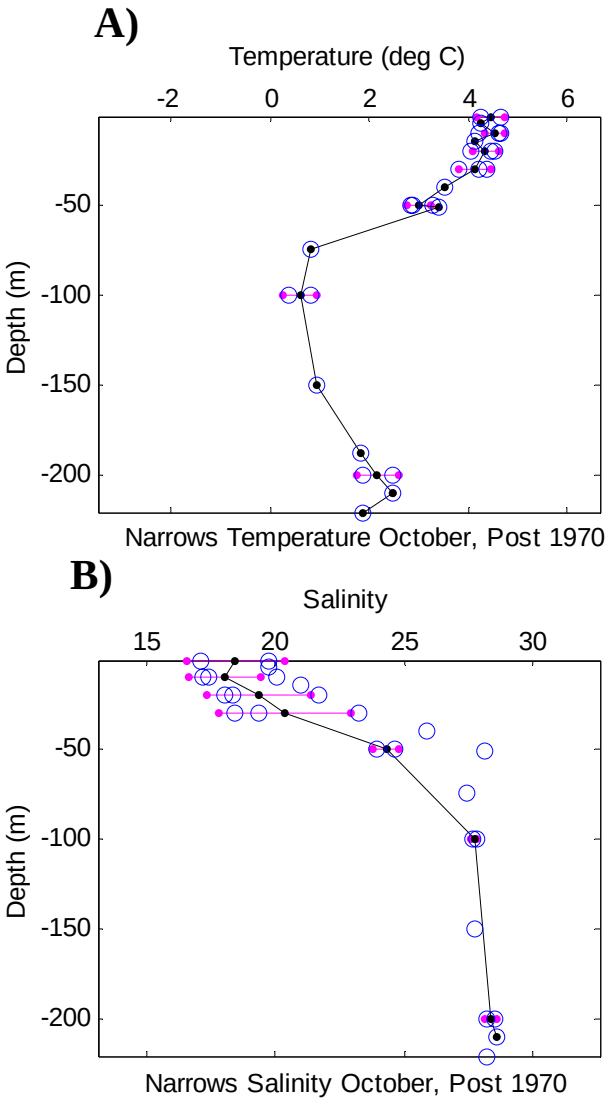


Figure 27: The Narrows temperature and salinity, post 1970. The circles represent each data point, the solid line is the mean and the horizontal bars are the standard deviation. A) temperature October, B) salinity October.

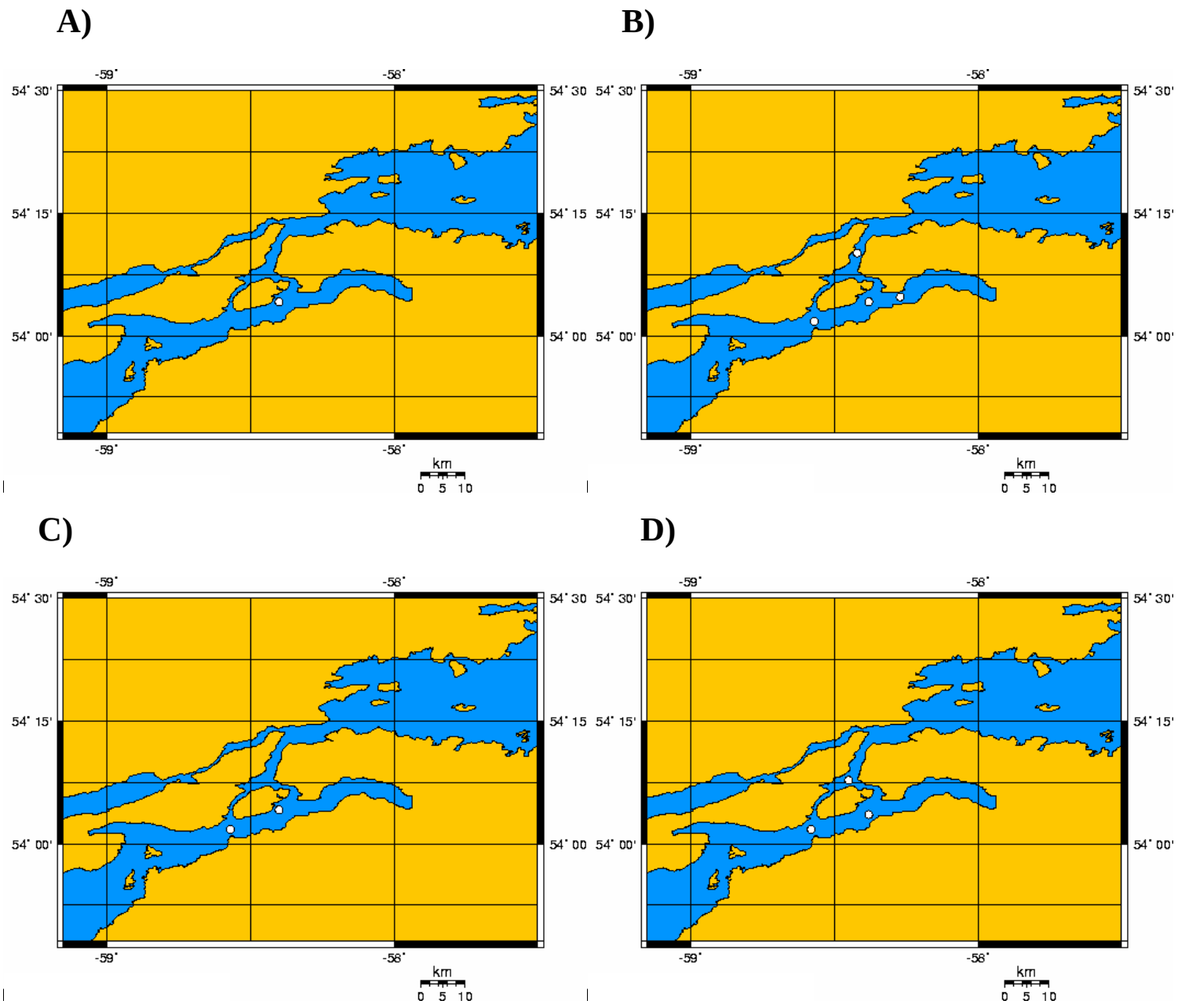


Figure 28: Location of oxygen and phosphorus data collection, The Narrows**.**

A) phosphorus August, Pre 1970, B) oxygen July, Pre 1970, C) oxygen August, Pre 1970, D) oxygen October, Post 1970.

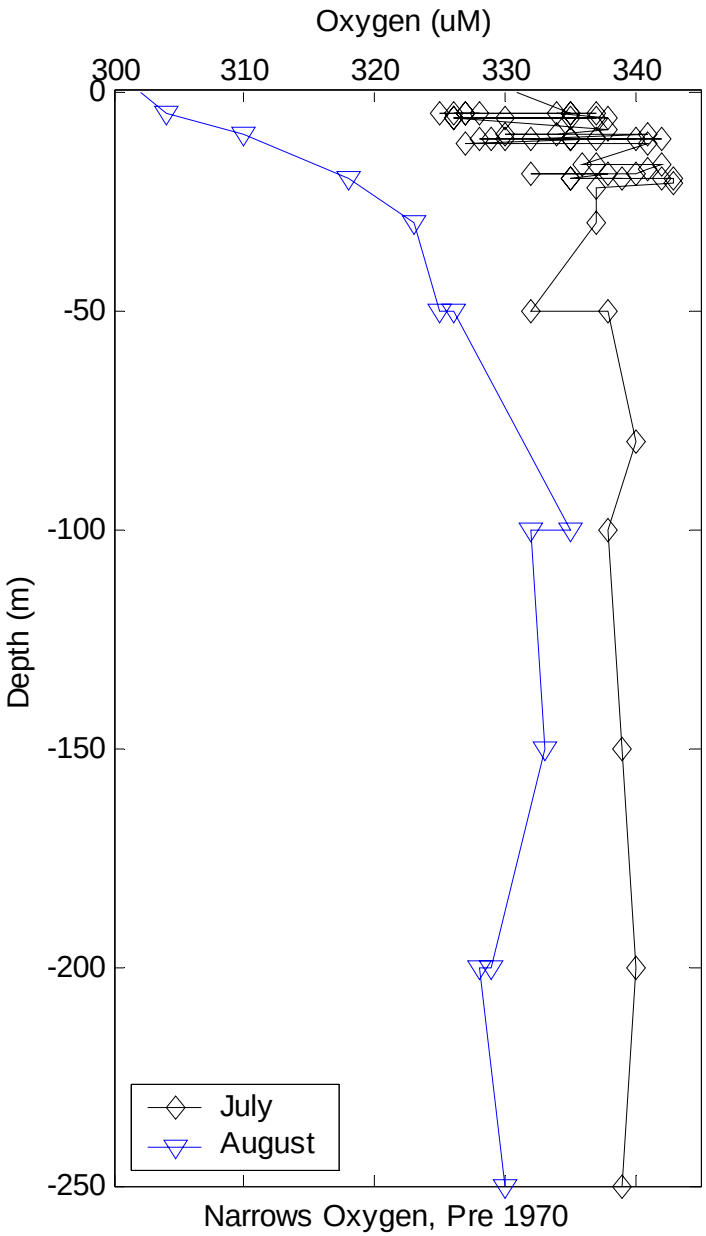


Figure 29: The Narrows oxygen, pre 1970.

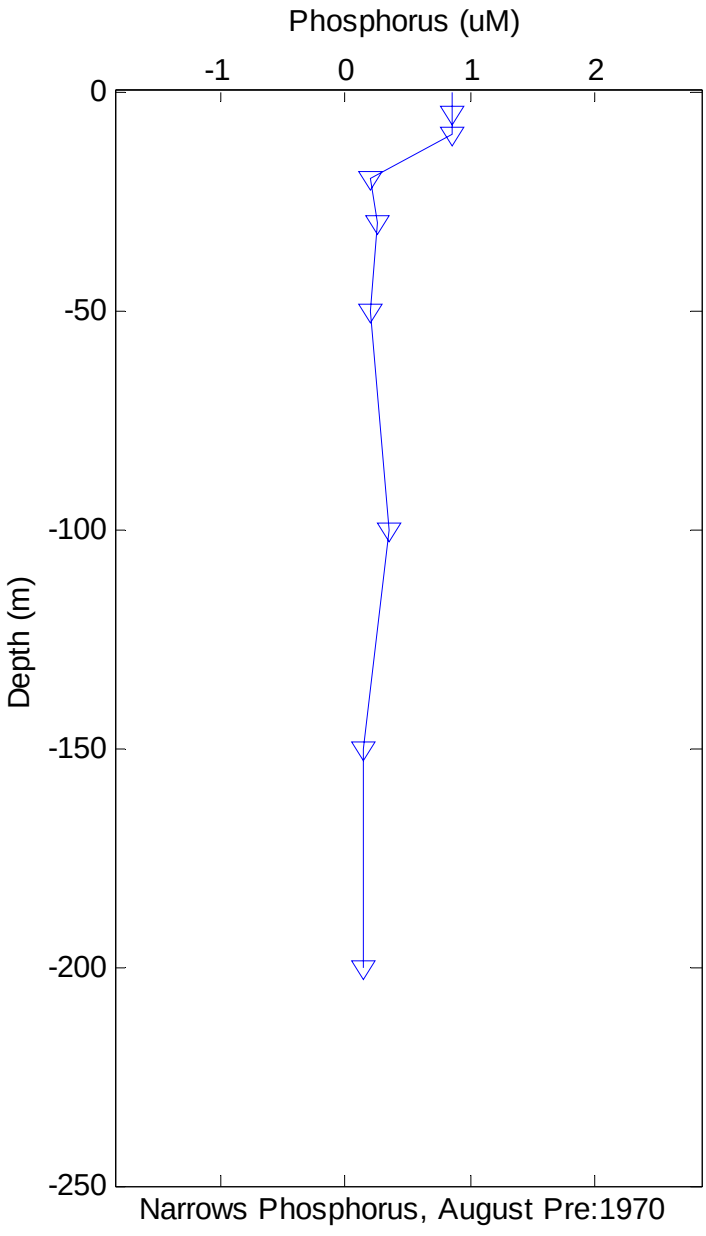


Figure 30: The Narrows phosphorus August, pre 1970.

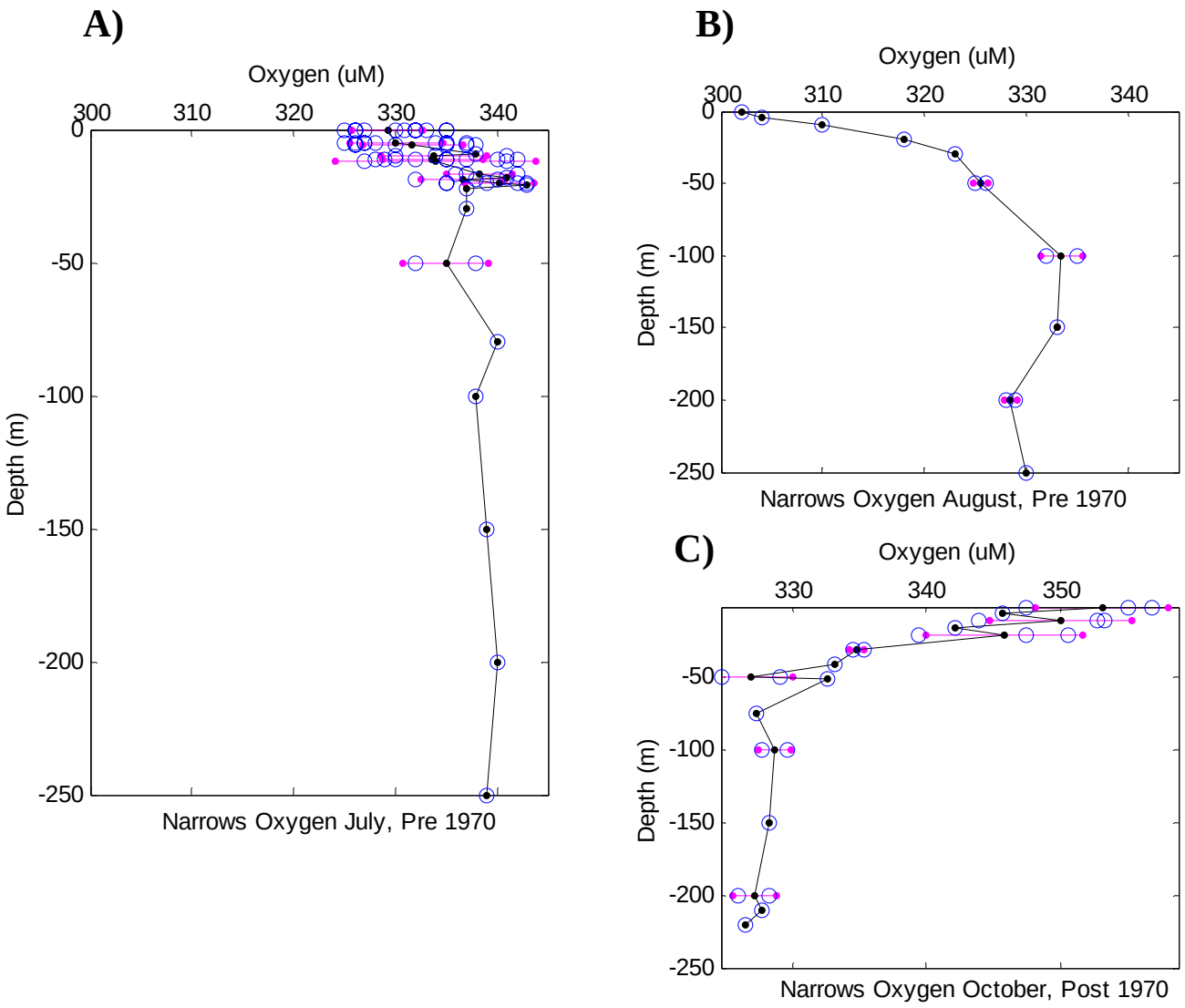


Figure 31: Monthly The Narrows oxygen. The circles represent each data point, the solid line is the mean and the horizontal bars are the standard deviation.
A) July pre 1970, B) August pre 1970, C) October post 1970.

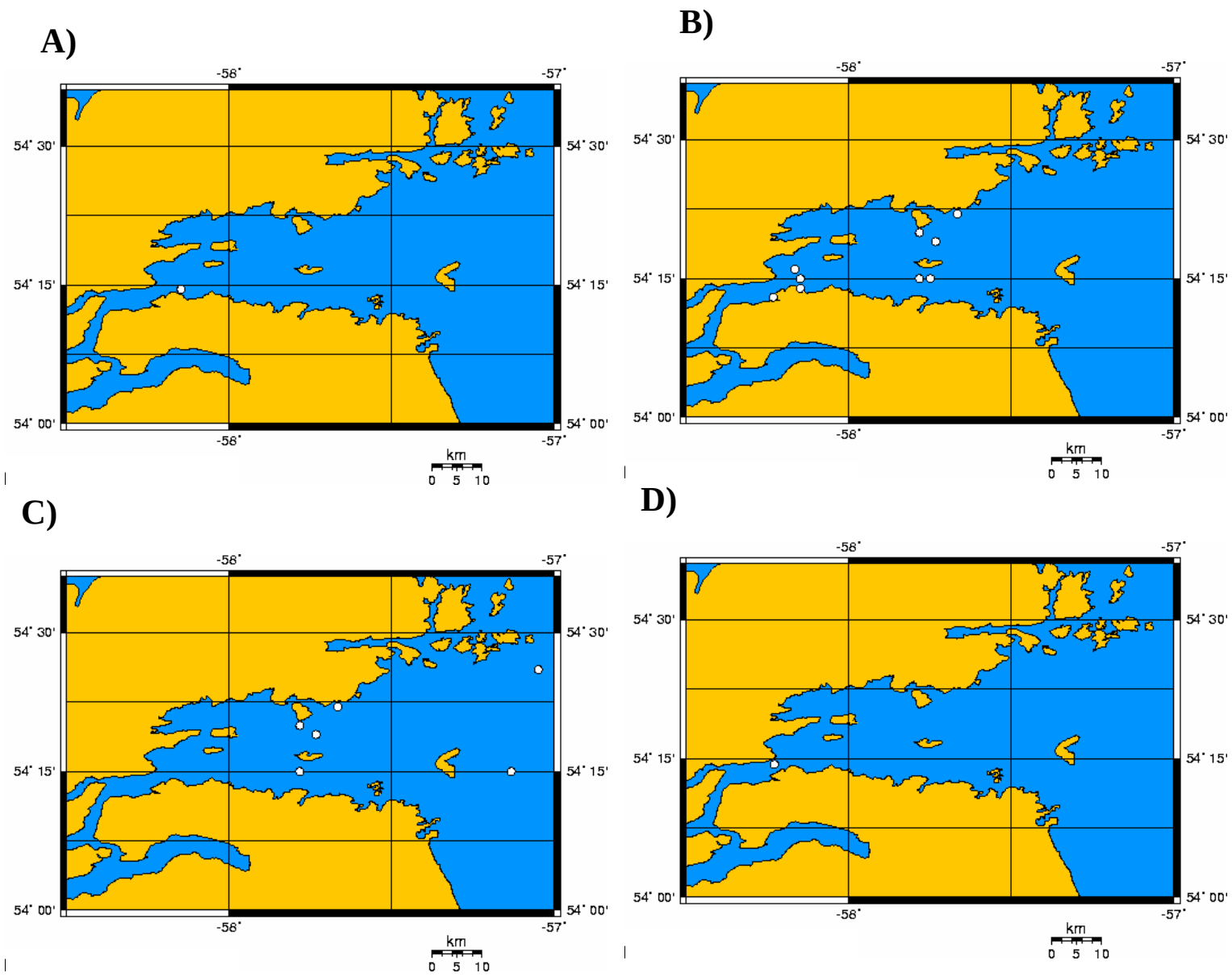
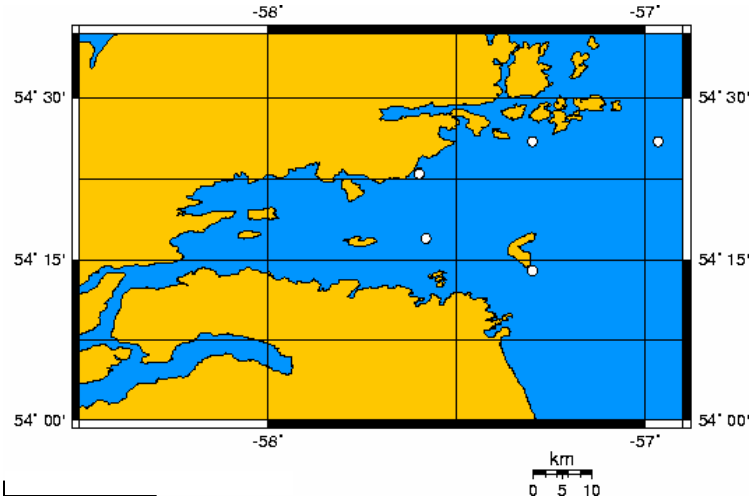


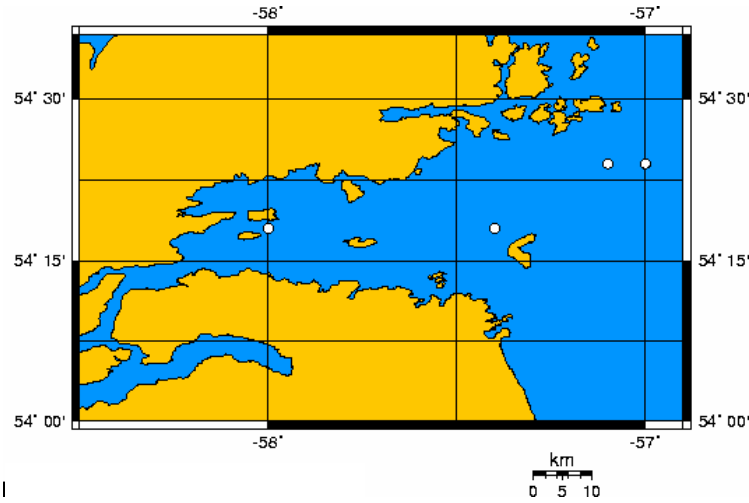
Figure 32: Location of temperature and salinity data collection, Groswater Bay.

A) temperature/salinity March, Pre 1970, B) temperature/salinity July, Pre 1970,
C) temperature/salinity August, Pre 1970, D) temperature/salinity October, Pre 1970.

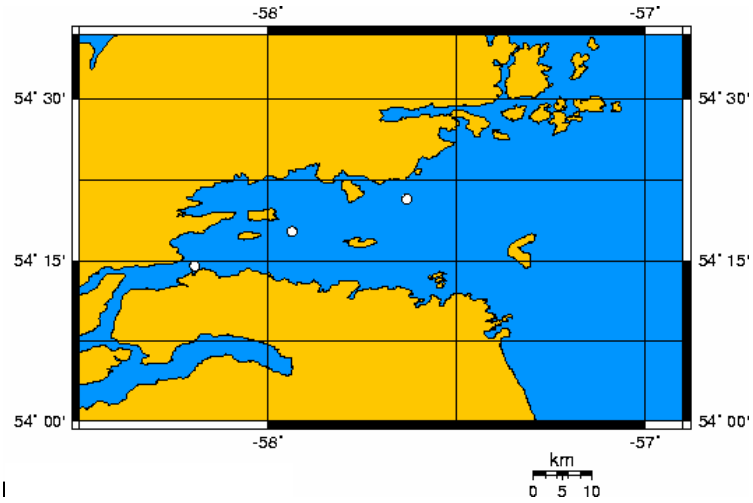
E)



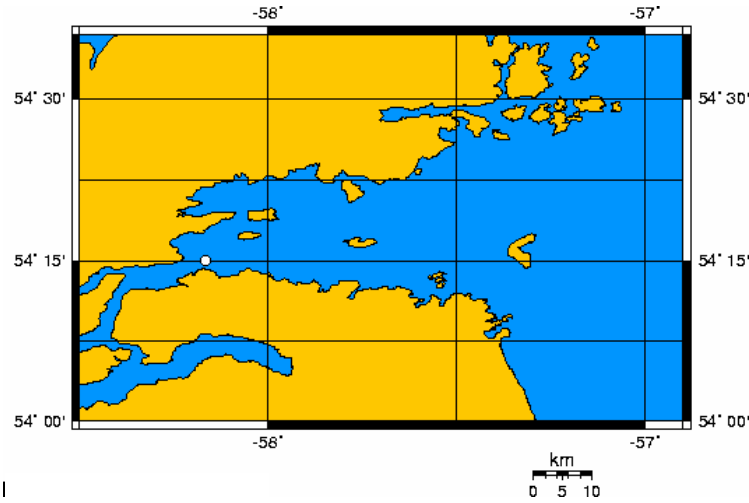
F)



G)



H)



I)

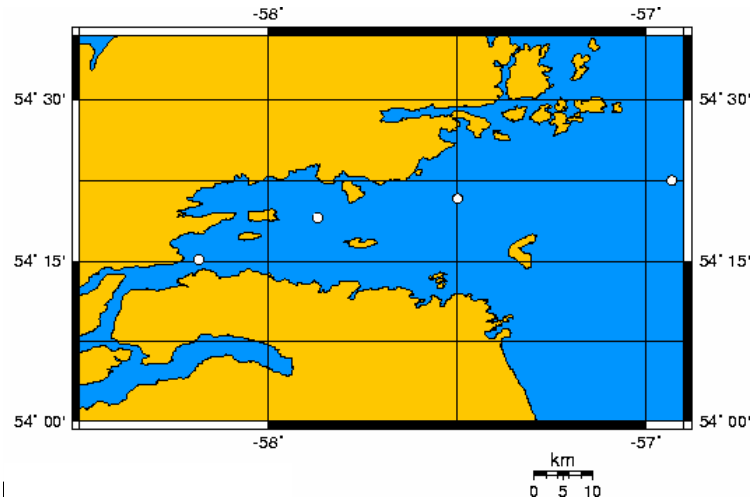


Figure 32: Location of temperature and salinity data collection, Groswater Bay.
E) temperature/salinity June, Pre 1970,
F) temperature January, Post 1970,
G) temperature/salinity August, Post 1970,
H) temperature/salinity September, Post 1970,
I) temperature/salinity October, Post 1970.

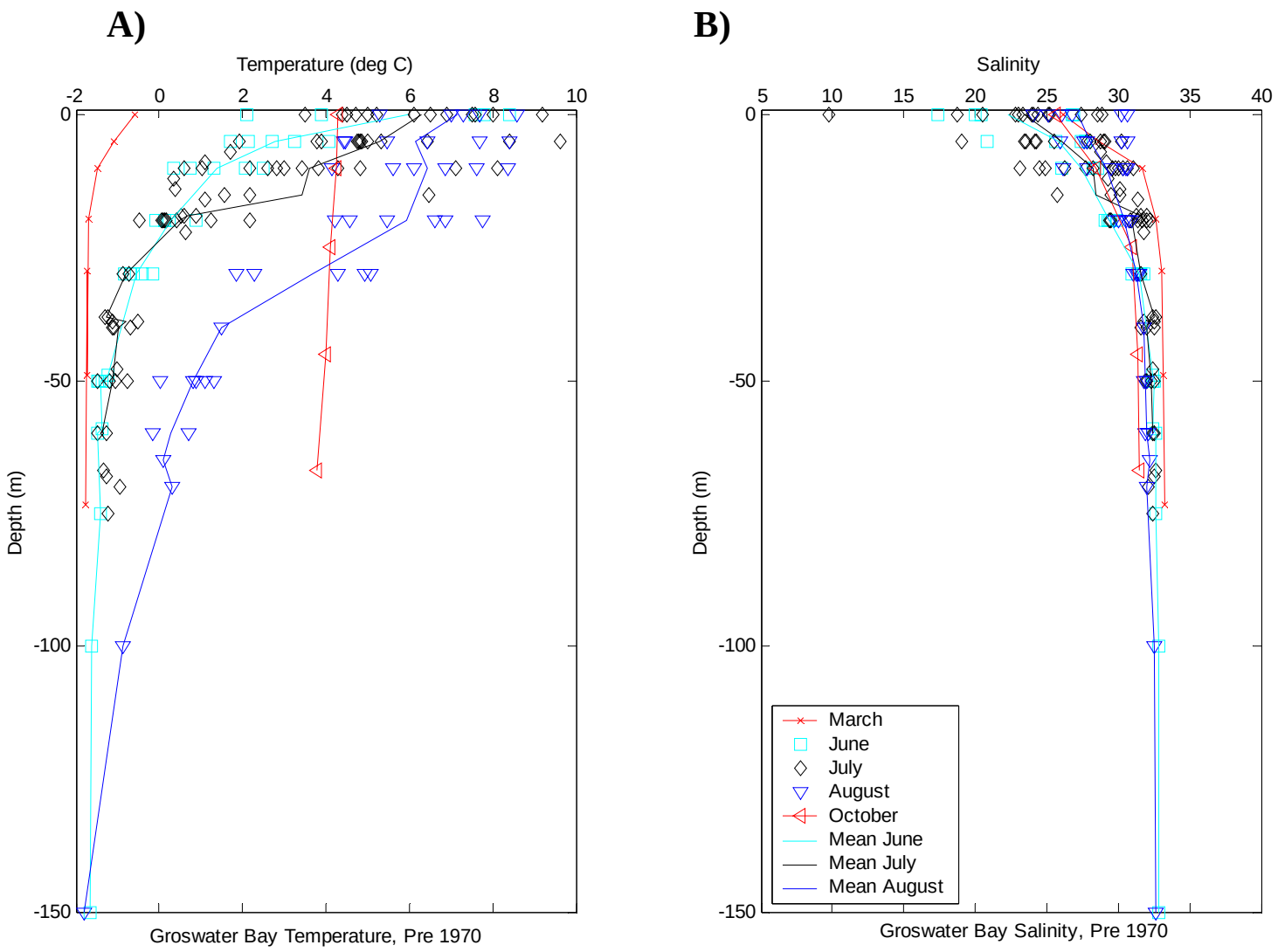


Figure 33: Groswater Bay temperature and salinity, pre 1970. A) all temperature data, B) all salinity data.

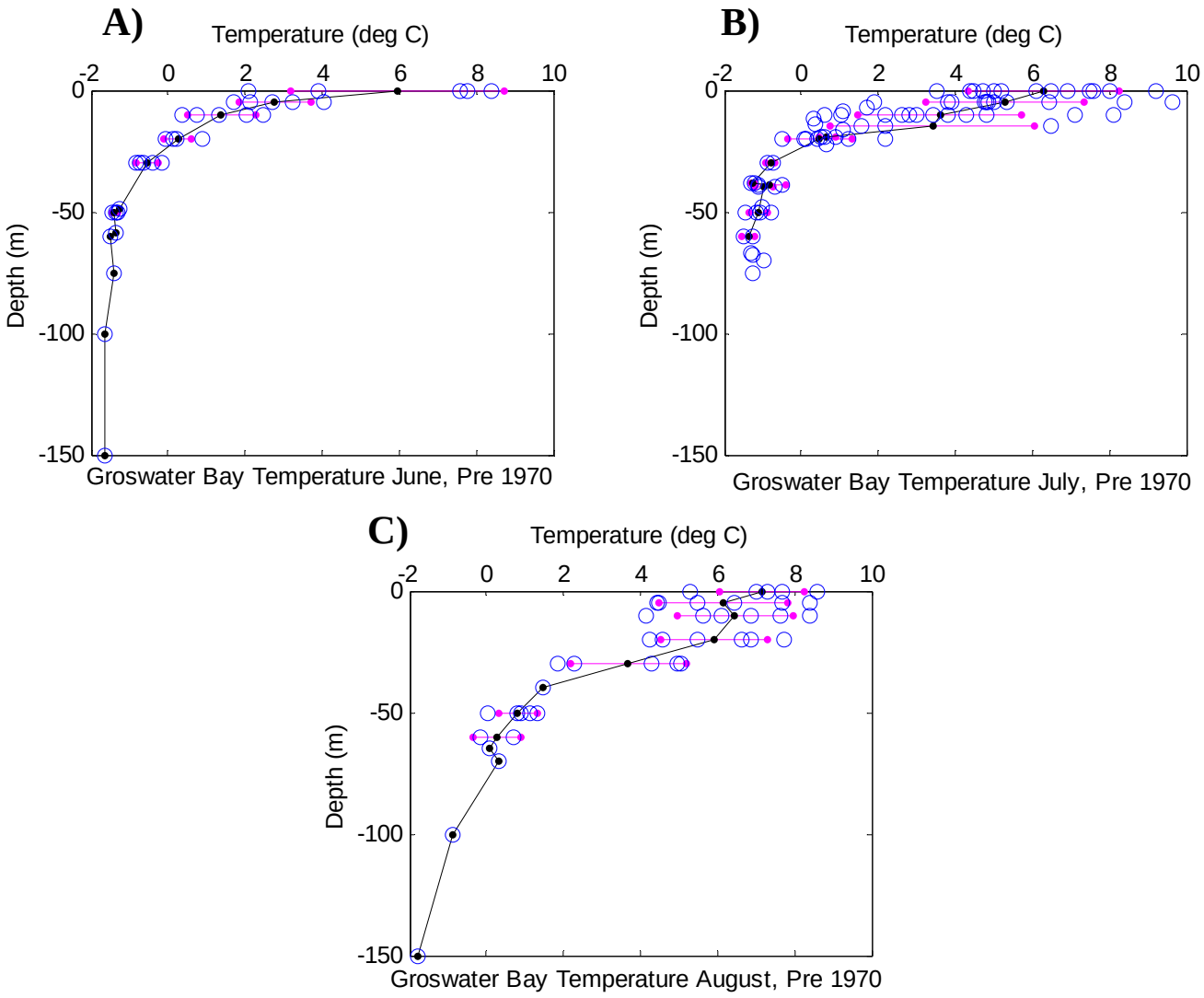


Figure 34: Monthly Groswater Bay temperature, pre 1970. The circles represent each data point, the solid line is the mean and the horizontal bars are the standard deviation. A) June, B) July, C) August.

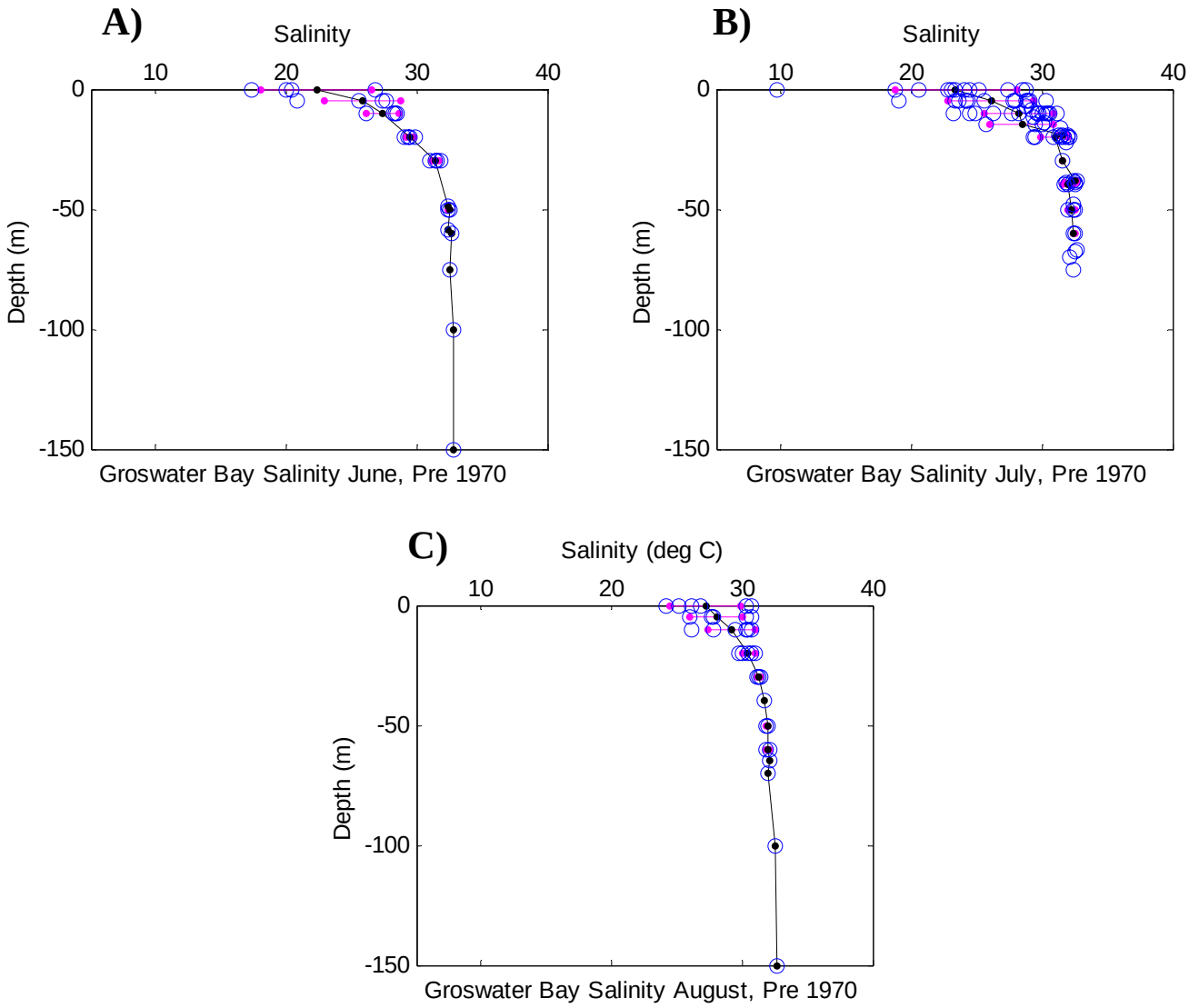


Figure 35: Monthly Groswater Bay salinity, pre 1970. The circles represent each data point, the solid line is the mean and the horizontal bars are the standard deviation.

A) June, B) July, C) August.

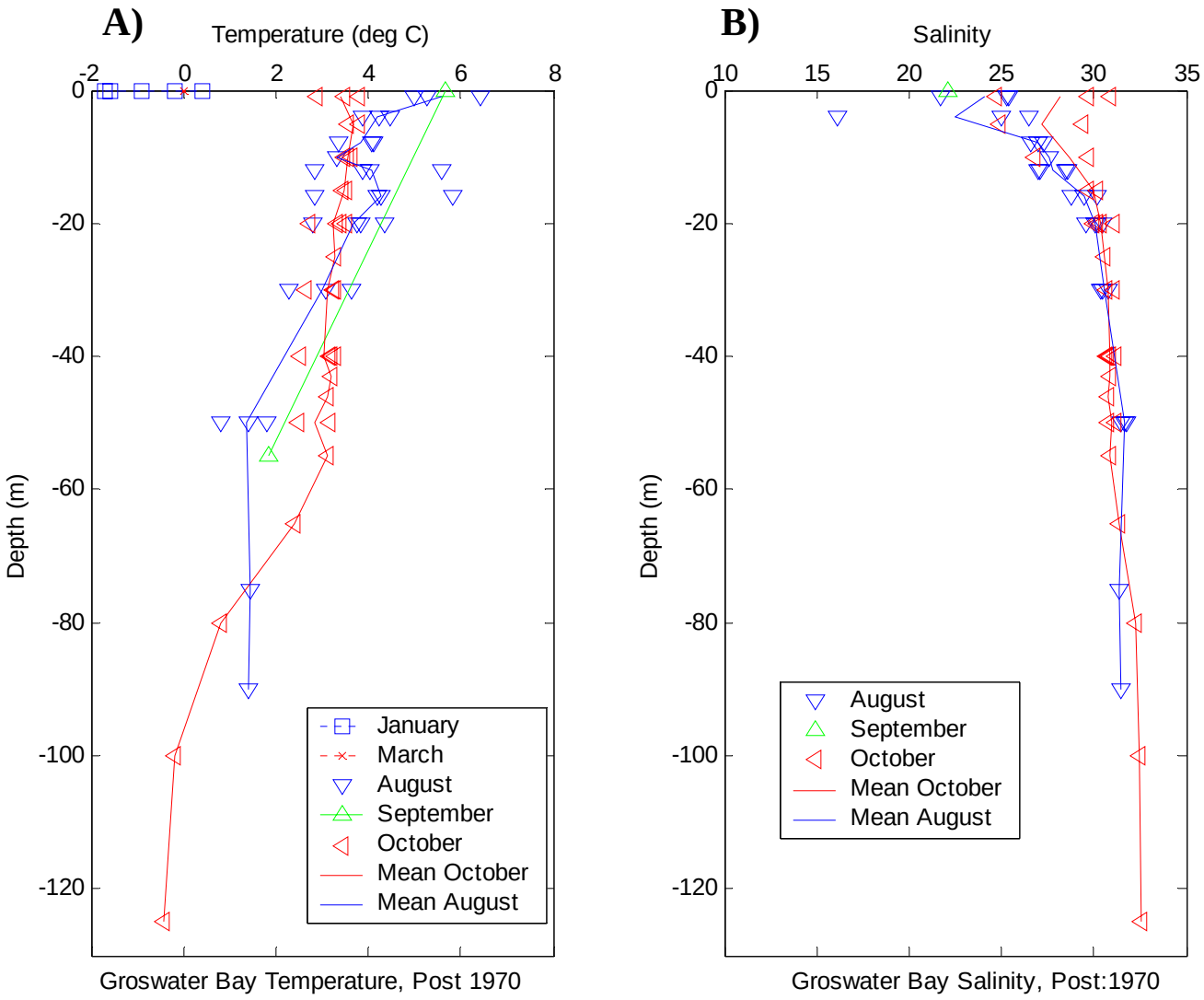


Figure 36: Groswater Bay temperature and salinity, post 1970. A) all temperature data, B) all salinity data**.**

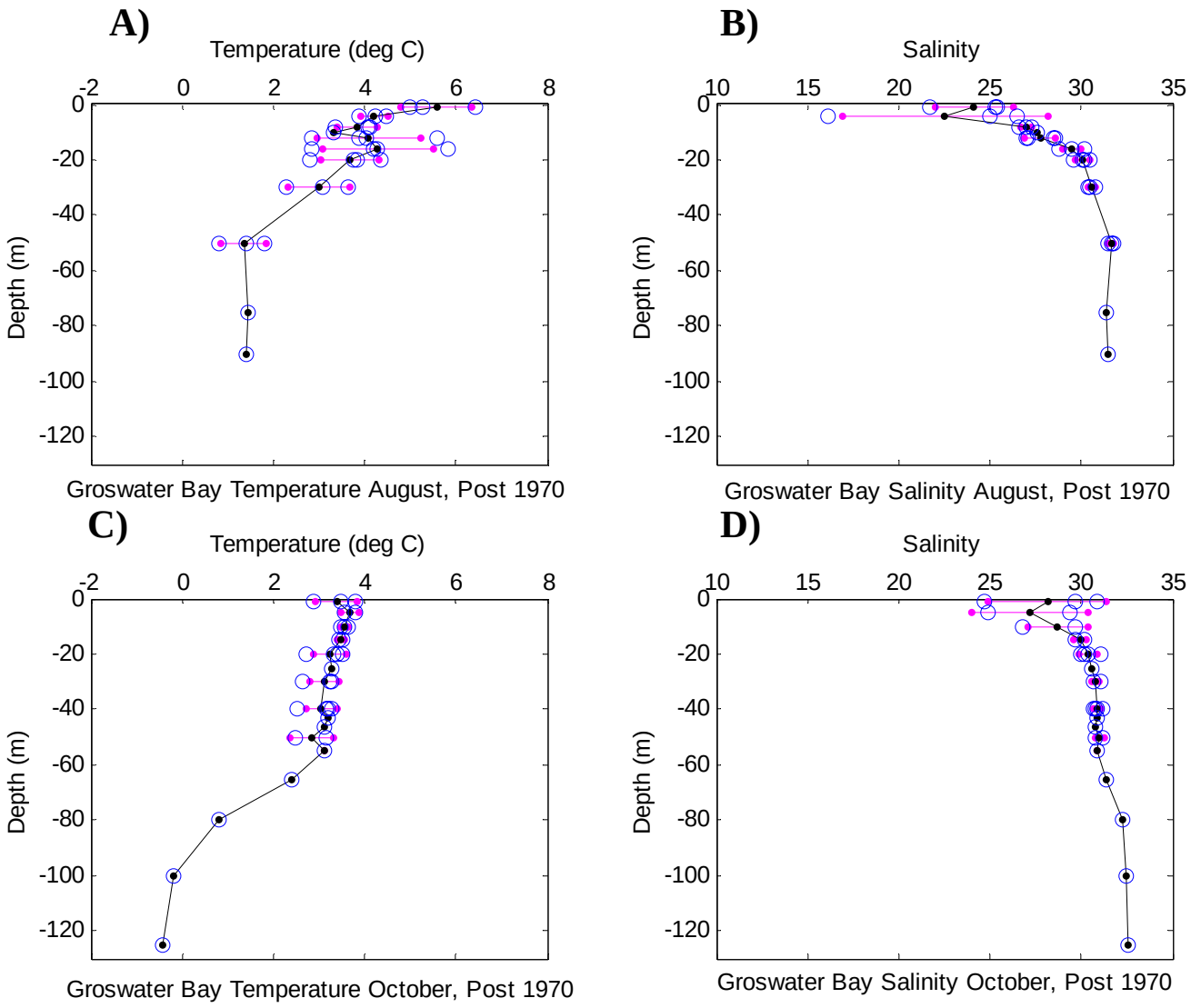


Figure 37: Monthly Groswater Bay temperature and salinity, post 1970. The circles represent each data point, the solid line is the mean and the horizontal bars are the standard deviation. A) temperature August, B) salinity August, C) temperature October, D) salinity October.

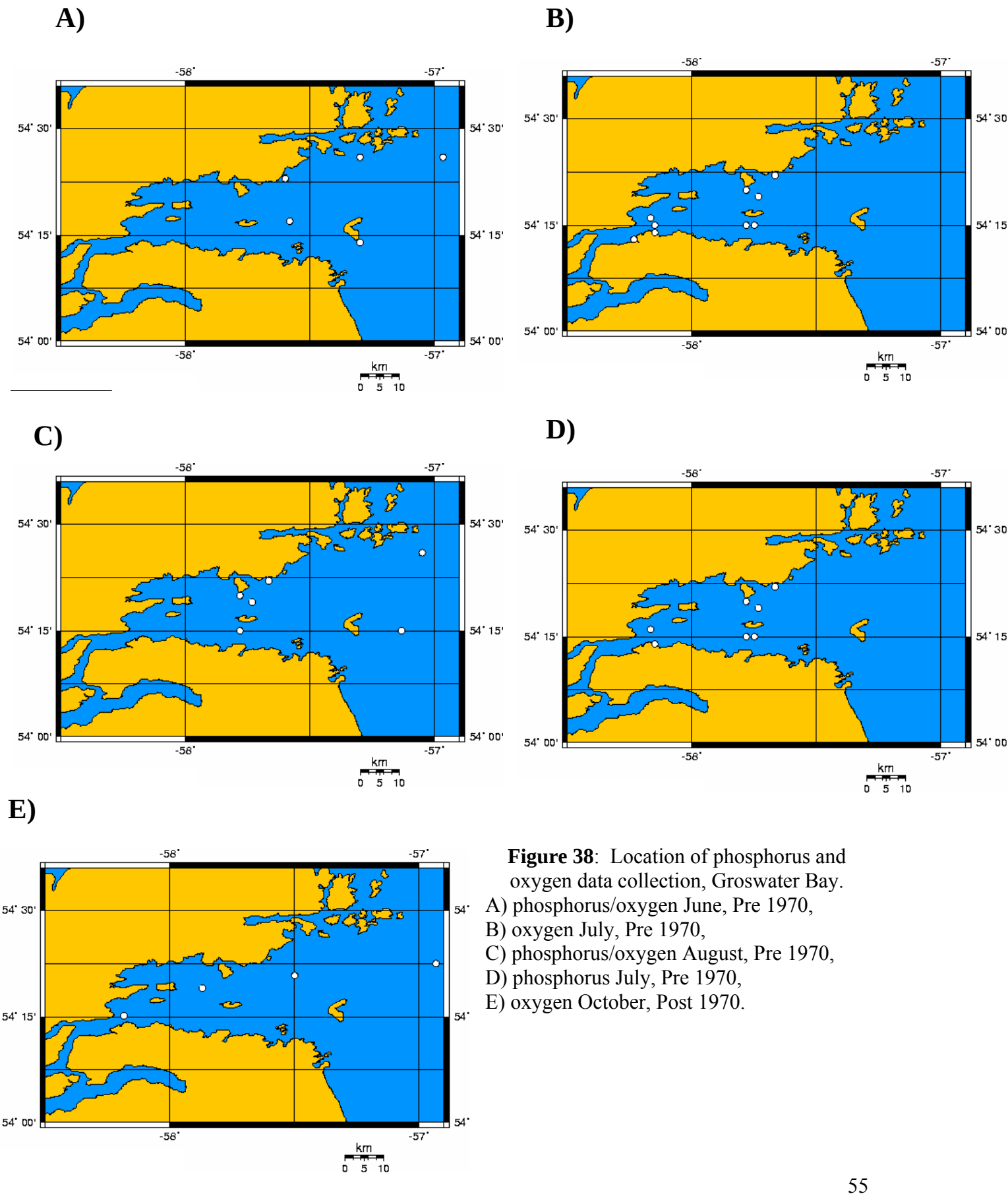


Figure 38: Location of phosphorus and oxygen data collection, Groswater Bay.
A) phosphorus/oxygen June, Pre 1970,
B) oxygen July, Pre 1970,
C) phosphorus/oxygen August, Pre 1970,
D) phosphorus July, Pre 1970,
E) oxygen October, Post 1970.

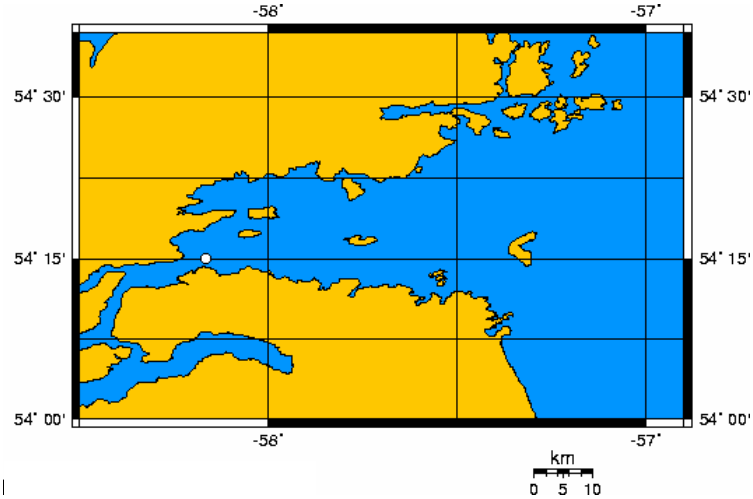


Figure 39: Location of nitrogen, silicate, and chlorophyll data collection, October, Post 1970, Groswater Bay.

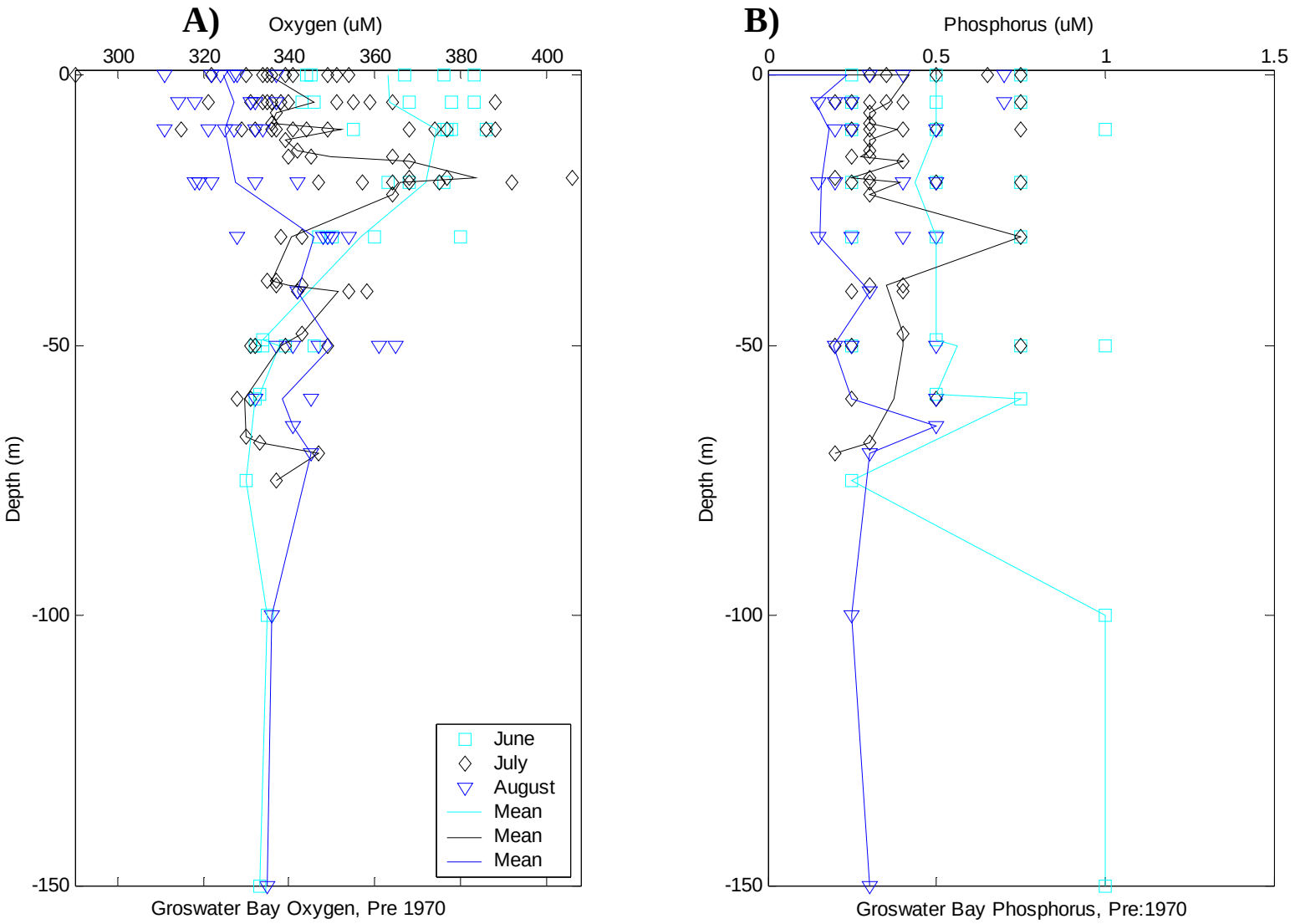


Figure 40: Groswater Bay oxygen and phosphorus, pre 1970. A) all oxygen data, B) all phosphorus data.

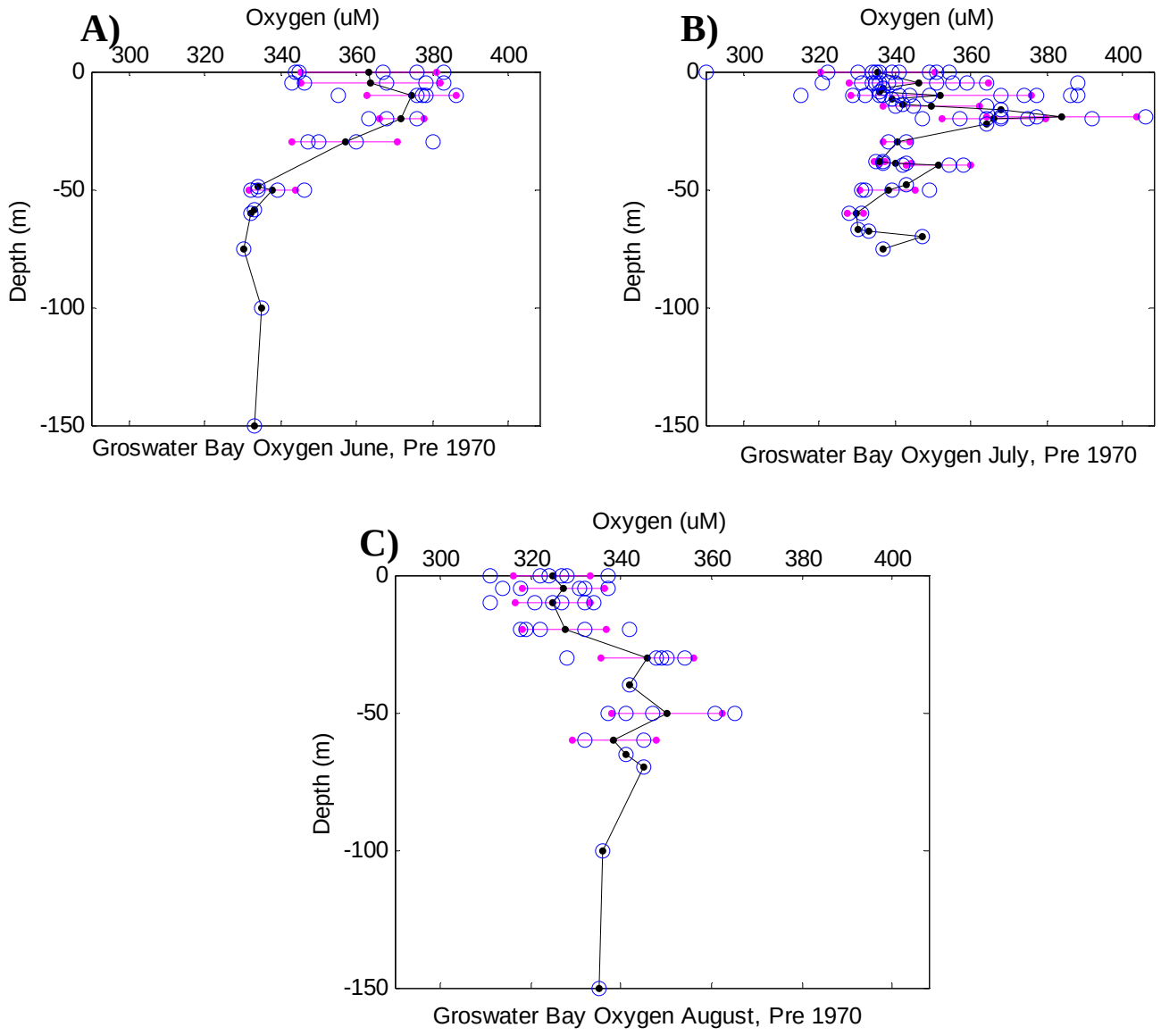


Figure 41: Monthly Groswater Bay oxygen, pre 1970. The circles represent each data point, the solid line is the mean and the horizontal bars are the standard deviation.

A) June, B) July C) August.

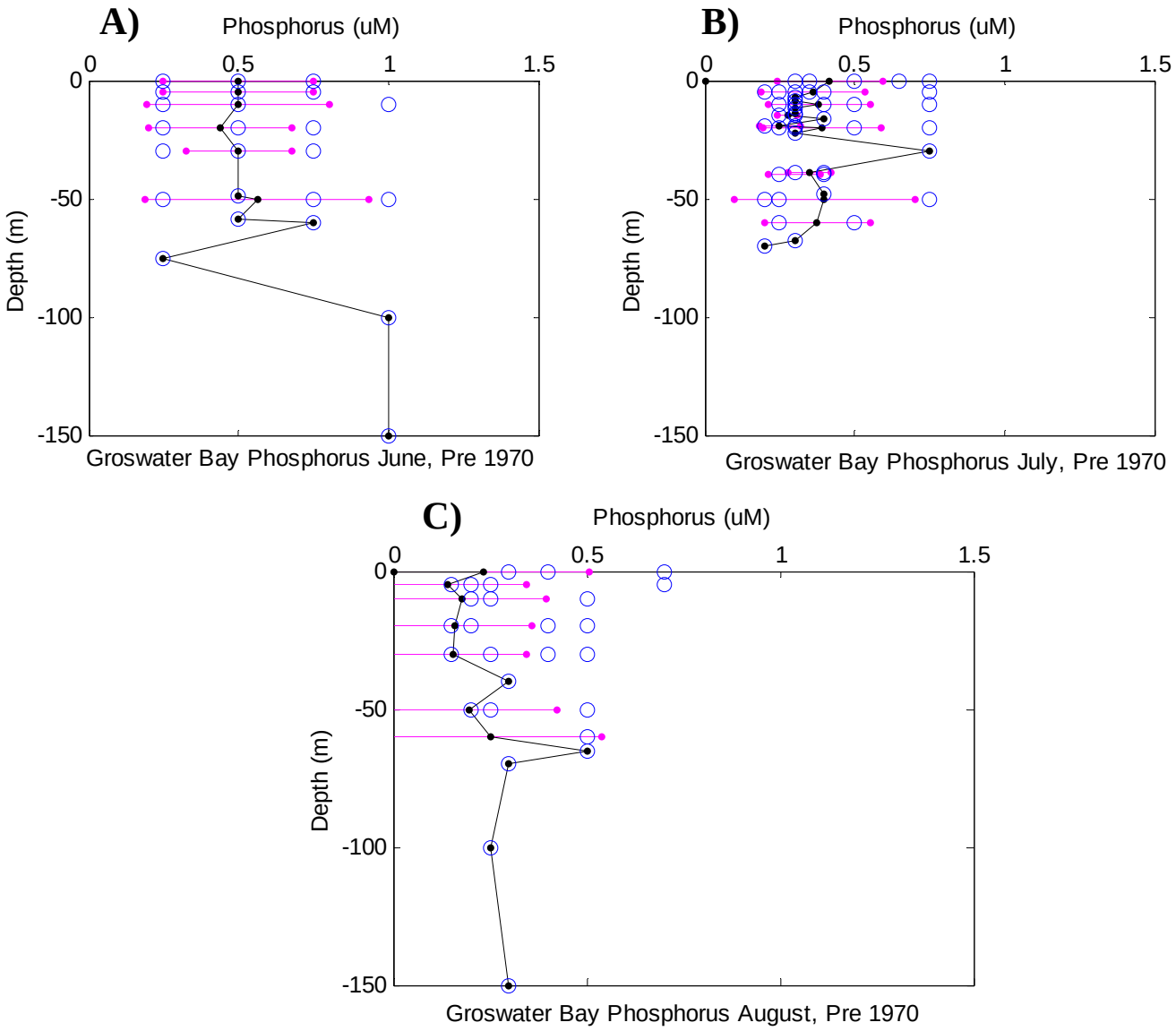


Figure 42: Monthly Groswater Bay phosphorus, pre 1970. The circles represent each data point, the solid line is the mean and the horizontal bars are the standard deviation.

A) June, B) July C) August.

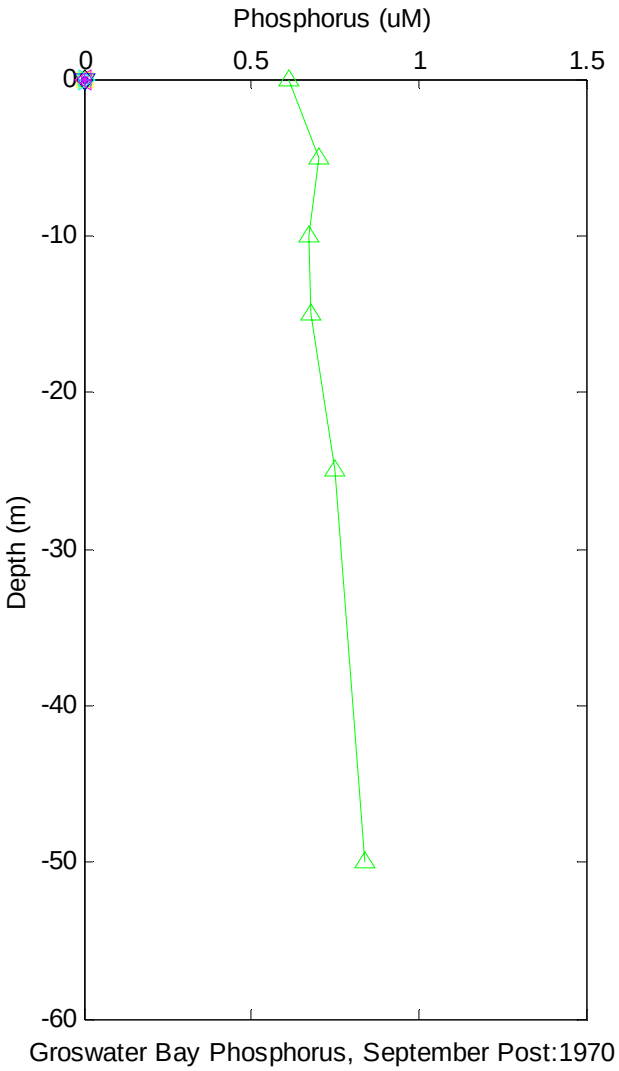


Figure 43: Groswater Bay phosphorus September, post 1970.

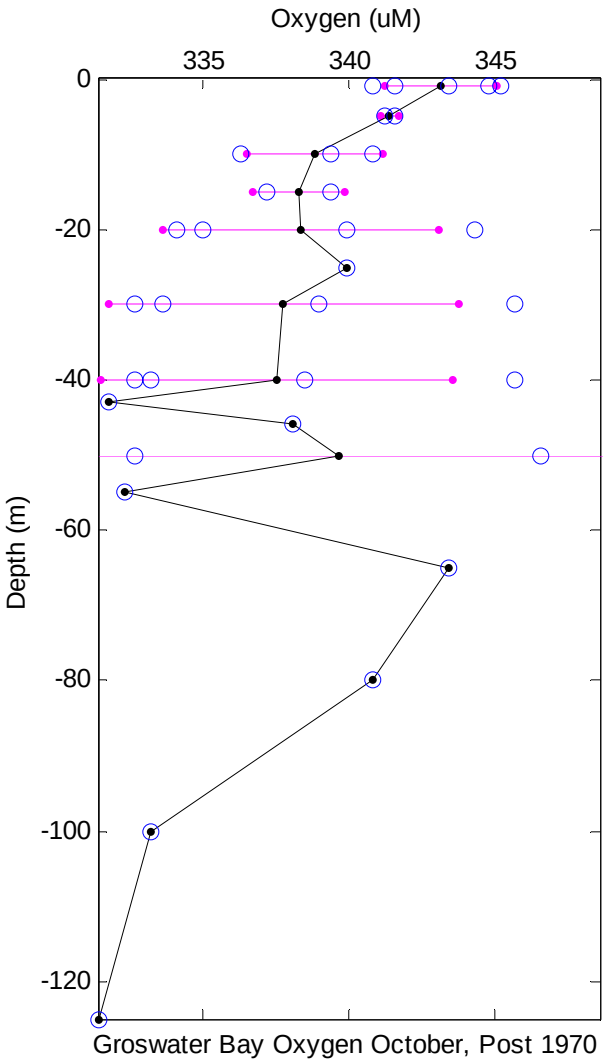


Figure 44: Groswater Bay oxygen October, post 1970. The circles represent each data point, the solid line is the mean and the horizontal bars are the standard deviation.

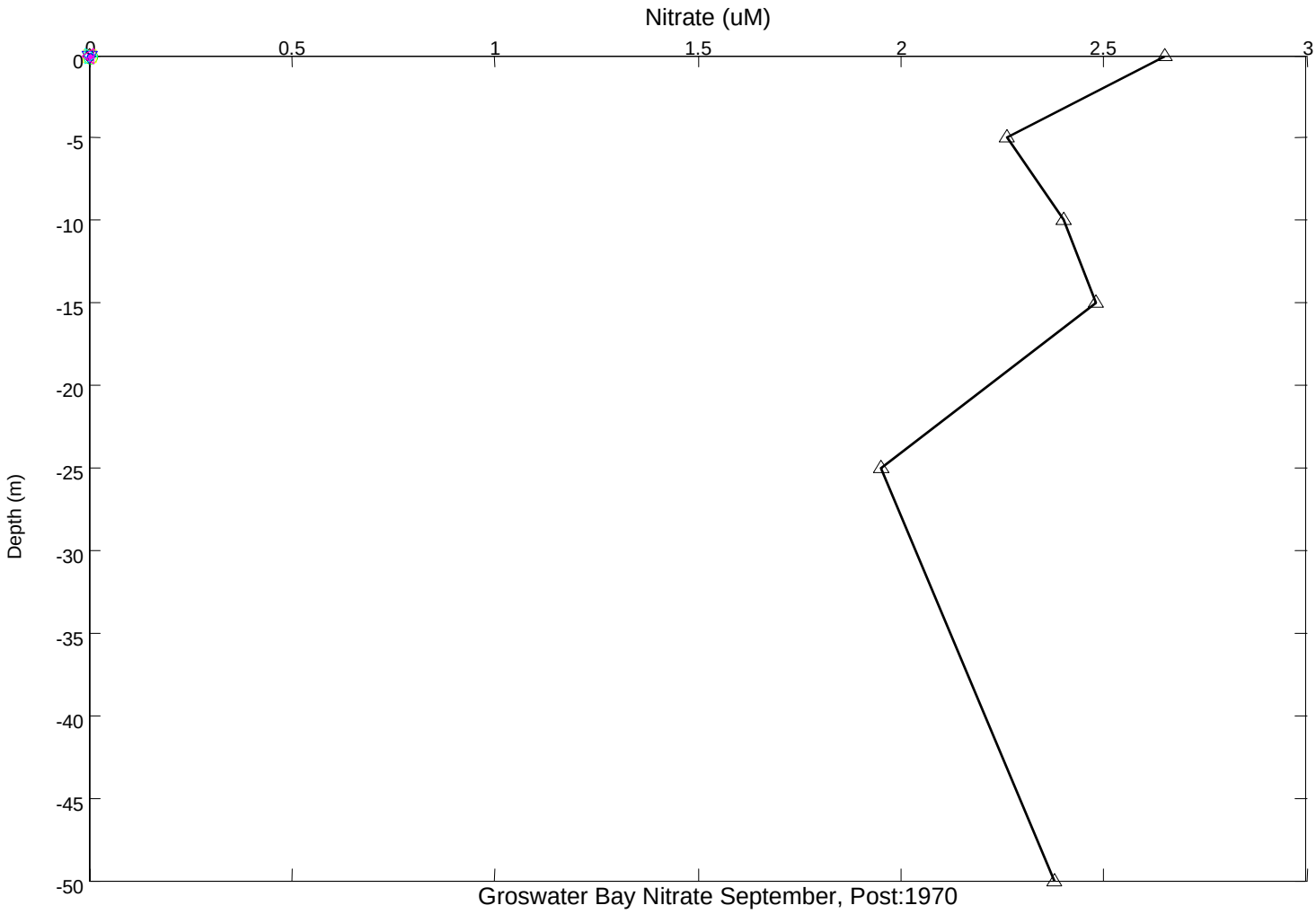


Figure 45: Groswater Bay nitrate September, post 1970.

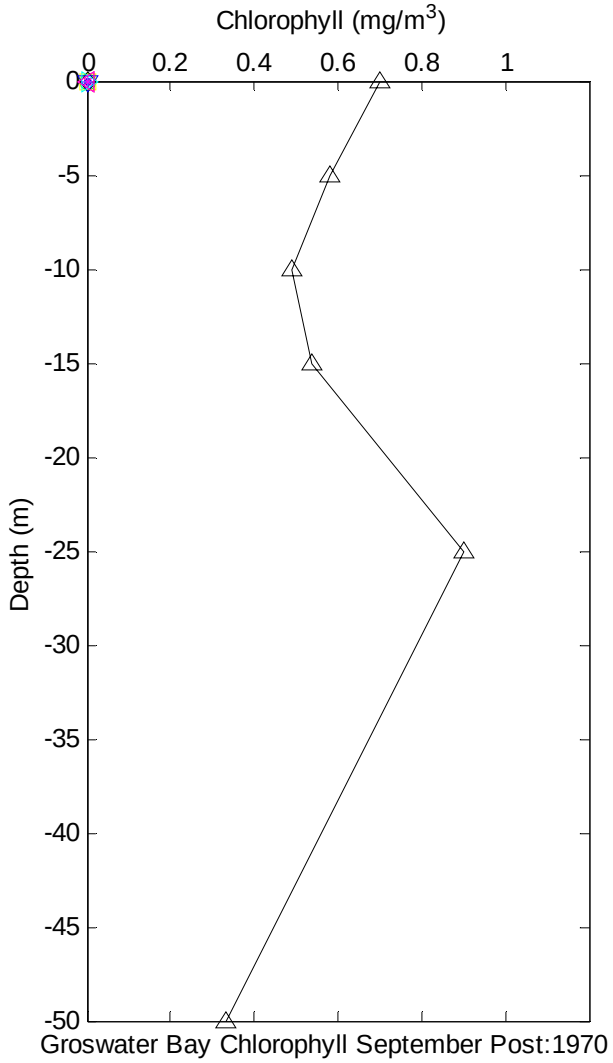


Figure 46: Groswater Bay chlorophyll September, post 1970.

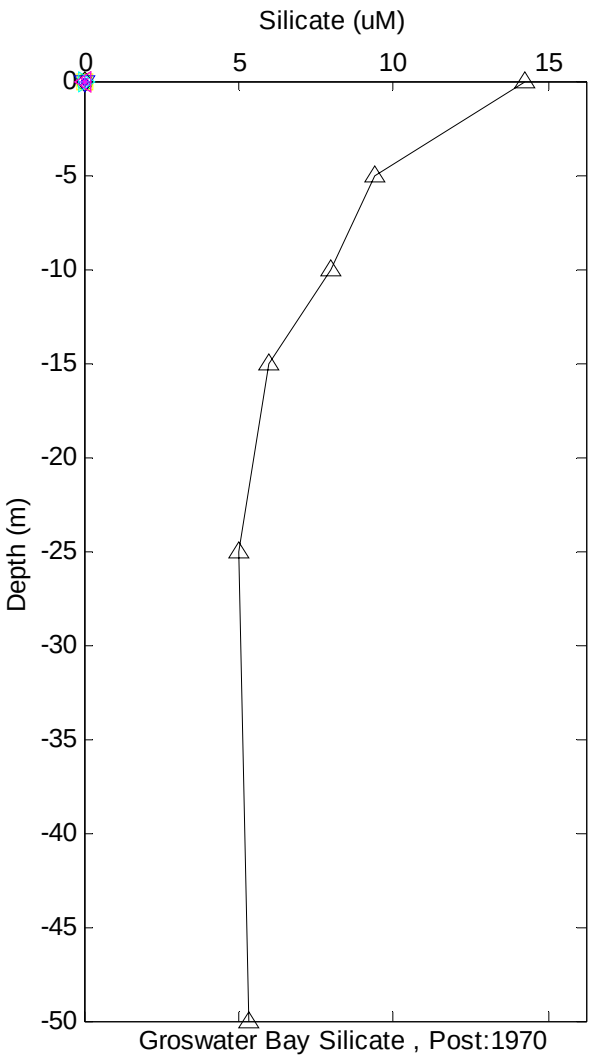


Figure 47: Groswater Bay silicate September, post 1970.

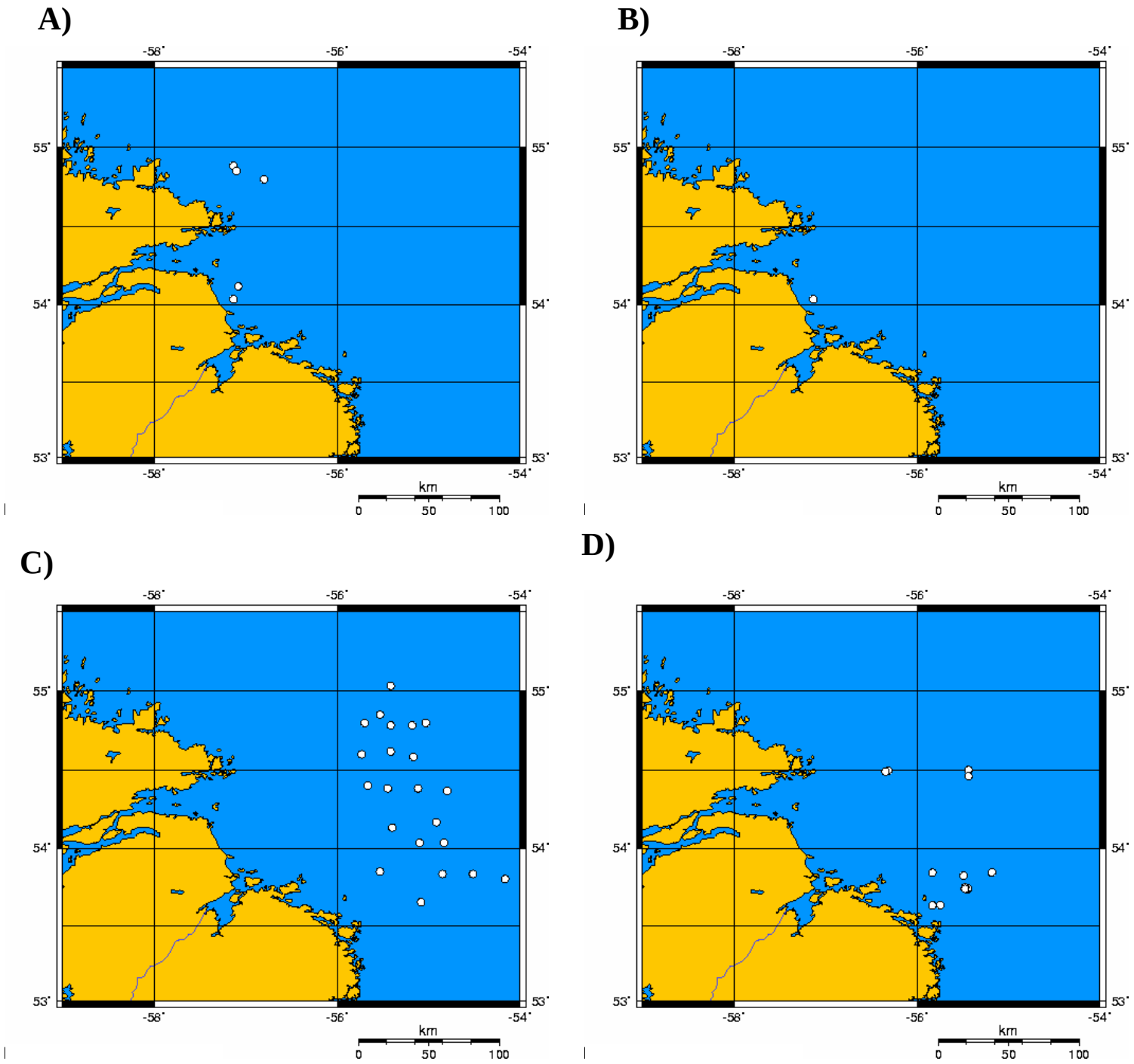


Figure 48: Location of temperature and salinity data collection, offshore.

A) temperature/salinity June, Pre 1970, B) temperature/salinity August, Pre 1970,
C) temperature September, Pre 1970, D) temperature Jan, Feb, Mar, Apr, May, Post 1970.

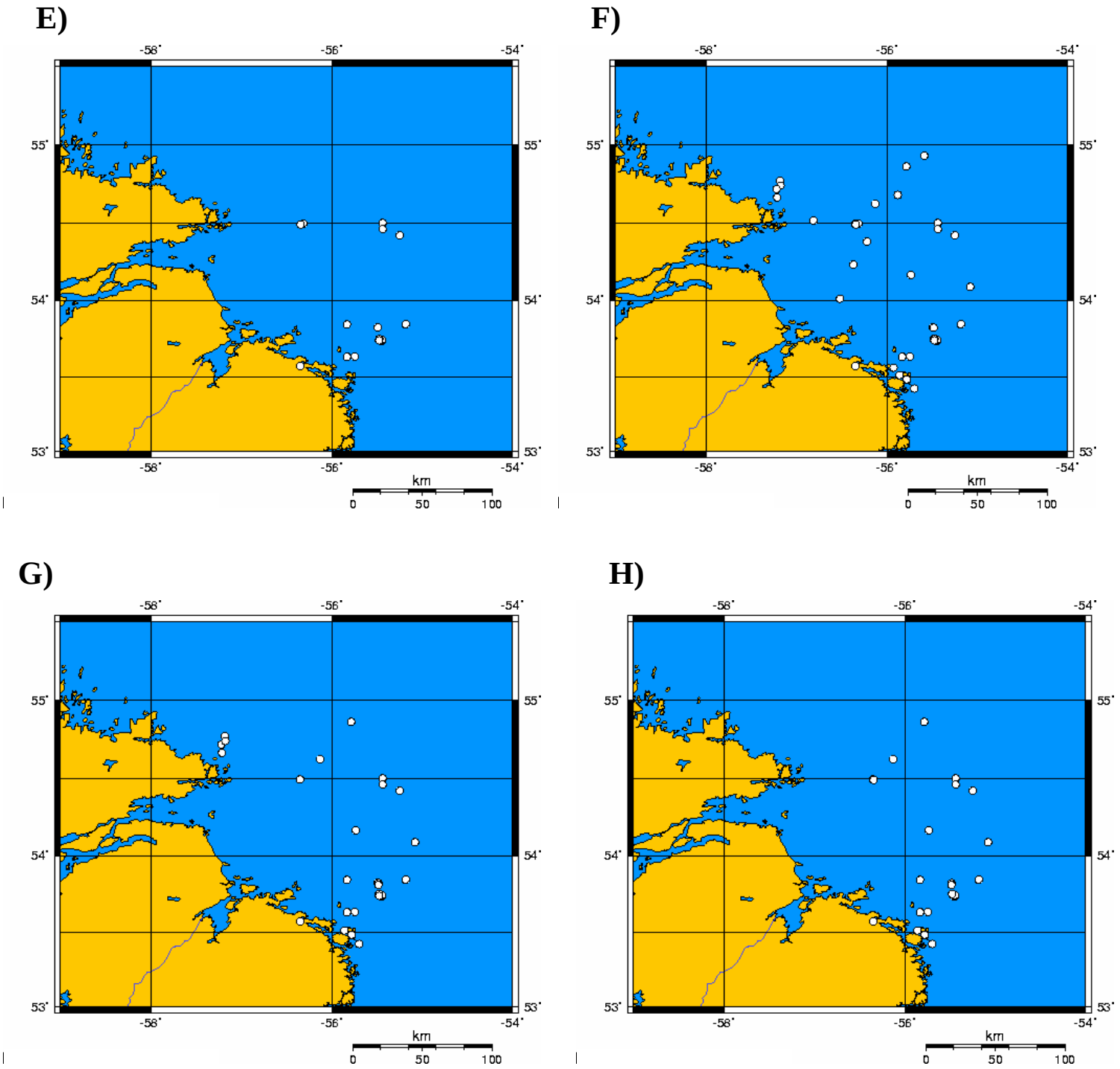


Figure 48: Location of temperature and salinity data collection, offshore.

E) temperature June, Post 1970, F) temperature July, Post 1970,
G) temperature August, Post 1970, H) temperature September, Post 1970.

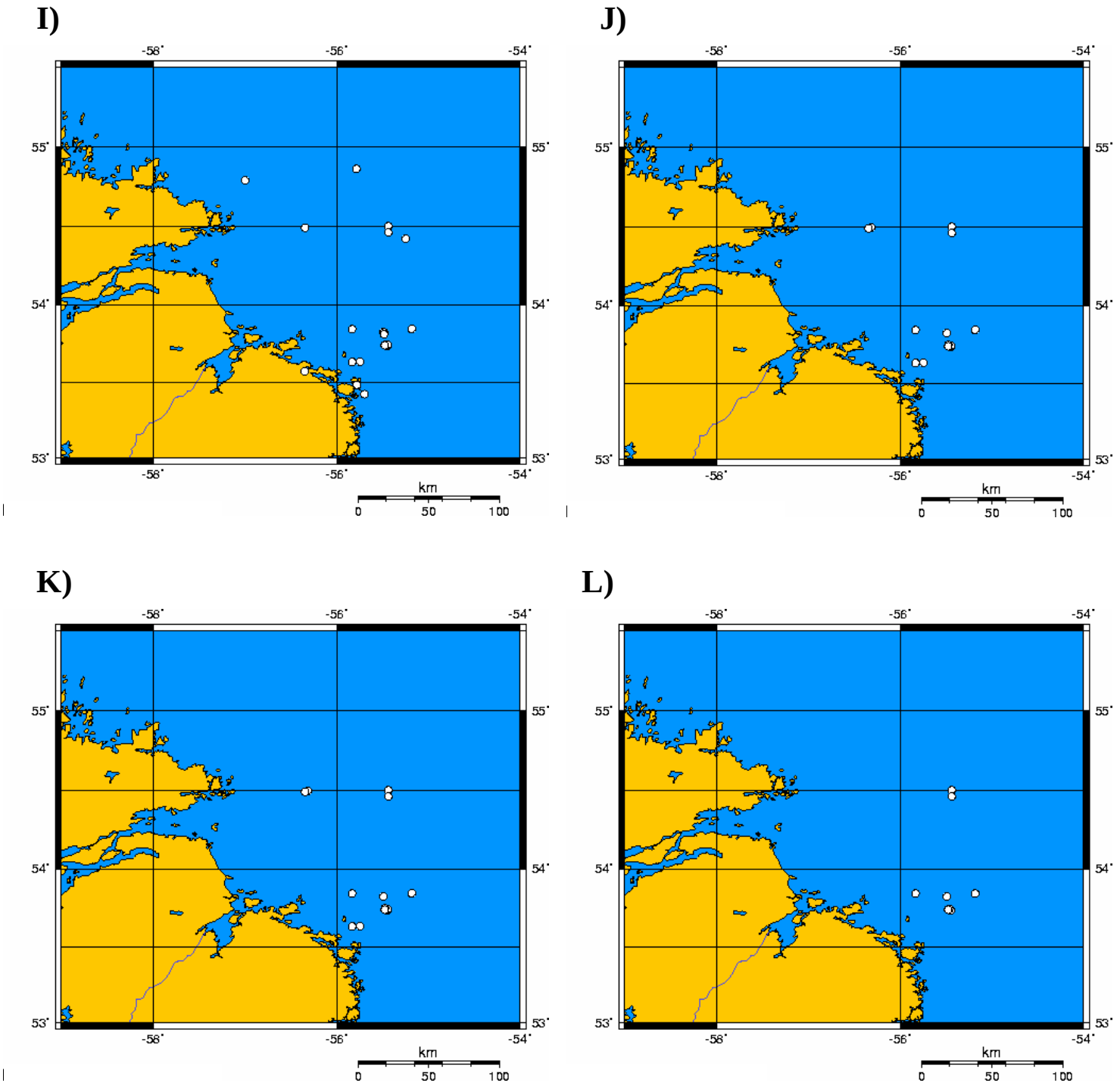


Figure 48: Location of temperature and salinity data collection, offshore.

I) temperature October, Post 1970, J) temperature November, Post 1970,
K) temperature December, Post 1970, L) salinity Jan, Feb, Mar, Apr, May, Post 1970.

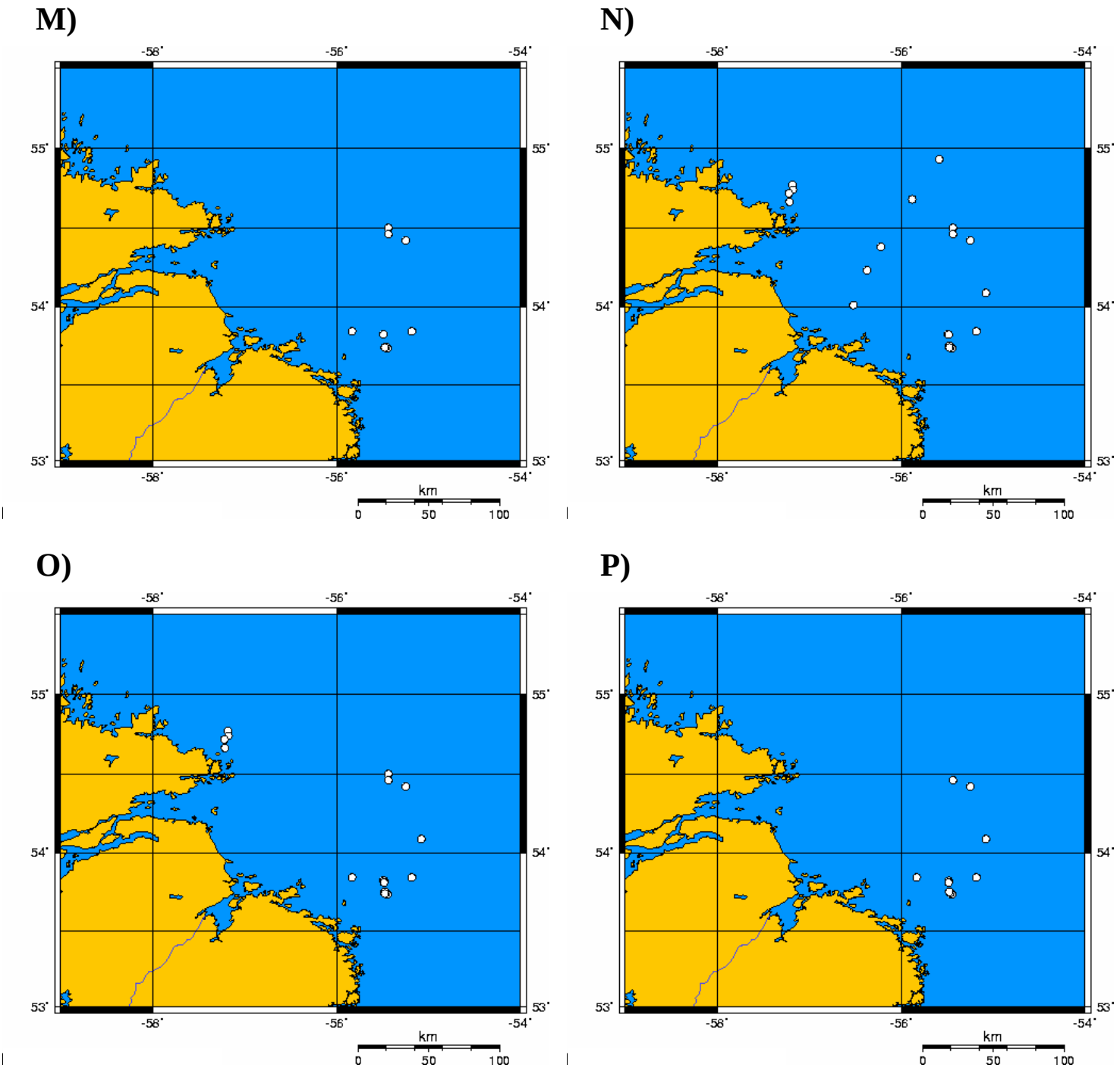


Figure 48: Location of temperature and salinity data collection, offshore.

M) salinity June, Post 1970, N) salinity July, Post 1970,
O) salinity August, Post 1970, P) salinity September, Post 1970.

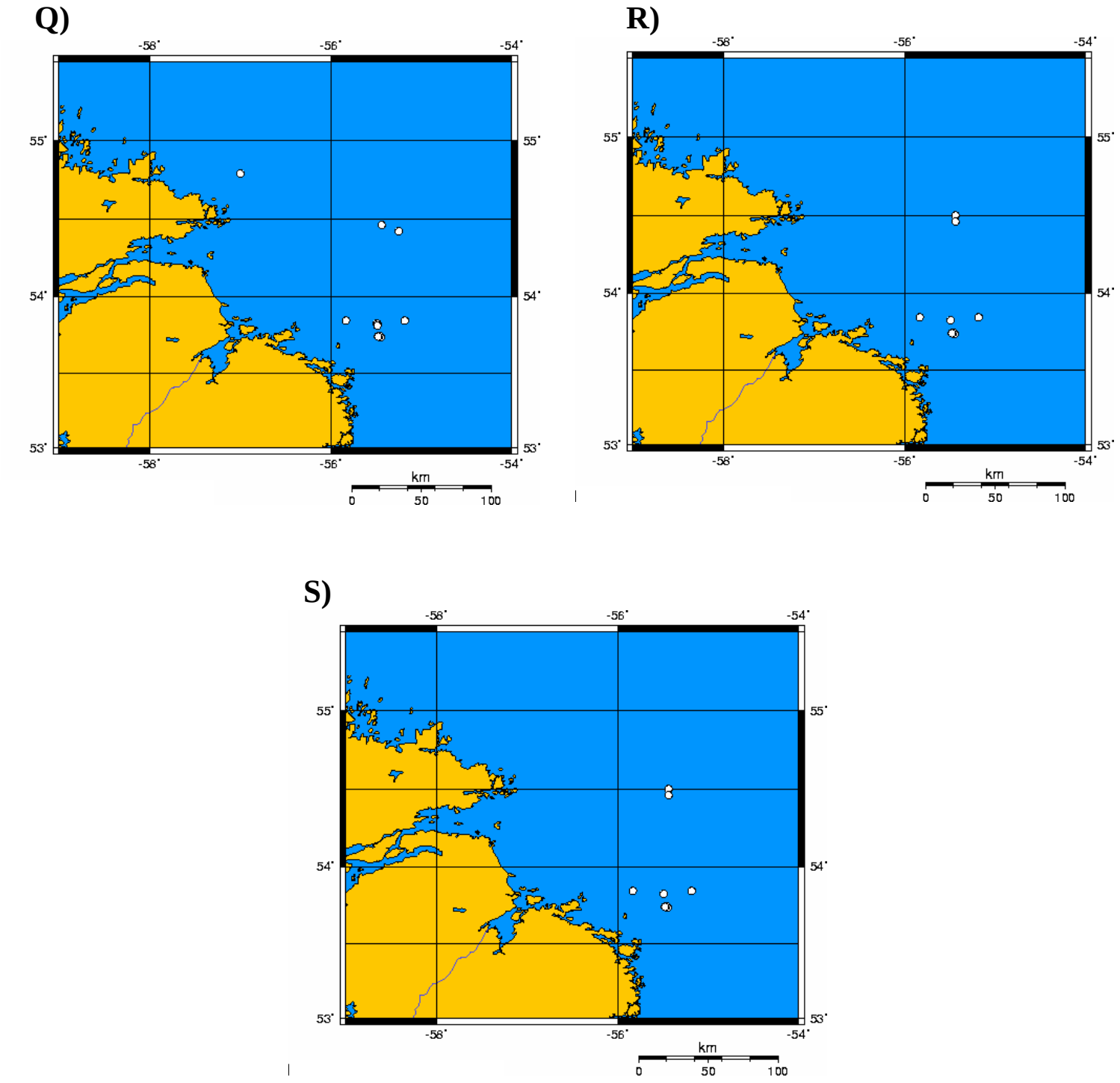


Figure 48: Location of temperature and salinity data collection, offshore.

Q) salinity October, Post 1970, R) salinity November, Post 1970, S) salinity December, Post 1970.

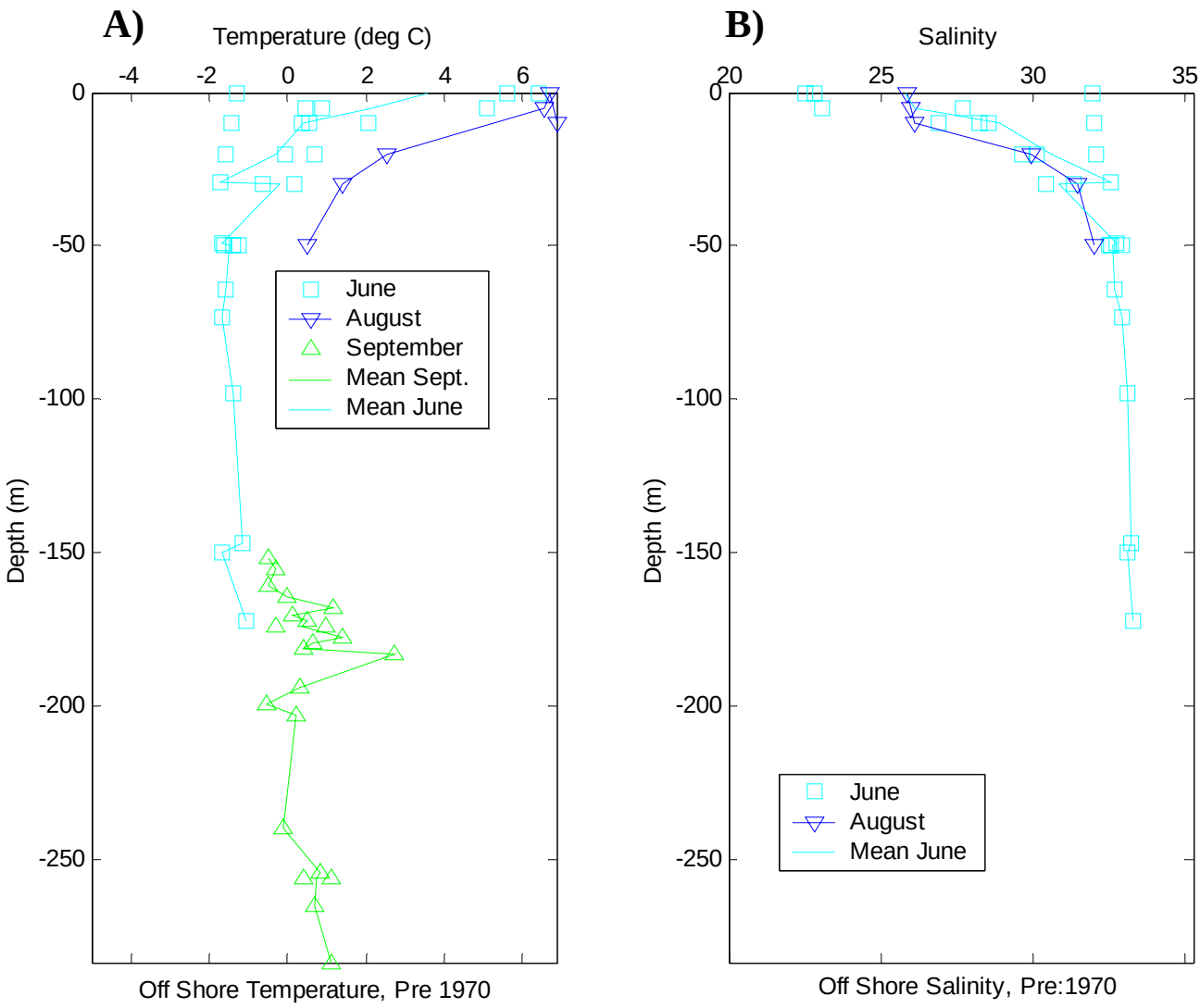


Figure 49: Offshore temperature and salinity, pre 1970. A) all temperature data, B) all salinity data**.**

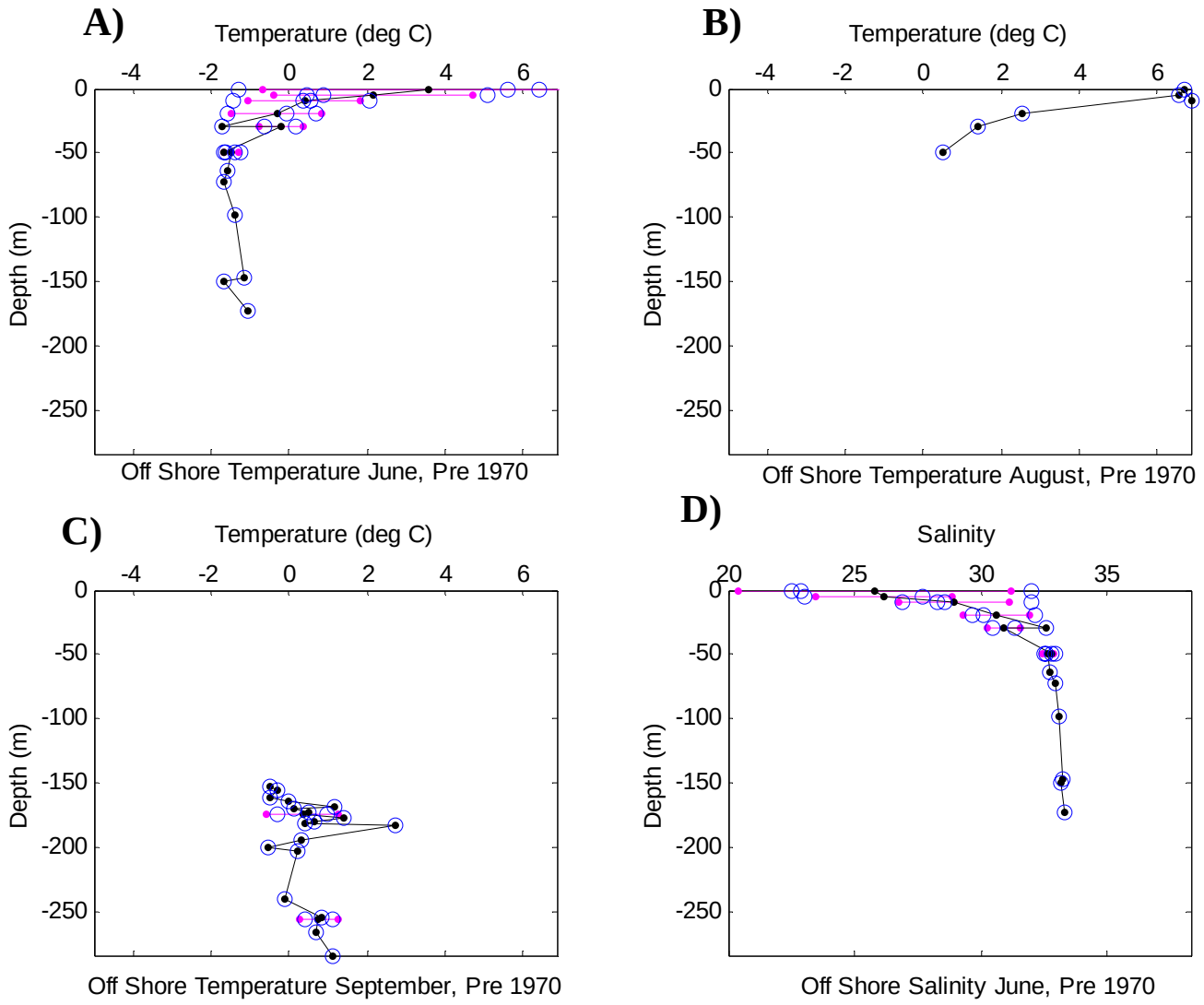


Figure 50: Monthly offshore temperature and salinity, pre 1970. The circles represent each data point, the solid line is the mean and the horizontal bars are the standard deviation. A) temperature June, B) temperature August, C) temperature September, D) salinity June.

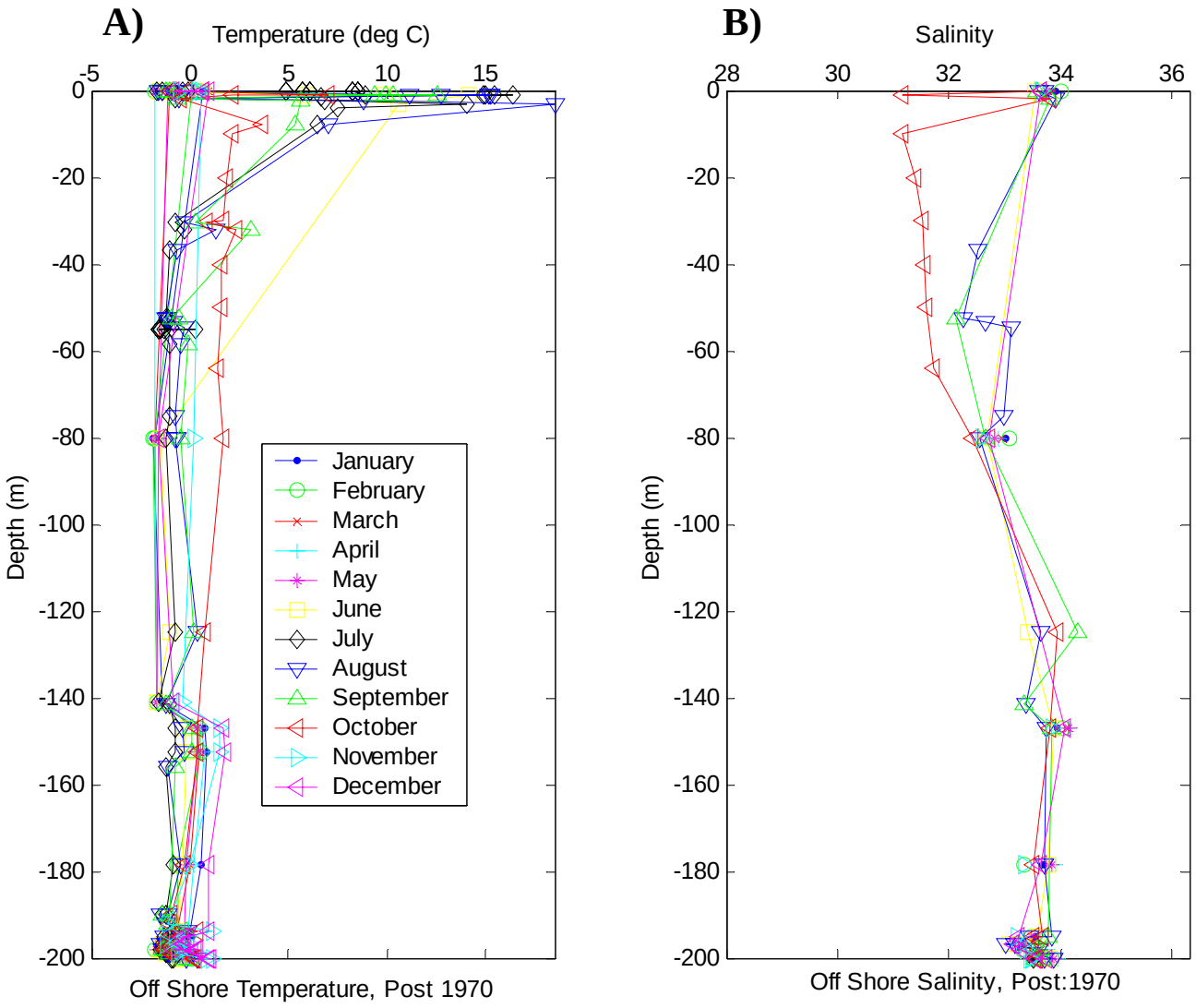


Figure 51: Offshore temperature and salinity, post 1970. A) all temperature data, B) all salinity data.

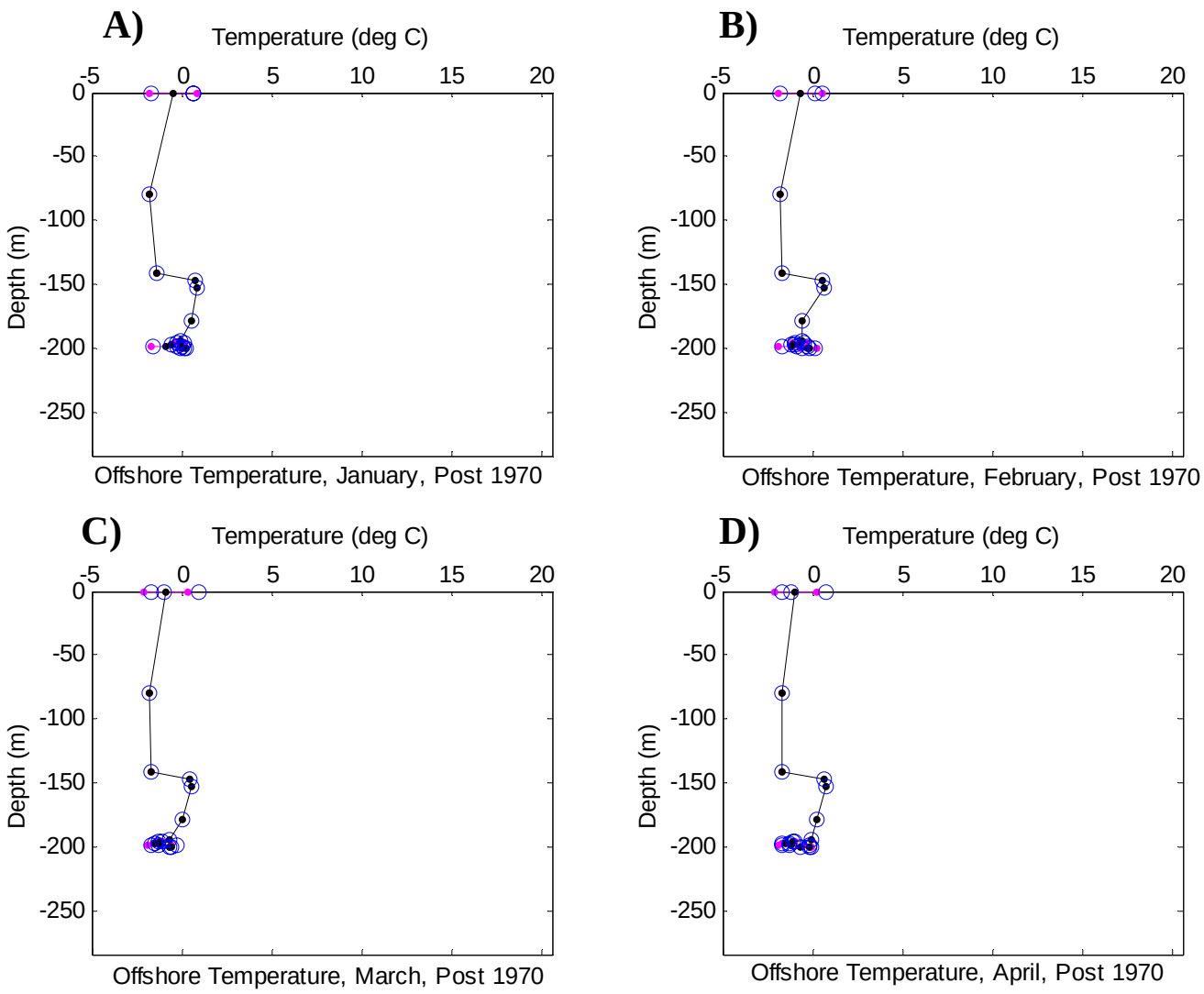


Figure 52: Monthly offshore temperature, post 1970. The circles represent each data point, the solid line is the mean and the horizontal bars are the standard deviation.

A) January, B) February, C) March, D) April.

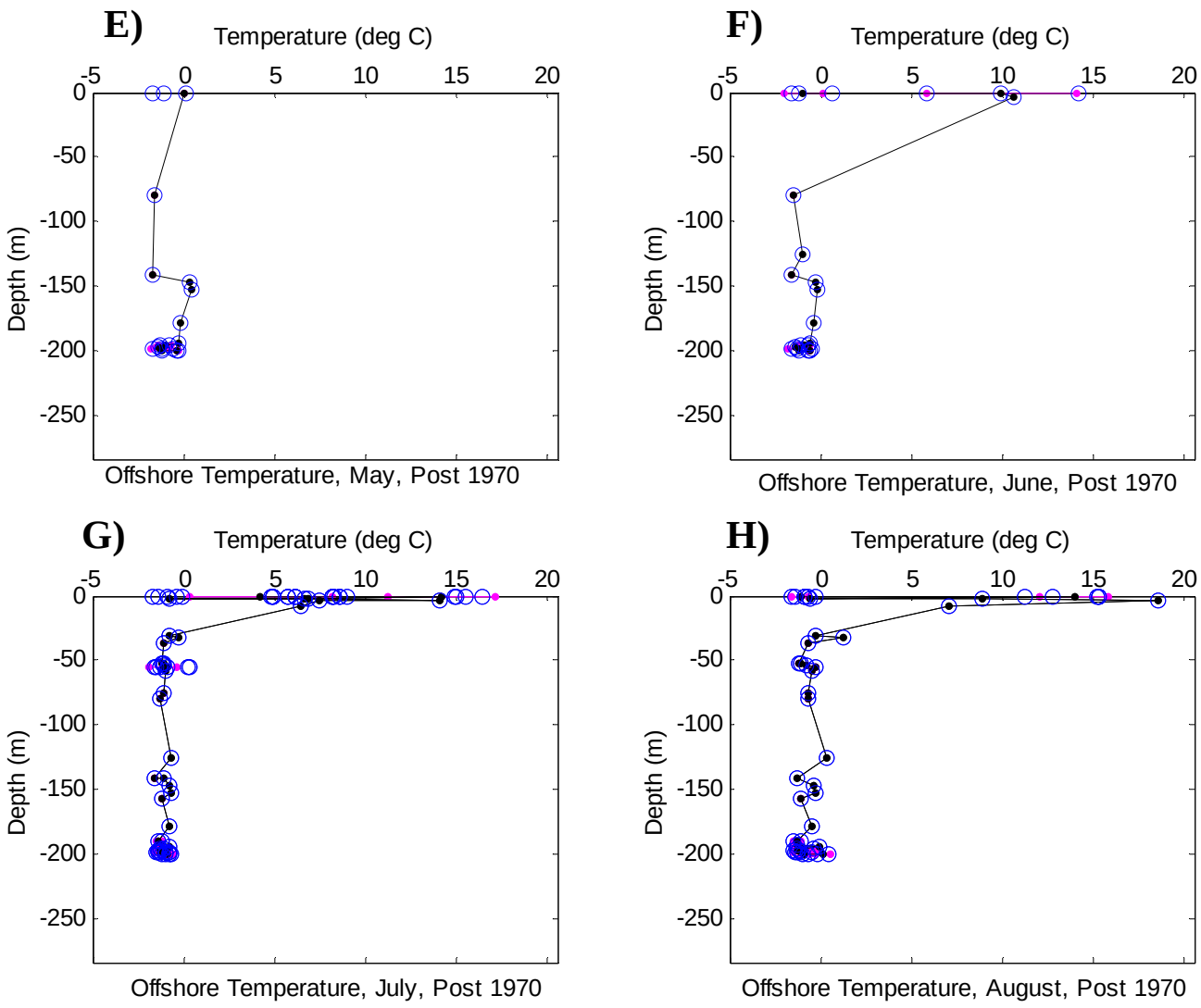


Figure 52: Monthly offshore temperature, post 1970. The circles represent each data point, the solid line is the mean and the horizontal bars are the standard deviation.

E) May, F) June, G) July, H) August.

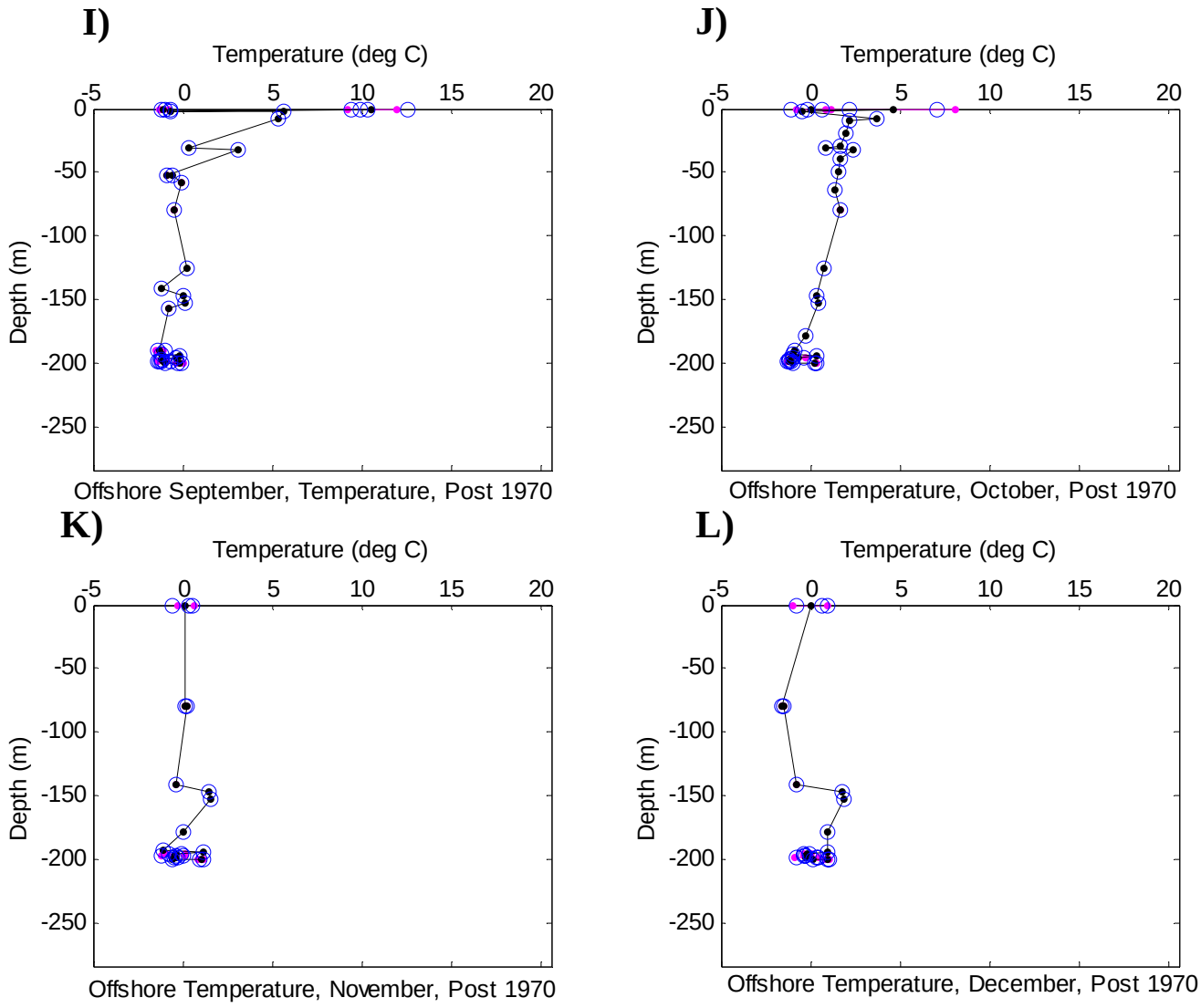


Figure 52: Monthly offshore temperature, post 1970. The circles represent each data point, the solid line is the mean and the horizontal bars are the standard deviation.

I) September, J) October, K) November, L) December.

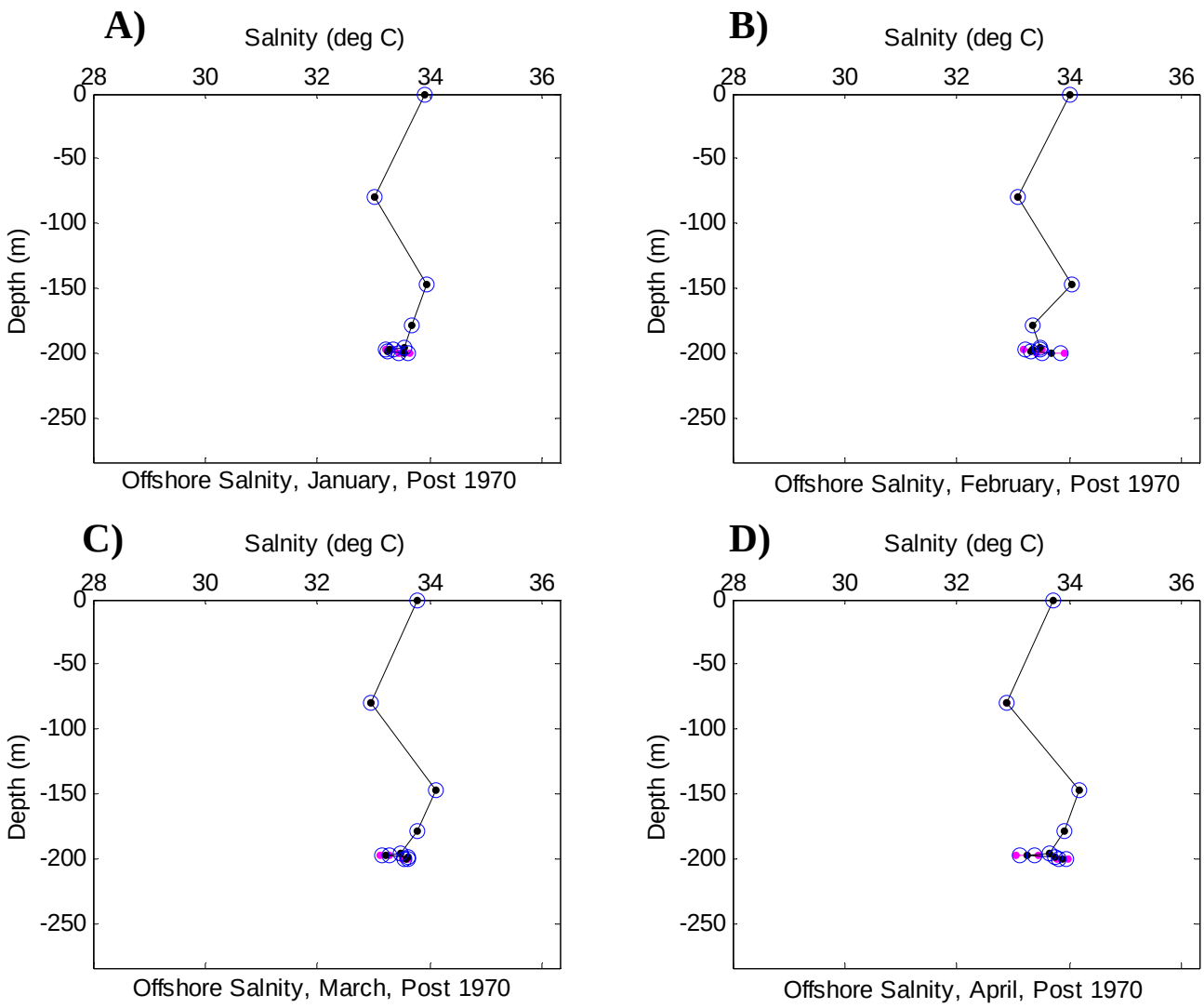


Figure 53: Monthly offshore salinity, post 1970. The circles represent each data point, the solid line is the mean and the horizontal bars are the standard deviation. A) January, B) February, C) March, D) April.

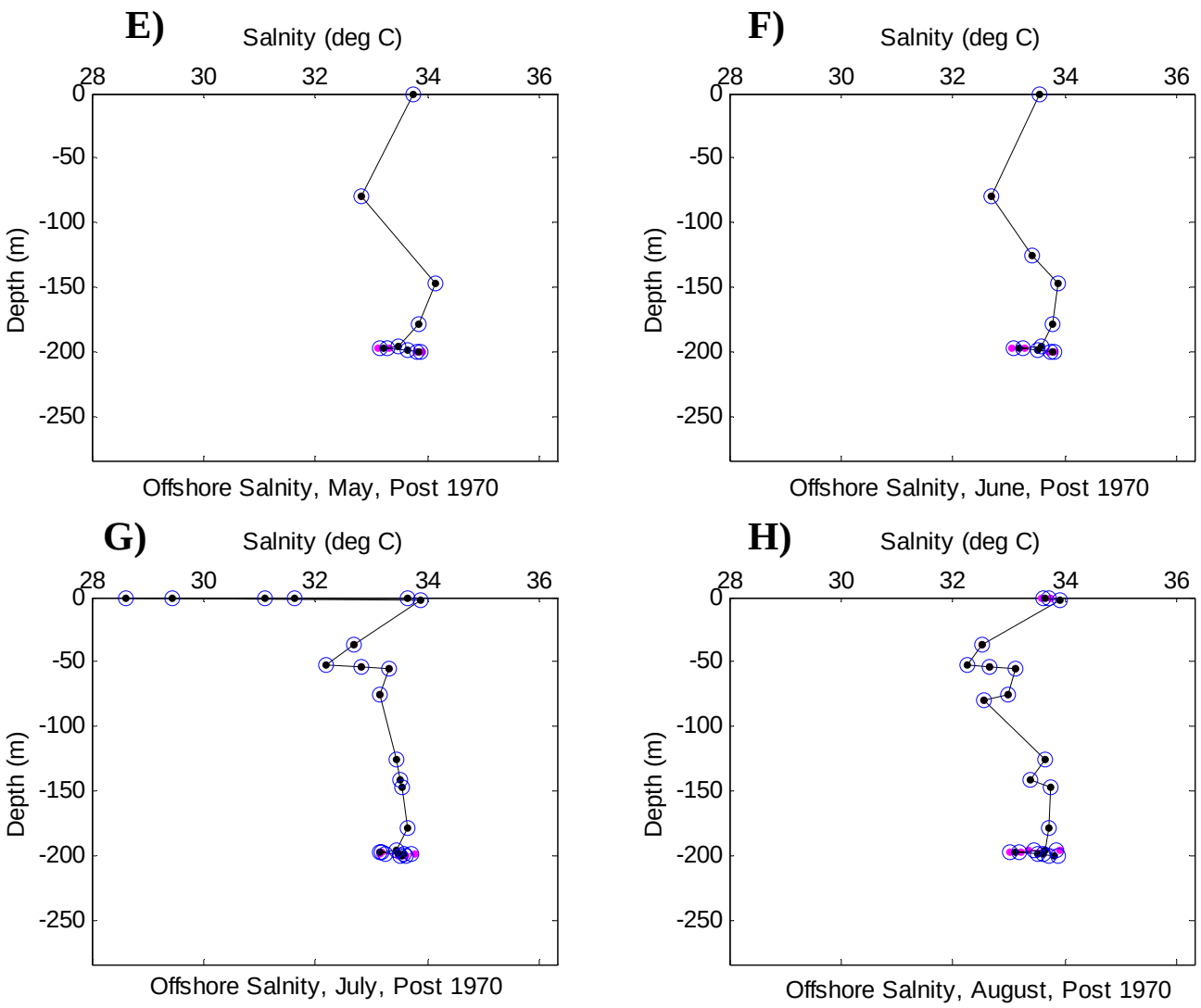


Figure 53: Monthly offshore salinity, post 1970. The circles represent each data point, the solid line is the mean and the horizontal bars are the standard deviation. E) May, F) June, G) July, H) August.

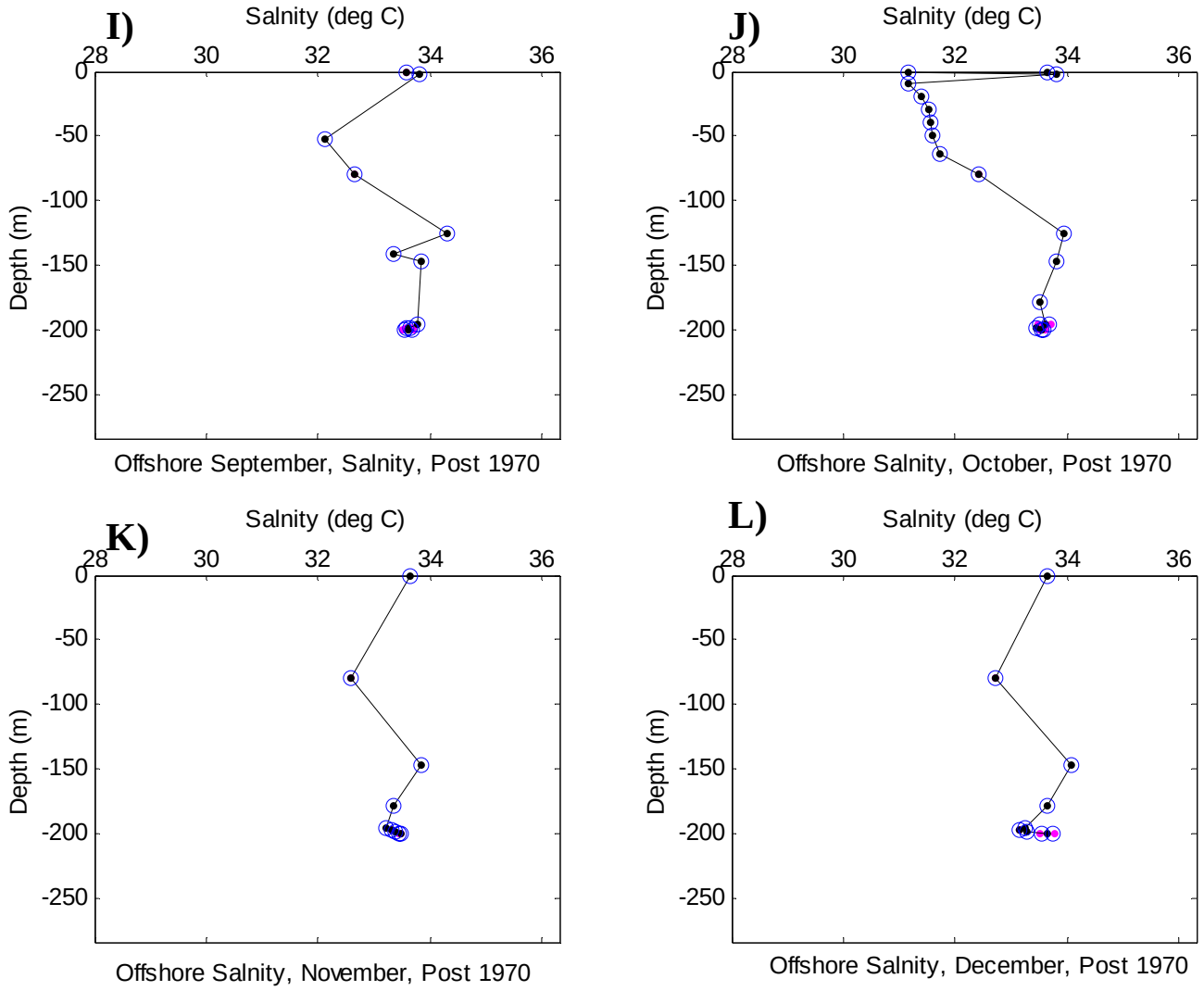


Figure 54: Monthly offshore salinity, post 1970. The circles represent each data point, the solid line is the mean and the horizontal bars are the standard deviation.

I) September, J) October, K) November, L) December.

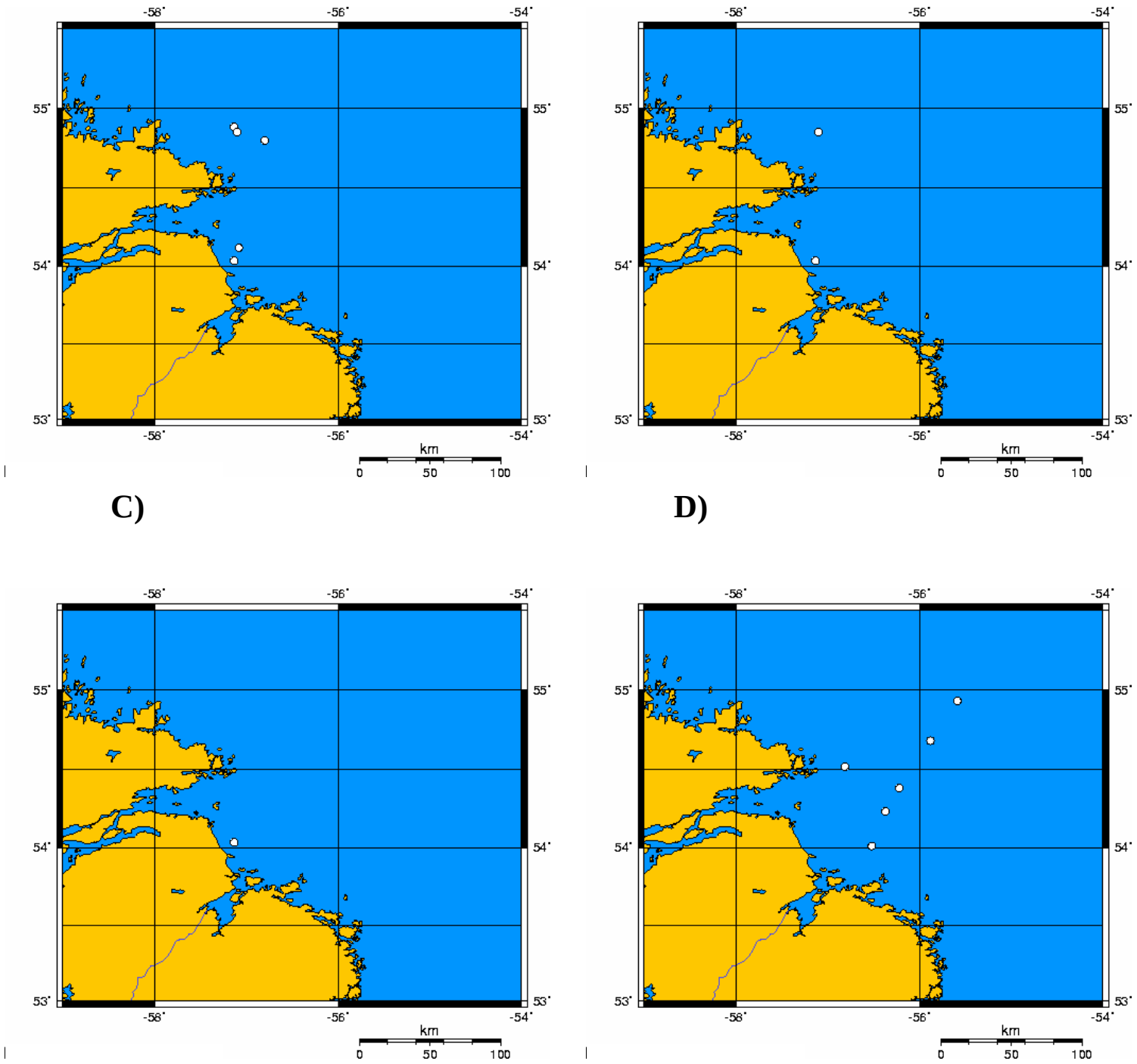


Figure 55: Location of phosphorus, oxygen data collection, offshore.

A) oxygen June, Pre 1970, B) phosphorus June, Pre 1970,
C) phosphorus/oxygen August, Pre 1970, D) phosphorus July, Post 1970.

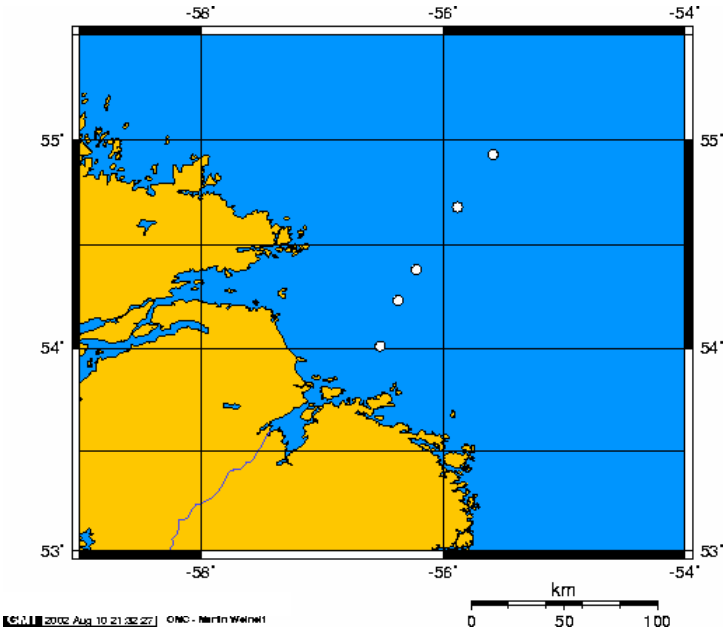


Figure 56: Location of nitrogen, silicate, and chlorophyll data collection, July, Post 1970, offshore.

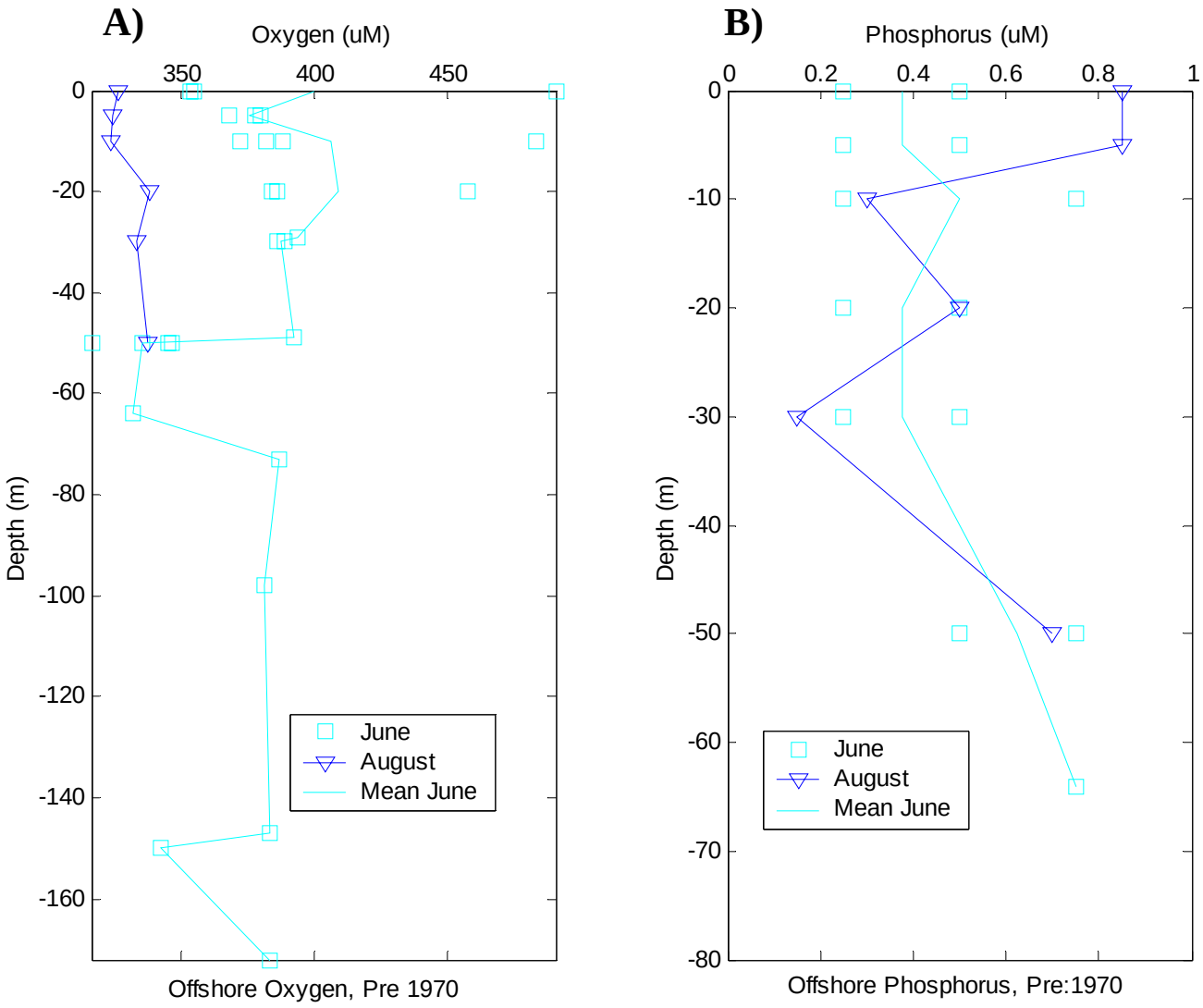


Figure 57: Offshore oxygen and phosphorus, pre 1970. A) all oxygen data, B) all phosphorus data .

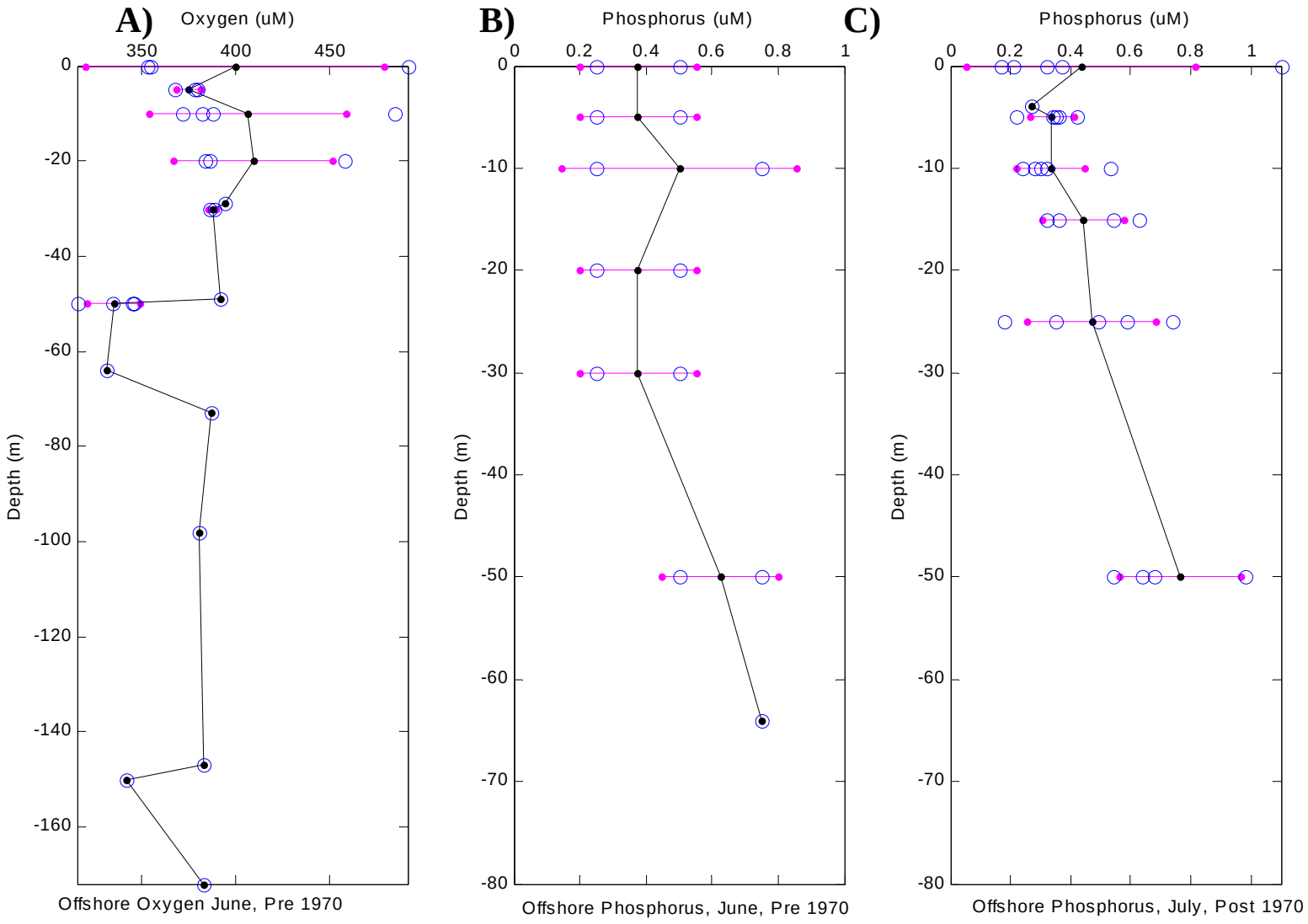


Figure 58: Monthly offshore oxygen and phosphorus. The circles represent each data point, the solid line is the mean and the horizontal bars are the standard deviation.

A) oxygen June pre 1970, B) phosphorus July pre 1970, C) phosphorus July post 1970.

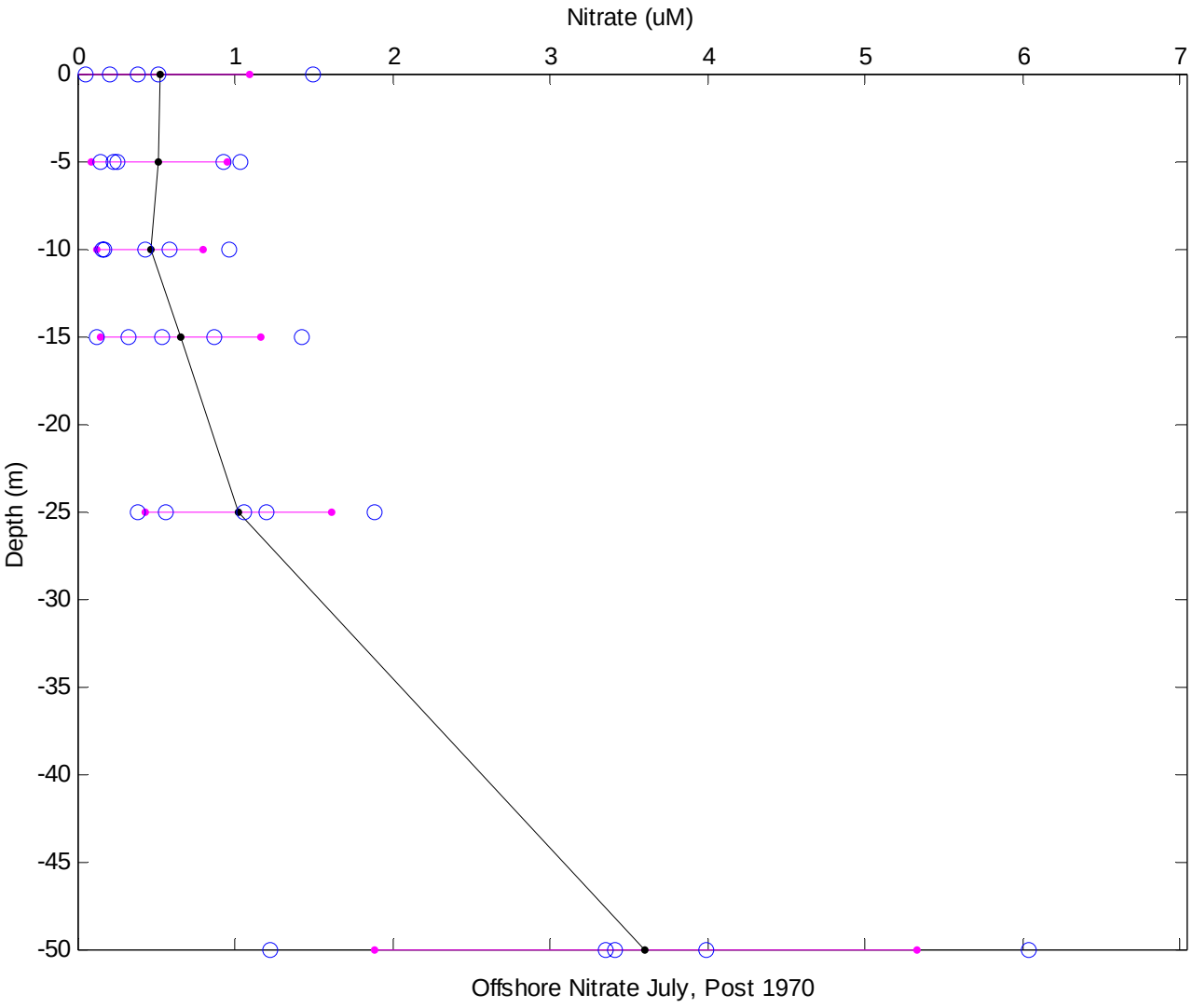


Figure 59: Offshore nitrate July, post 1970. The circles represent each data point, the solid line is the mean and the horizontal bars are the standard deviation.

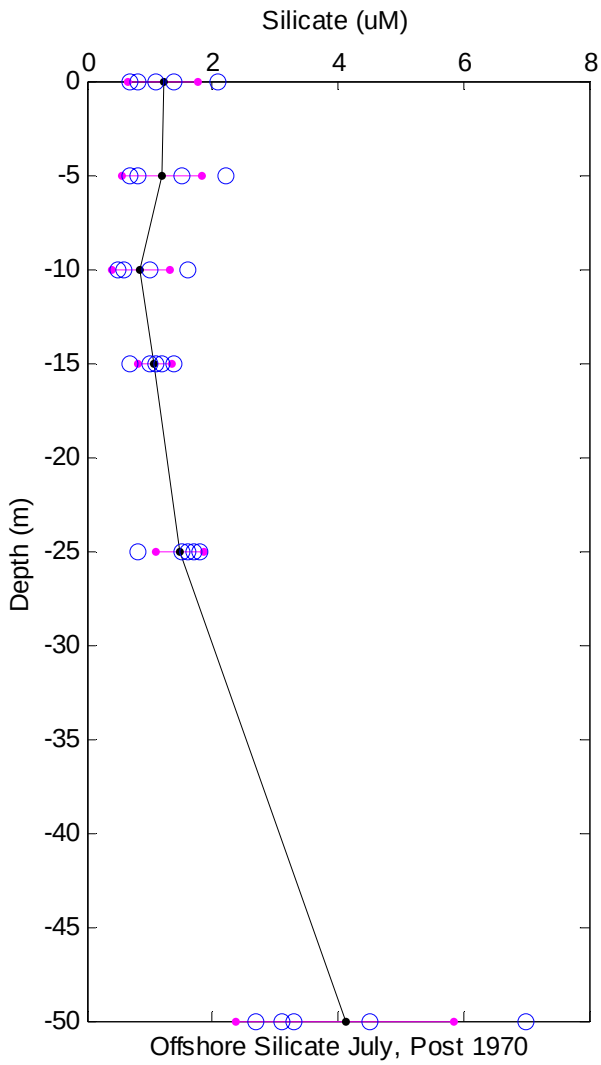


Figure 60: Offshore silicate July, post 1970. The circles represent each data point, the solid line is the mean and the horizontal bars are the standard deviation.

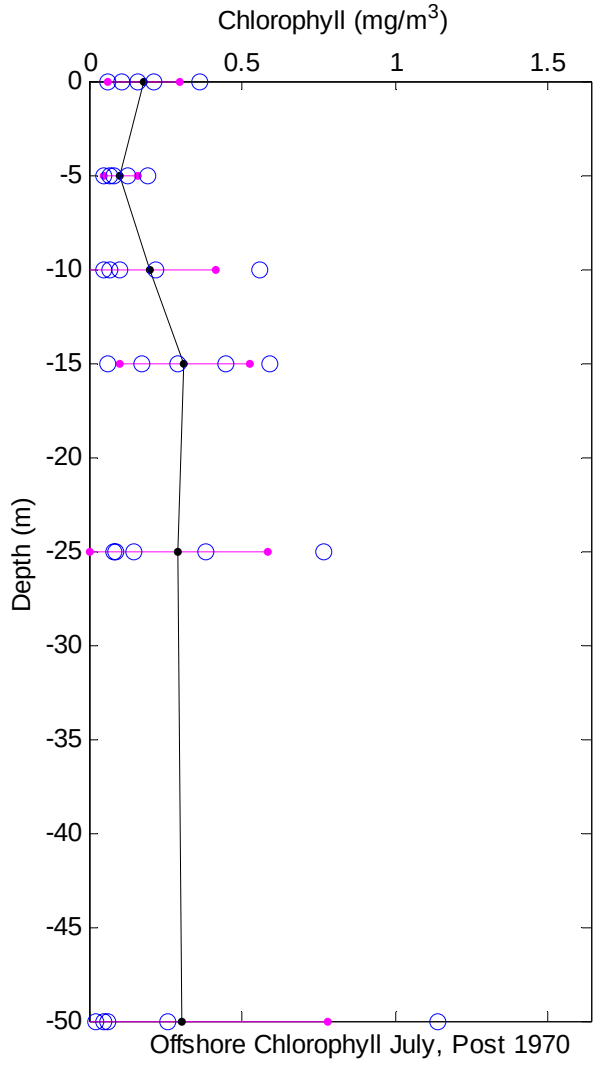


Figure 61: Offshore chlorophyll July, post 1970. The circles represent each data point, the solid line is the mean and the horizontal bars are the standard deviation.