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ON LONG TERM VARIATIONS OF SALINITY AND OXYGEN IN THE GULF OF BOTHNIA

by

Stig H. Fonselius

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Adress

Box 2566

403 17 Göteborg

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On long-term variations of salinity and oxygen in the Gulf of Bothnia

Om långtidsförändringar av saliniteten och syrgashalten i Bottniska viken

Sammanfattning av rapport (fakta med huvudvikt på resultatet)

Arbetet behandlar långtidsförändringarna i salinitet i ytvattnet och i djupvattnet på 7 hydrografiska stationer utvalda i olika delar av Bottniska viken. Mätserierna sträcker sig från 1960-talet fram till 1984. För varje serie har ett diagram ritats med regressionslinje och korrelationskoefficient och sannolikhetsvärde har beräknats med hjälp av dator. För 3 representativa stationer har syrgasförändringen i djupvattnet uppritats på samma sätt och korrelation och sannolikhetsvärde har beräknats.
Man kan från diagrammen finna en tydlig ökning av saliniteten med ett sannolikhetsvärde på 99,9%. Man kan också se att saliniteten i djupvattnet börjat avta sedan 1977-80. Även för syrgaskoncentrationen i djupvattnet kan man finna en motsvarande minskning, vilket tyder på delvis ökad belastning och delvis på ökad inströmning av östersjövatten med lägre syrgashalt.

Förslag till nyckelord samt ev anknytning till geografiskt område, näringsgren eller vattendrag

Långtidsförändringar, salinitet, syrgas, Ålands hav, Kvarken, Bottenhavet, Bottenviken, Norra Kvarken

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ON LONG TERM VARIATIONS OF SALINITY AND OXYGEN IN THE GULF OF BOTHNIA

by

Stig H. Fonselius

Several authors have shown that the salinity of the Baltic Sea has increased since the beginning of the century (Fonselius 1969, Fonselius et al. 1984, Matthäus 1977 etc). Fonselius (loc. cit.) has shown that also the salinity of the Gulf of Bothnia has increased. The purpose of the present paper is to study the salinity variations since World War II in the Gulf of Bothnia. Several international deep stations with long salinity series can be found in the Gulf of Bothnia. The Gulf of Bothnia consists of the Åland sea, the Bothnian sea and the Bothnian bay. For the present study I have chosen seven stations, one from the Åland sea (F64), one from the entrance channel to the Bothnian sea (F33), three from different parts of the Bothnian sea (F24, SR5 and F24) and two from the Bothnian bay (F9 and F2). For all stations I have plotted the salinity values from 1963 to 1984 for 10 m and for a chosen depth below the halocline. The regression line, the correlation coefficient and the confidence level have been computed for each series of salinities. Fig. 1 shows a map of the Gulf of Bothnia with the stations used in the study.

Fig. 2 shows the salinity variations for the station F64 in the Åland sea at 0 m and 200 m. In the surface water we find a clear increase during the period, but the values are quite scattered due to the influence of river runoff and water exchange between the Baltic proper and the Gulf of Bothnia. In the deep water we can see seasonal variations of salinity. The deep water is formed through sinking of cold surface water in the northern Baltic proper, which flows over the sill into the Åland sea. This water has a higher salinity than the summer water, which is influenced by the river runoff. Therefore we find salinity maxima in the deep water during the winter. A general increase of the salinity can also be seen. It reached its maximum around 1978 and after this maximum, the salinity has begun to decrease. The salinity is at present as low as in the beginning of the period.

Fig. 3 shows the salinity variations for station F33 at Grundkallen for 0 m and 100 m. In the surface water the salinities were extremely low between 1966 and 1972. The same pattern could also be observed at F64. We also find the decrease after the weak maximum around 1977 in the deep water. Due to the smaller amount of data the seasonal variations in the deep water are difficult to detect. The general increasing trend of the salinity in the surface water is quite clear. The deep water shows an increasing trend for the period, but it is difficult to conclude if the decrease after 1977 will continue, or if it is only a short period variation.

The station SR5 (Fig. 4) is located in the southern part of the deep area of the Bothnian sea. The figure shows the salinity variations at 0 m and 100 m. Again we find an in general increasing trend for both surface and deep water. The low surface salinity during the period 1966 to 1972 can also be found here. In the deep water we find a maximum in 1980 and then a decreasing trend as at the previous station.

Fig. 5 shows the salinity variations in the northern Bothnian sea at station F22 at 0 m and 175 m. We again find an increasing general trend in both water masses. The surface water shows quite scattered values due to the neighborhood to the entrance to the Bothnian bay. In the deep water we find a weak maximum in 1980 and then the same decreasing trend as at the previous stations.

Station F24, the Ulvö Deep is located close to the Swedish coast, but I have included the station because of the large amount of salinity measurements. In the surface water we can see the scattering of values due to runoff. In the deep water the salinity increase is more clear, than in the surface water and the variations are very small. The series are from 0 m and 150 m. In the deep water we find the salinity maximum in 1981 and after that a decreasing trend. It seems that it takes around 3-4 years for the bottom water to flow from the Ålande sea around the Finngrundsbanks to the Ulvö Deep (Fig. 6).

Fig. 7 shows the salinity variations in the southern Bothnian bay at station F9 at 0 m and 100 m. Both in the surface water and the deep water we find a weak increasing trend. In the surface water seasonal variations may be seen due to river runoff during the spring. In the deep water some variations may be seen, which are not seasonal, but somewhat longer. We also find a decreasing trend from 1981 and especially during 1984.

Station F2 finally represents the conditions in the northern Bothnian bay. The water here seems to be too much influenced by river runoff and therefore it is not possible to establish any trend in this area. The correlation coefficients are too low for any conclusions (Fig. 8). For the whole Gulf of Bothnia, we may draw the conclusion that the salinity of the surface water is increasing since World War II and that the salinity in the deep water has increased until a maximum around 1977-1981 and is now decreasing. It is not possible to establish from existing measurements, if this salinity decrease will continue or if it is a short decreasing period after which the salinity will continue to increase.

In the figures the asterisks after the correlation coefficients show the confidence level according to the t-test. Three asterisks show a confidence level of 99.9 %, two asterisks show 99 % and one asterisk shows 95 % confidence.

It has earlier been shown that there may be a decreasing trend for dissolved oxygen in the deep water of the Ulvö Deep since the beginning of the century (Fonselius 1969, 1971).

In order to investigate this trend closer during the period after WWII dissolved oxygen values in the deep water of the above mentioned stations were plotted against time from 1960 - 1984. Regression lines, correlation coefficients and confidence levels were calculated for every station. Only for the stations F 33, SR 5 and F 24 significant decreasing trends with acceptable confidence levels could be found. Fig. 9 shows the results from these stations. It is evident that the oxygen concentration in the deep water of the Bothnian Sea is decreasing in the deepest parts.

The reason for this decreasing may be the unusually warm winters during recent years, which have prevented an effective vertical convection down to the deepest parts during the winter. Another possiblility may be inflow of small amounts of Baltic deep water with a very low oxygen content (Fonselius 1985). A third possiblility may be the increasing load of nutrients and easily oxidized organic matter from land (Larsson et al. 1984).

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Matthäus, W., 1977: Zur säkularen Veränderlichkeit des Oberfläckensaltzgehaltes in der offenen Ostsee. Beitr. z. Meeresk. Helft 39.

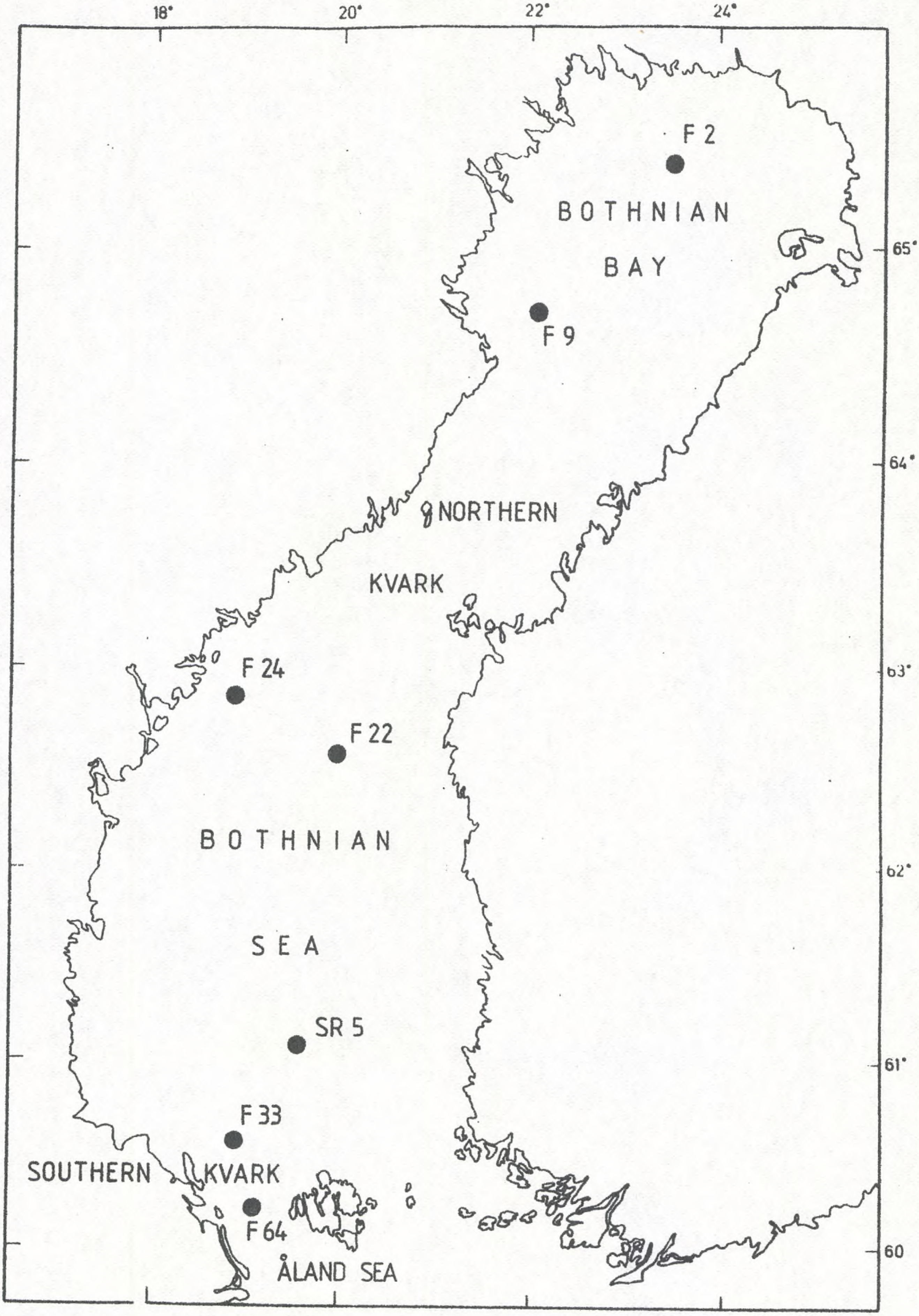
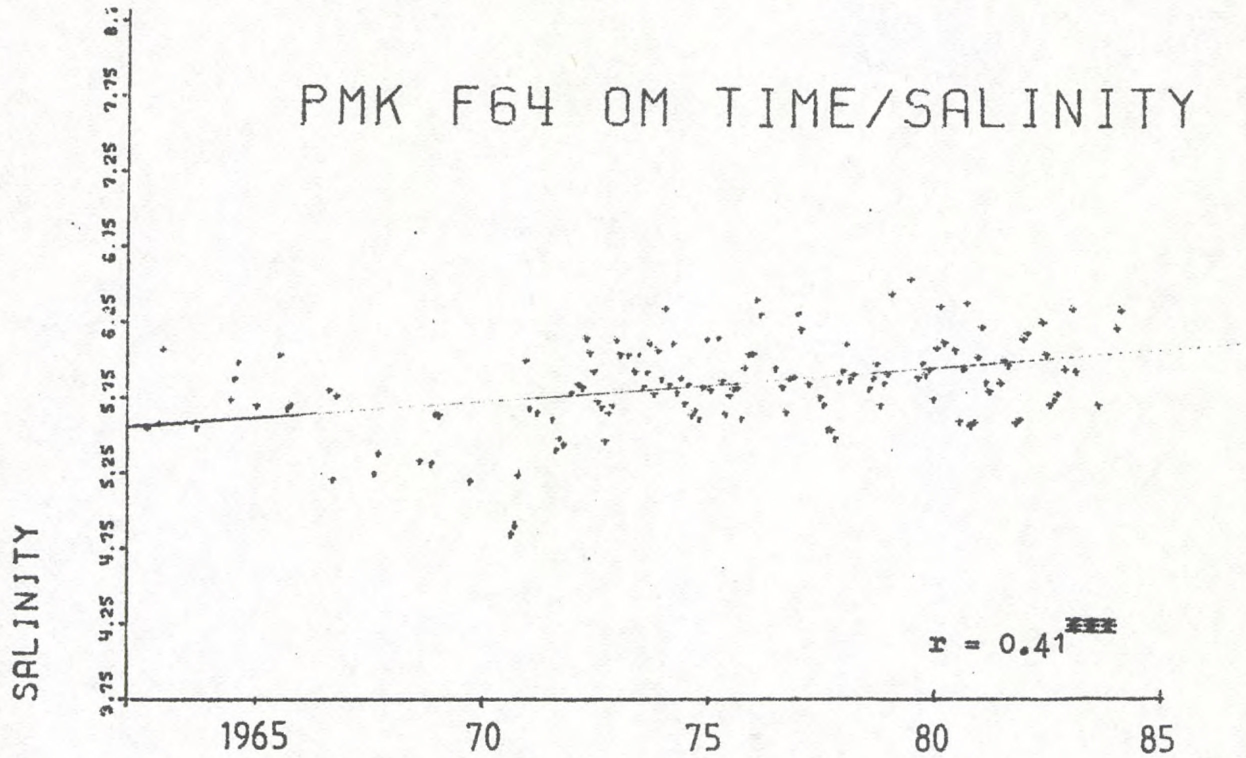

18°
20°
22°
24°
65°
64°
63°
62°
61°
60
F 2
BOTHNIAN
BAY
F 9
NORTHERN
KVARK
F 24
F 22
BOTHNIAN
SEA
SR 5
F 33
SOUTHERN
KVARK
F 64
ÅLAND SEA

FIG. 1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SALINITY
r = 0.41***
1965
70
75
80
85

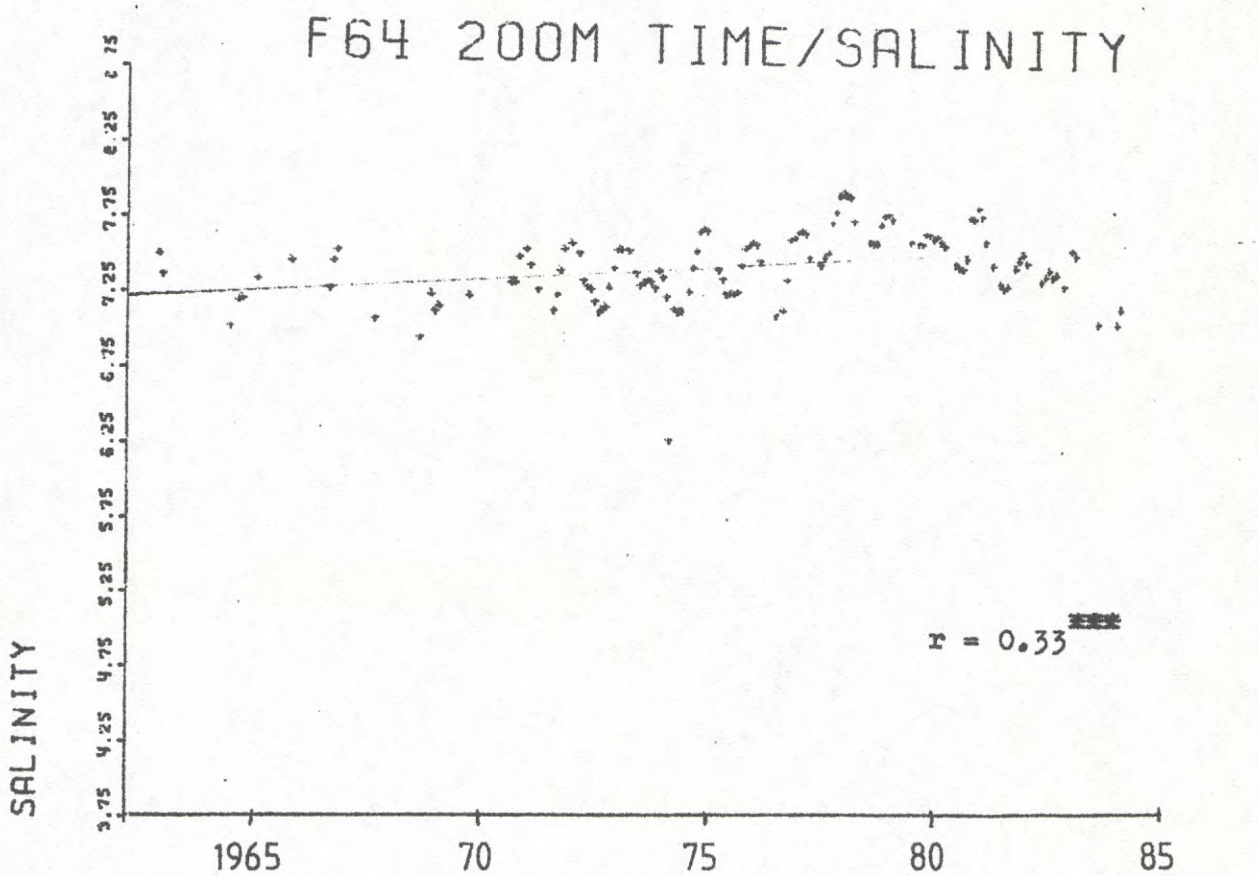
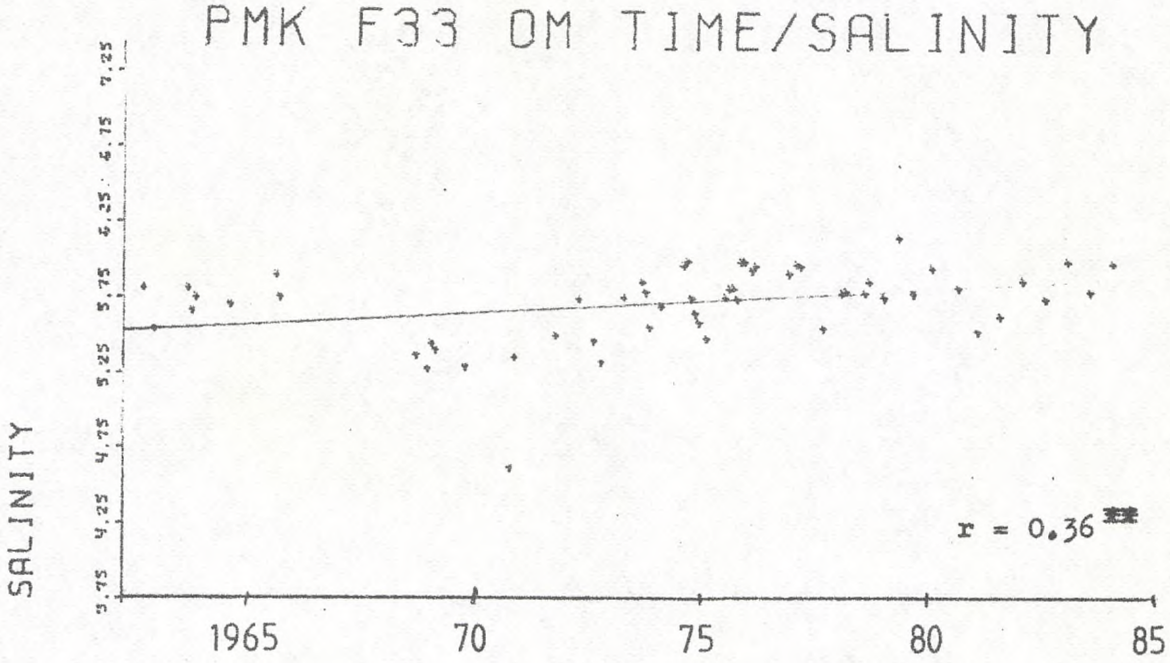

F64 200M TIME/SALINITY
SALINITY
r = 0.33***
1965
70
75
80
85

FIG. 2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SALINITY
3.75
4.25
4.75
5.25
5.75
6.25
6.75
7.25
1965
70
75
80
85
r = 0.36**

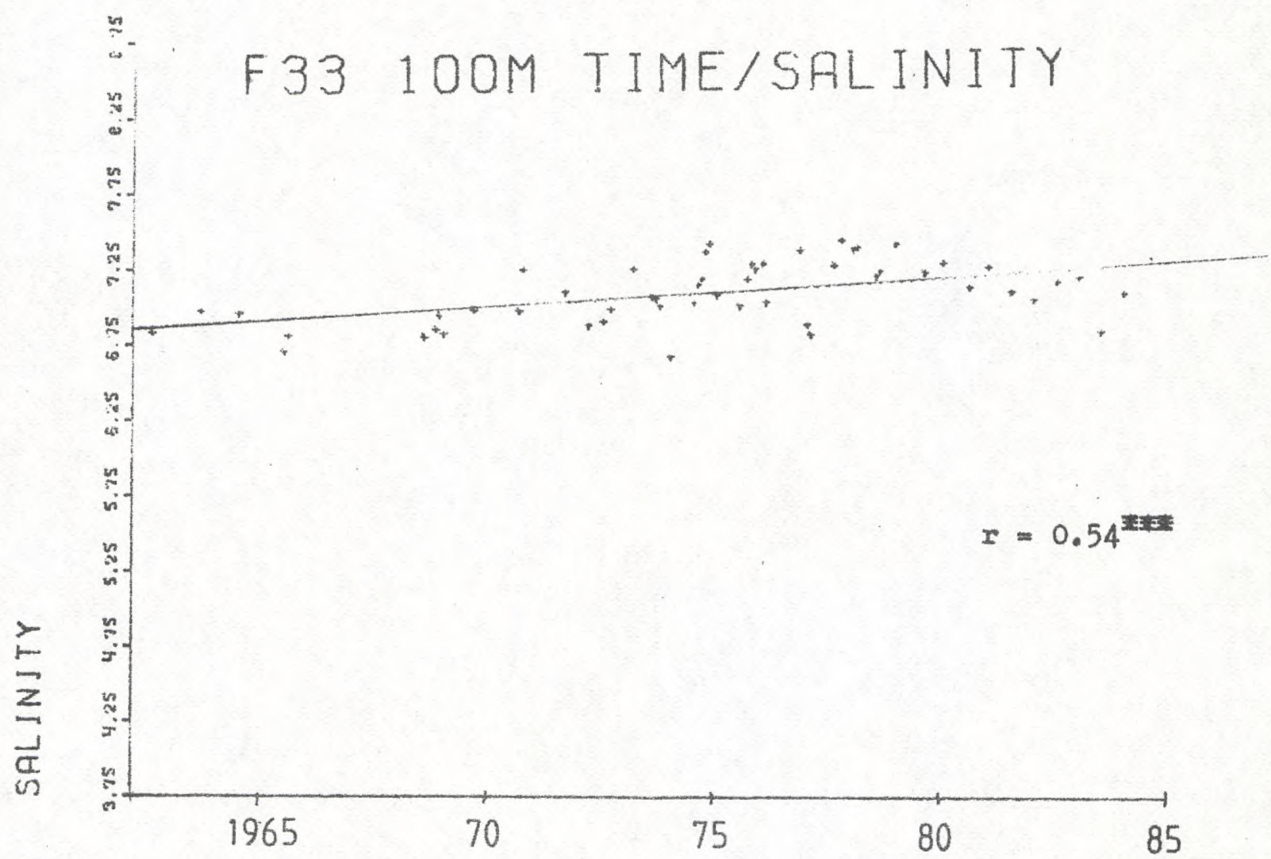
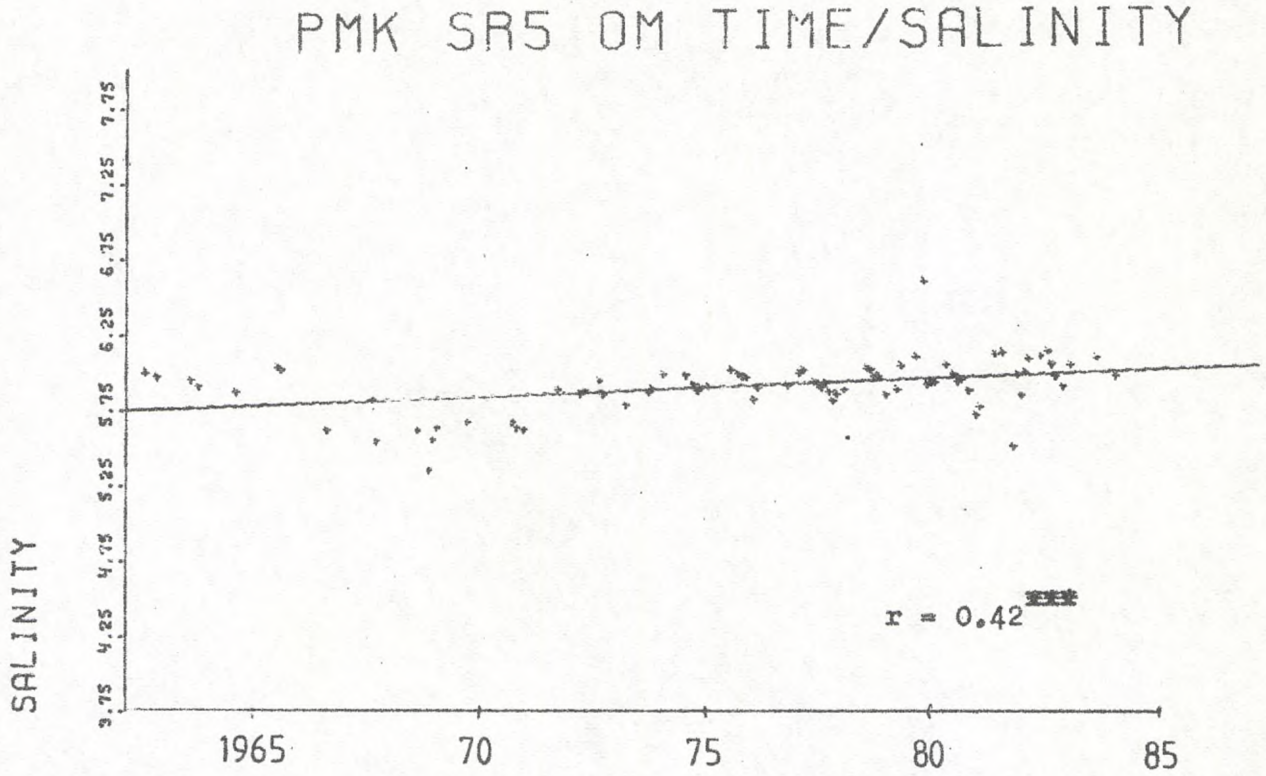

F33 100M TIME/SALINITY
SALINITY
3.75
4.25
4.75
5.25
5.75
6.25
6.75
7.25
7.75
8.25
8.75
1965
70
75
80
85
r = 0.54***

FIG. 3


PMK SR5 0M TIME/SALINITY
SALINITY
3.75
4.25
4.75
5.25
5.75
6.25
6.75
7.25
7.75
1965
70
75
80
85
r = 0.42***

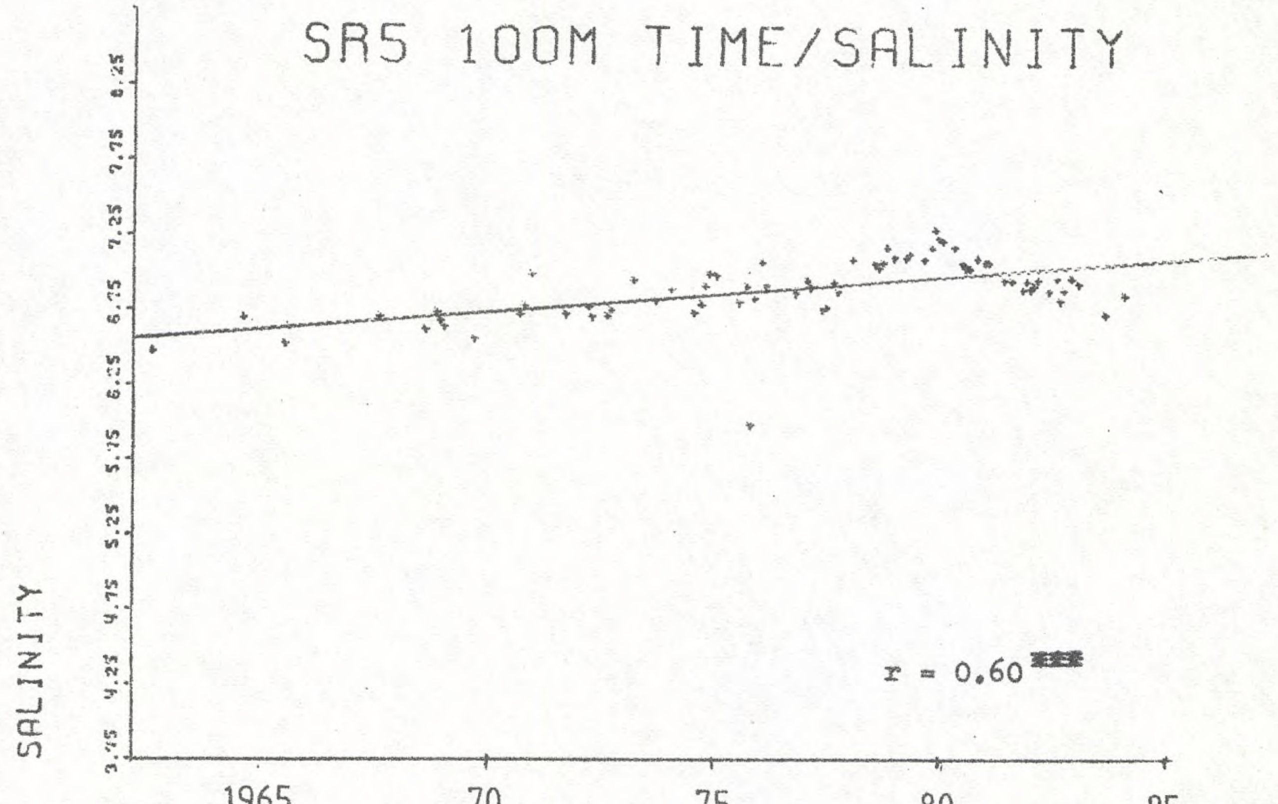
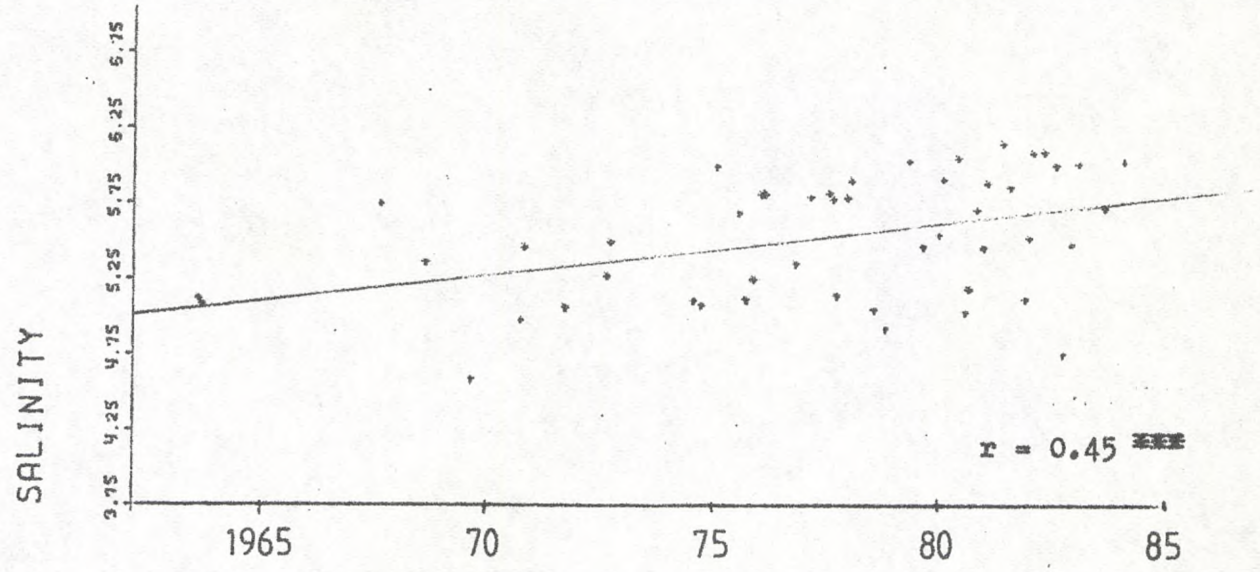

SR5 100M TIME/SALINITY
SALINITY
4.25
4.75
5.25
5.75
6.25
6.75
7.25
7.75
8.25
1965
70
75
80
85
r = 0.60***

FIG. 4

PMK F22 OM TIME/SALINITY



F22 175M TIME/SALINITY

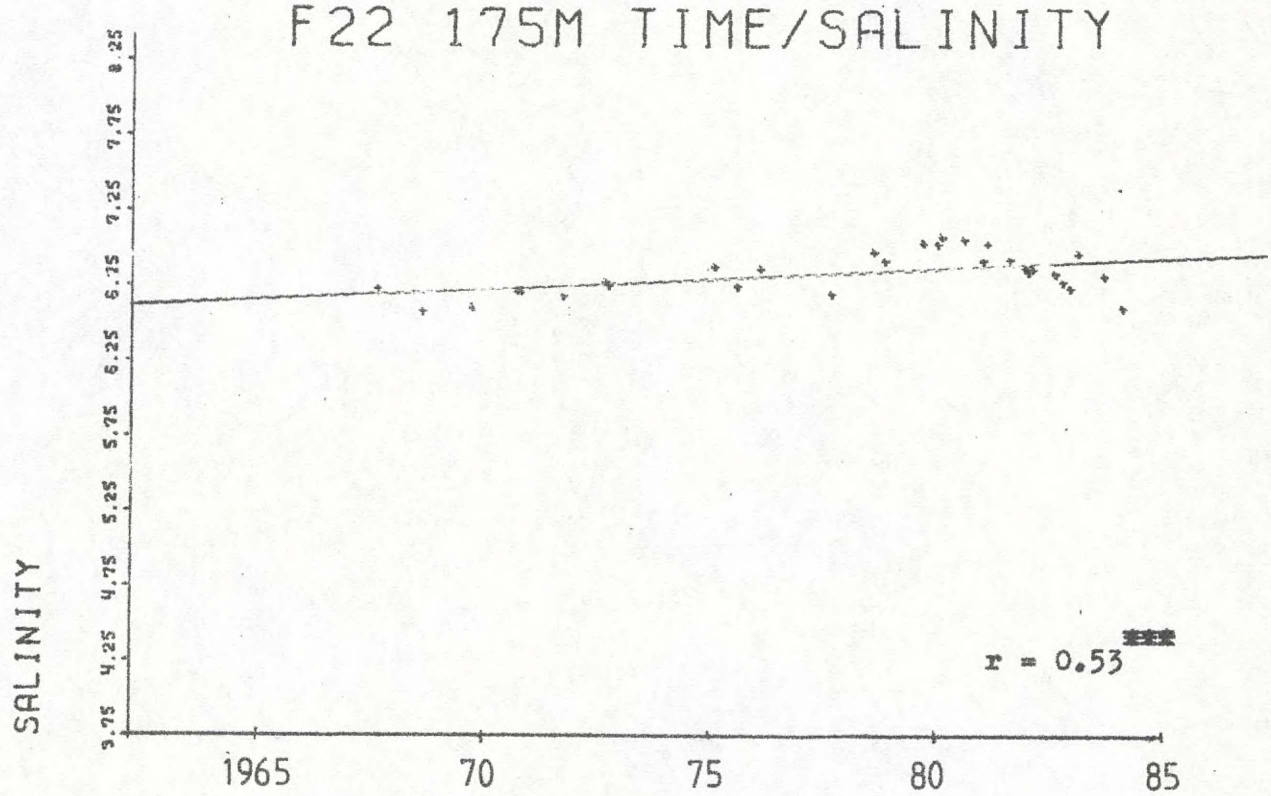


FIG. 5

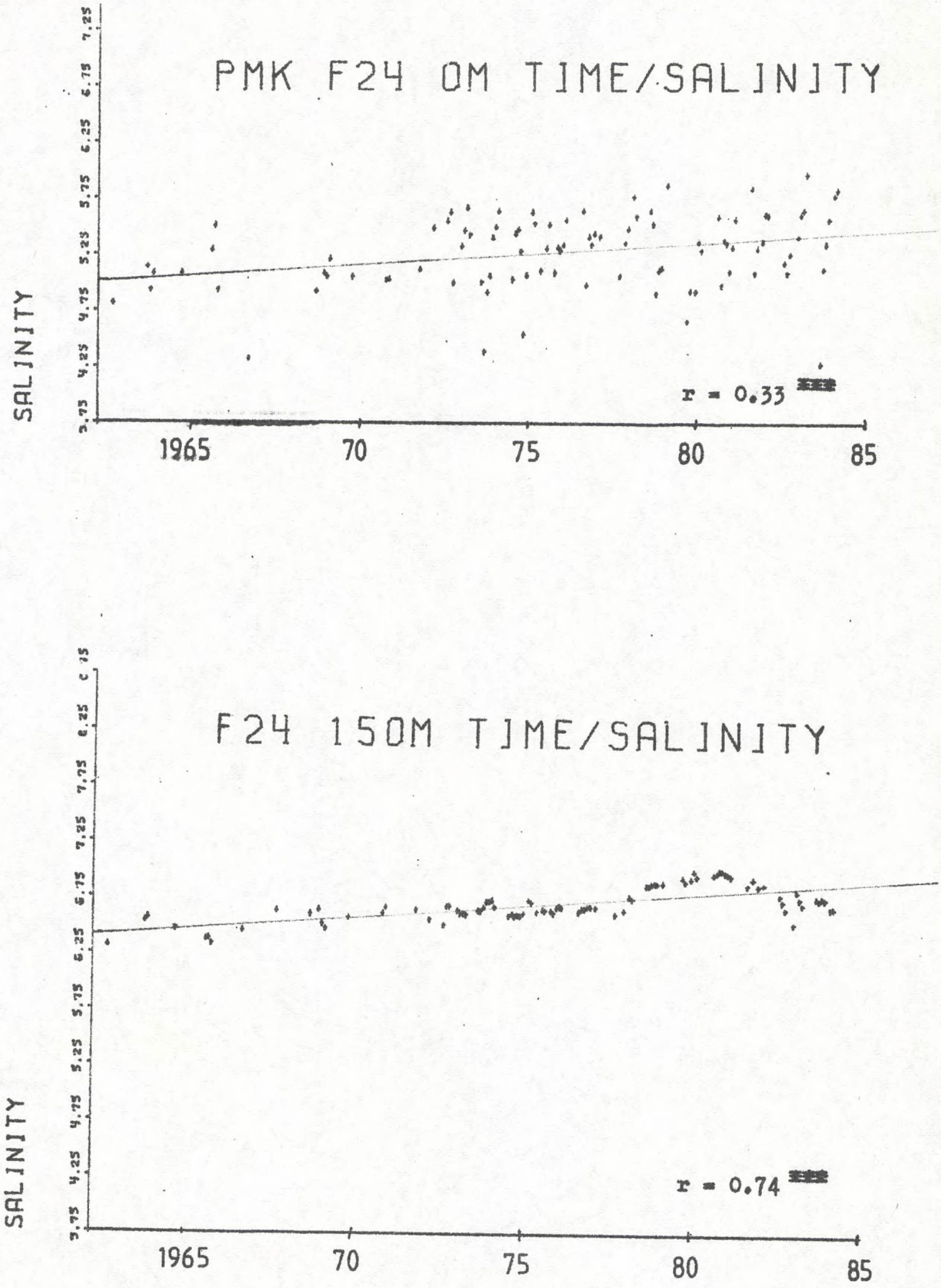
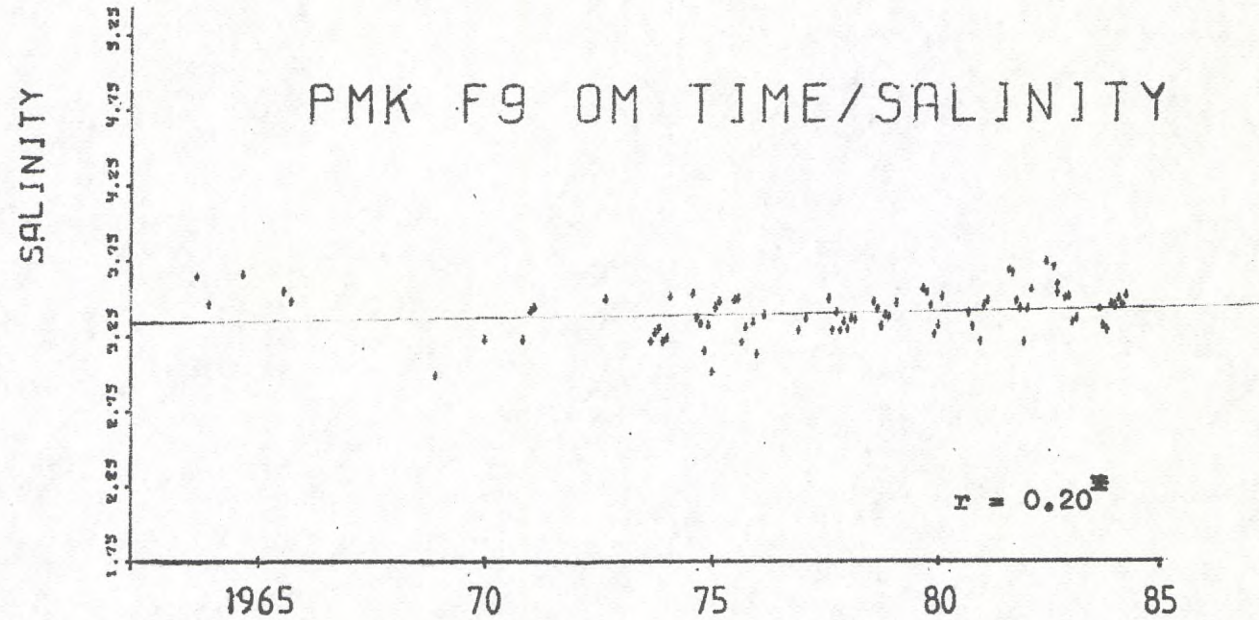

PMK F24 0M TIME/SALINITY
SALINITY
r = 0.33 ***
1965
70
75
80
85
F24 150M TIME/SALINITY
SALINITY
r = 0.74 ***
1965
70
75
80
85

FIG. 6


PMK F9 OM TIME/SALINITY
SALINITY
r = 0.20*
1965
70
75
80
85

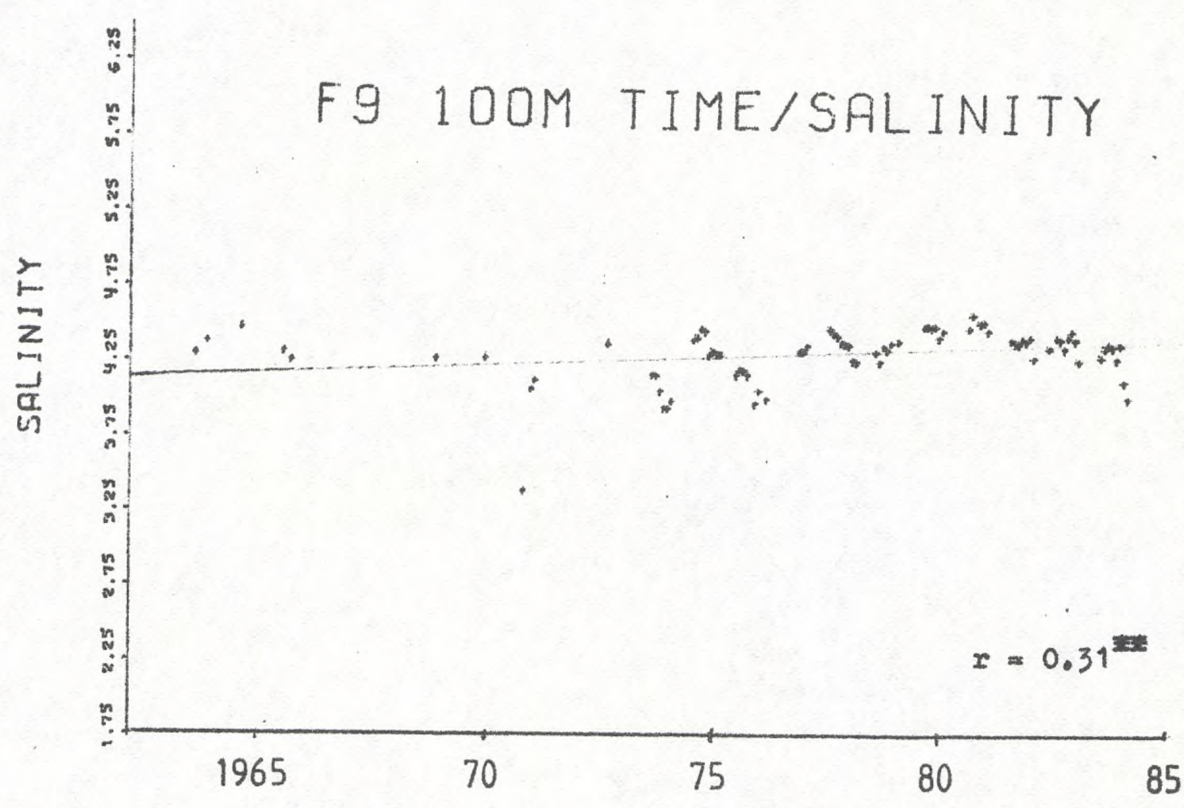
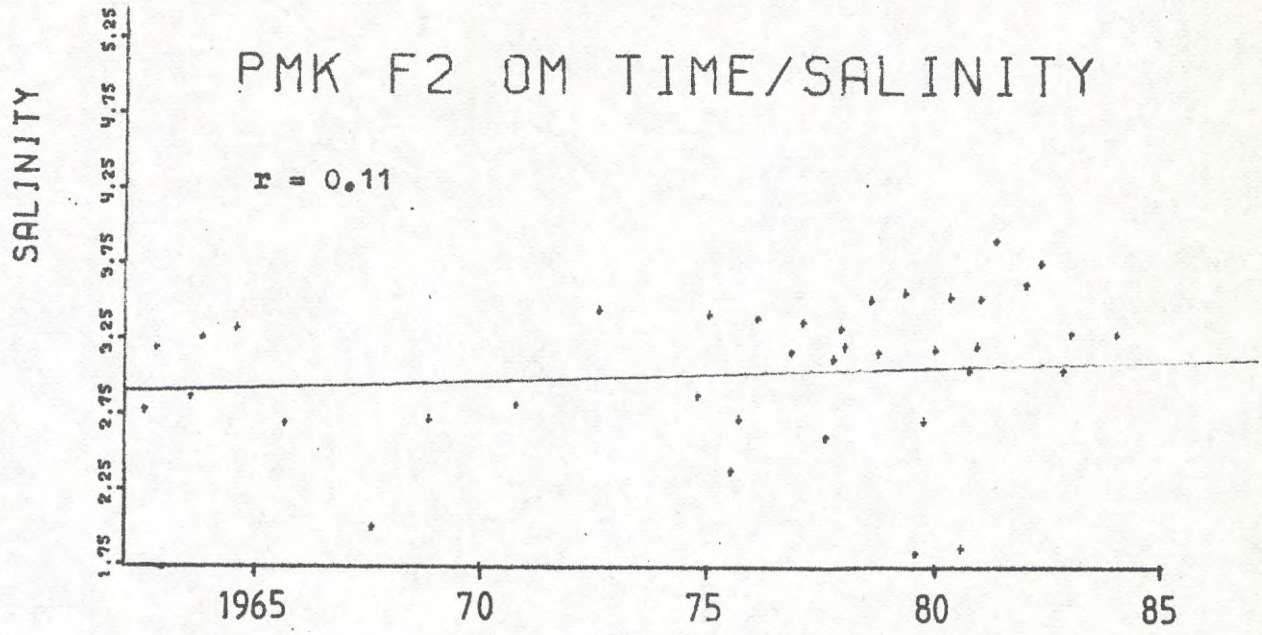

F9 100M TIME/SALINITY
SALINITY
r = 0.31**
1965
70
75
80
85

FIG. 7


PMK F2 0M TIME/SALINITY
r = 0.11
SALINITY
1.75
2.25
2.75
3.25
3.75
4.25
4.75
5.25
1965
70
75
80
85

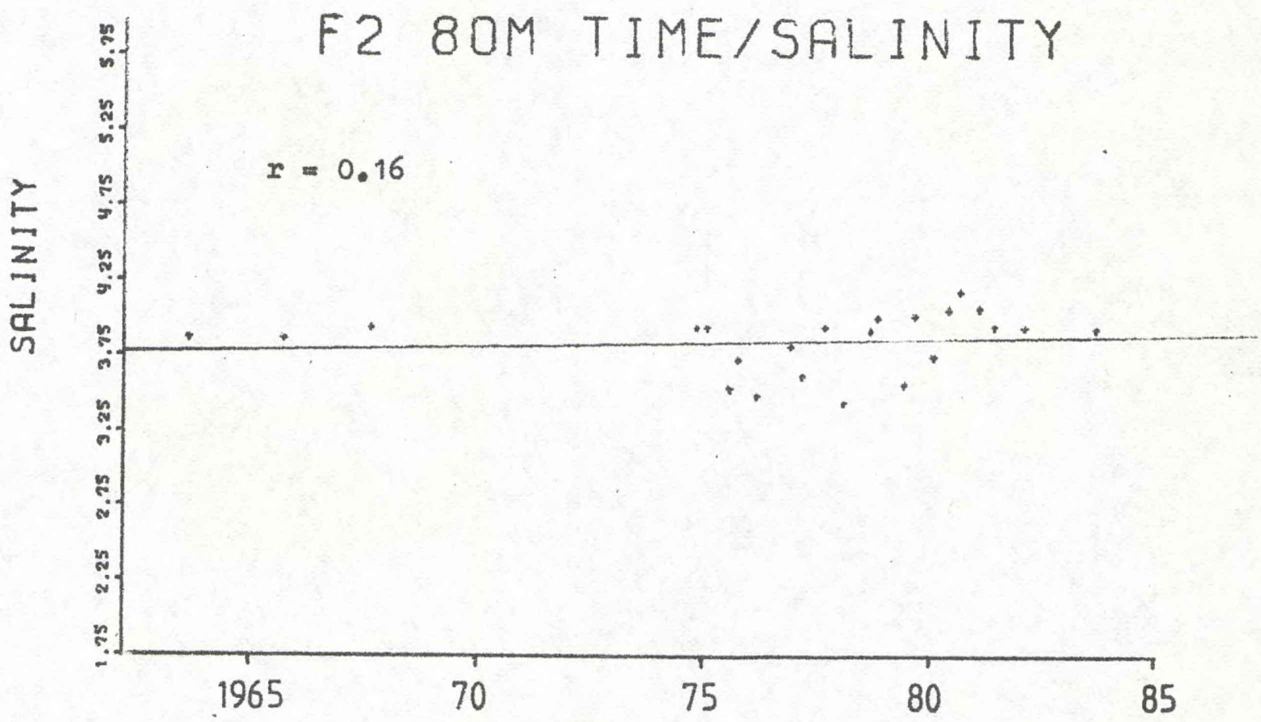

F2 80M TIME/SALINITY
r = 0.16
SALINITY
1965
70
75
80
85

FIG. 8

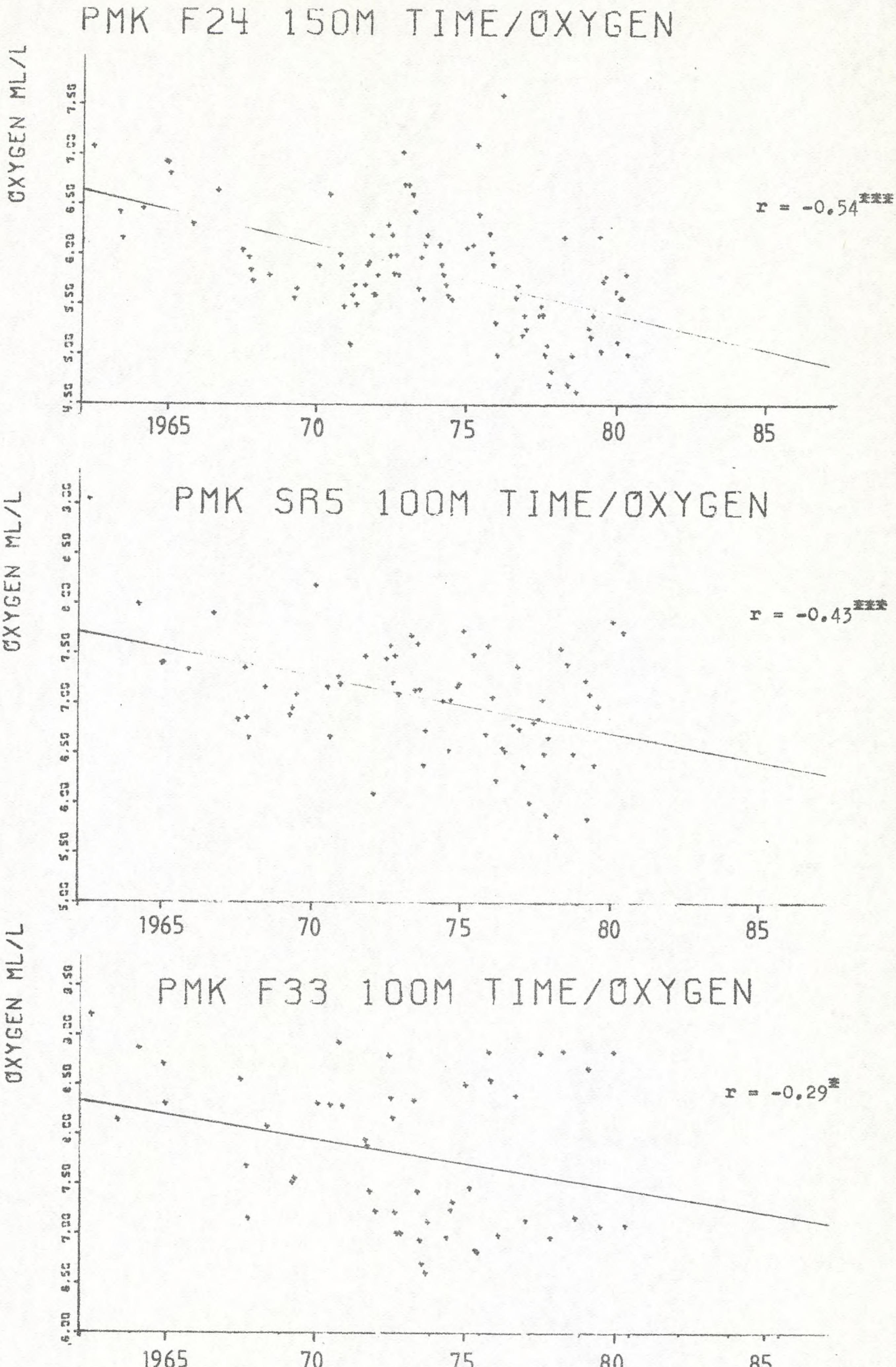

PMK F24 150M TIME/ØXYGEN
ØXYGEN ML/L
r = -0.54***
1965
70
75
80
85
PMK SR5 100M TIME/ØXYGEN
ØXYGEN ML/L
r = -0.43***
1965
70
75
80
85
PMK F33 100M TIME/ØXYGEN
ØXYGEN ML/L
r = -0.29*
1965
70
75
80
85

FIG. 9