Northwest Atlantic Fisheries Organization

Serial No. N307

NAFO SCR Doc. 81/VI/28

SCIENTIFIC COUNCIL MEETING - JUNE 1981

Forecasting inshore abundance of short-finned squid (*Illex illecebrosus*) at Newfoundland

by

E. G. Dawe, and G. V. Hurley[1]
Department of Fisheries and Oceans
Research and Resource Services
Newfoundland Region
P. O. Box 5667
St. John's, Newfoundland
A1C 5X1

Abstract

Set details were examined from spring research surveys directed for various groundfish species and squid on the Grand Bank since 1948. Relationships were found between squid catch rates and Grand Bank bottom temperatures.

Criteria were established for use of these data in establishing an index for forecasting inshore squid abundance. The southwest slope of the Grand Bank was identified as the most suitable area for such surveys. Sets conducted between mid-May to mid-July were selected for use in establishing a forecast index. However, based on the relationships between catch rate and bottom temperature, the last three weeks in June was identified as the optimal period for such future surveys.

The relationship between catch rates during surveys and estimates of inshore abundance is used to forecast inshore abundance in a qualitative sense. Relationships between inshore squid abundance and January sea surface temperature south of Newfoundland may be useful in providing an early indication of actual population abundance. Anomalously high numbers of icebergs south of latitude 48°N may reflect conditions unfavourable for inshore migration in some years.

---

[1] Present address: Bonavista Cold Storage Company, P. O. Box 1357, St. John's, Newfoundland, Canada A1C 5N5

Introduction

The short-finned squid (Illex illecebrosus) is a seasonal migrant to the Newfoundland area (NAFO Subarea 3). It has historically been captured incidentally during May-July groundfish surveys on the Grand Bank (Squires 1957) and between July and November it supports a substantial inshore fishery along the northeast and south coasts of Newfoundland (Hurley 1980a).

Longevity of this squid is believed to be between 9 and 24 months (Au, MS 1975; Efanov and Puzhokov, MS 1975; Mesnil, 1977; Squires, 1967). Environmental perturbations are likely to be of paramount importance in determining recruitment success for such a short-lived species. Because of this, and the fact that little is known of the early life history of the species, yearly variations in abundance cannot be predicted using conventional methods of biomass assessment. Thus, it was recommended that management for such a species should be based on determining pre-season levels of abundance which may later become available to inshore and offshore fisheries (ICNAF, 1978). Short-term forecasting has been successfully used in managing the fishery for the Japanese common squid (Todarodes pacificus), another member of the family Ommastrephidae (Kasahara, 1975).

The basis for such a forecast for short-finned squid is the observation of Squires (1957) that there is a relationship between incidental squid catches on the Grand Bank during May-June and later inshore abundance at Newfoundland. Hodder (1964) compared catch magnitude on the Grand Bank during May-June to a qualitative scale of yearly inshore squid abundance developed by Squires (1957). Based on this relationship and high squid catches during May-June on the Grand Bank he was able to successfully predict high inshore abundance of squid in 1964. Because of the usefulness of this relationship it was updated to 1965 (Squires, MS 1959; Mercer, MS 1966) from the original period (1946-52) considered by Squires (1957).

This paper provides a revision and a further updating of the relationship for the period 1966-80. The qualitative scale of inshore squid abundance is also updated for this period to provide an index of relative yearly abundance which can be compared with pre-season survey results. These estimates provide a more reliable index of yearly variations in inshore abundance than does catch magnitude, which has historically been influenced by existing market conditions (Hurley, MS 1980b).

Criteria are established for areal coverage and timing of pre-season surveys. These criteria are applied to survey data toward achieving compatability of historical and recent surveys and attaining a more reliable index for forecasting inshore squid abundance. The relationship of temperature with catch rate of Illex illecebrosus on the Grand Bank is examined and the dynamics of temperature effects on squid catch are considered in relation to the usefulness of the forecast index. Relationships between environmental parameters and inshore squid abundance are also examined and their significance in forecasting inshore abundance is discussed.

Materials and Methods

Information used to qualitatively describe yearly variations in inshore abundance of short-finned squid at Newfoundland was derived from several sources. For the years 1948-54 relative annual abundance was taken from Squires (1957). This was based on annual reports of the Research and Resource Services Branch of Department of Fisheries and Oceans, as well as newspaper comments as to general abundance or scarcity of squid in those years. Estimates of abundance for the years 1955-64 were obtained from Templeman (1966). Annual reports of Research and Resource Services provided general information for the years 1965-79. Additional information for some years was obtained from weekly reports of field officers of the Department of Fisheries and Oceans Inspection Branch (1968, 1969, 1972) and weekly reports of district offices of the Conservation and Protection Branch (1976-79). Staff of the Invertebrates Section of Research and Resource Services provided subjective information which was useful in ranking abundance for more recent years. Categories of inshore abundance levels were assigned numerical values ranging from 1 (very scarce) to 5 (very abundant), for use in statistical analysis.

Pre-season (May-July) catch rates and mean bottom temperatures on the Grand Bank were calculated using set details from surveys undertaken by Department of Fisheries and Oceans research and chartered fishing vessels since 1948. Earlier surveys conducted by the INVESTIGATOR II (1948-65) and A.T. CAMERON (1964-68, 1970, 1974-79) provided information on incidental catches of squid during regular groundfish surveys. These surveys, usually directed for haddock, were carried out along pre-established transects across the Grand Bank until 1968, after which they were terminated (Templeman et al. 1978). More recently, other types of groundfish surveys have provided information on incidental catches of squid. Surveys conducted using the vessels E.E. PRINCE (1971-72), NEWFOUNDLAND HAWK (1978) and ZAGREB (1979-80) were directed specifically for *Illex illecebrosus*.

Sea surface temperature isotherms for each of 1978 and 1979 cruise periods were redrawn from a corresponding weekly chart of sea surface temperatures distributed by Maritime Command Headquarters, Halifax, Nova Scotia. Yearly means of January sea surface temperature in the vicinity of the Gulf Stream were calculated from mid-monthly observations for selected stations, also provided by Maritime Command Headquarters (W.B. Bailey, pers. comm.).

Estimates of May-June iceberg numbers south of latitude 48°N were taken from Scobie (1975) for the period 1953-72. For the period 1973-80 estimates were taken from annual reports of the International Ice Patrol (Crowell, MS 1974; Ketchen and Jennings, MS 1977; Knutson and Neill, MS 1978; Super and Crowell, MS 1975; Super, Ketchen and Jennings, MS 1976; U.S. Coast Guard Commander, International Ice Patrol, MS 1979; MS 1980; MS 1981).

Catch rate during pre-season surveys is expressed as percent of total trawling time in which squid was caught (percent positive trawling time). This index is less variable than trawl catches expressed as number per unit time. Further, it was found to give better relationships with temperature and inshore squid abundance.

Since survey designs have varied greatly a standard area was selected to ensure compatability of historical and recent surveys (Fig. 1). This area was selected based on the relationship of squid distribution to temperature conditions on the Grand Bank. Mean bottom temperatures and catch rates were derived only from sets conducted within this area.

It was evident from examination of set details that catch rates calculated from data collected too early or late in the season were not related to bottom temperature or inshore squid abundance. Therefore it was arbitrarily decided to select only sets which were executed between May 15 and July 14. Also, since timing of surveys has varied historically, seasonal aspects of the relationship between catch rate and mean bottom temperature were investigated within the May 15-July 14 period. This period was arbitrarily divided into 8 intervals of approximately equal duration of 6 to 8 days each. The relationship of pre-season catch rate with corresponding mean bottom temperature was then investigated for each interval.

Time series survey data are incomplete since in some years surveys were not even in part conducted within the May 15-July 14 period and for many years no survey sets were executed during June 9-30. Individual sets were rejected if bottom temperature was not recorded.

Least squares regression was used to describe relationships between yearly means of Grand Bank catch rate and bottom temperature. Temperature was selected as the independent variable for all regressions. Statistical significance of relationships was determined by using the Students' t-test to test the correlation coefficient. The Kendall rank correlation coefficient was calculated to determine statistical significance for associations of January sea surface temperature or June 9-30 catch rates with estimates of inshore squid abundance. Relationships were accepted as being statistically significant based on the 0.05 probability level.

Results

Although there exists considerable yearly variation in temperature distribution on the Grand Bank, it is apparent that the area of the southwest slope of the Grand Bank and St. Pierre Bank is the most consistently suitable to squid habitation due to generally favourable temperature conditions (Hodder, 1964; Hurley, MS 1980b). For this reason this area was selected as the standard survey area (Fig. 1) and only sets conducted within this area were selected for further analysis in establishing and interpreting a predictive relationship.

Investigation of seasonality of the relationship between catch rate and bottom temperature shows that they are strongly related for most of the survey period (Fig. 2A-H). For the two time periods examined during May (Fig. 2A, B) the relationship was significant ($P < 0.05$) but relatively weak ($r = 0.59$ for May 15-22 and $r = 0.57$ for May 23-31). For these periods, in some years, there were no catches even when corresponding mean bottom temperatures exceeded 4°C.

Although this relationship is highly significant for the June 1-8 period ($P < 0.001$, Fig. 2C), no catches were experienced in the majority of years for which data are available. Catches did not occur when mean bottom temperatures were less than 3.0°C.

A strong direct relationship exists between catch rate and mean bottom temperature for the last three intervals in June (r ranging 0.71-0.82, Fig. 2D-F). Also, for these periods positive catch rates occurred in most years, even when mean bottom temperature was less than 3.0°C. The relationship between catch rate and mean bottom temperature for the June 9-30 period as a whole is presented in Fig. 3 ($P < 0.05$).

For the two intervals in July catch rates were not related to temperature (Fig. 2G-H, $P > 0.05$). For July 8-14, catch rate did not decline below 50% positive trawling time even at mean bottom temperatures of 3.0°C and lower (Fig. 2H).

The relationship between qualitative estimates of inshore squid abundance at Newfoundland and catch rates from June 9-30 survey sets is presented in Fig. 4. Although catch rates range considerably, especially for higher levels of inshore squid abundance, a direct relationship exists ($r = 0.53$, $P < 0.01$). For all years of abundant or very abundant inshore squid occurrence except 1960, June 9-30 catch rates exceeded 10% positive trawling time. Also, for moderate and scarce years, catch rates did not exceed 5% positive trawling time, with the exception of 1957. Low mean bottom temperatures were associated with low catch rates for these years, especially for 1957, 1959 and 1963 (Fig. 3).

Years of lowest inshore squid abundance (1972 and 1974) were associated with anomalously high June 9-30 catch rates (Fig. 4). Associated with poor relationships for these two years is record high number of icebergs drifting south of latitude 48°N during May-June (Fig. 5). In fact, five of the seven years of very scarce to moderate inshore abundance shown in Fig. 4 were associated with unusually high numbers of icebergs drifting south of latitude 48°N during May-June.

The relationship between 1962-80 inshore squid abundance and means of January sea-surface temperatures in the vicinity of the Gulf Stream (Fig. 6) is shown in Fig. 7. This relationship excluding anomalous 1972 and 1974 values, is highly significant ($P < 0.001$). This indicates a close direct relationship between January surface temperatures in this area and later inshore abundance of squid at Newfoundland. Surface temperature means for 1972 and 1974 are indicative of higher levels of inshore abundance than observed for those years, as were June 9-30 catch rates (Fig. 4). Thus, record high iceberg numbers are associated with anomalous years in the relationship of inshore squid abundance to January sea surface temperatures as well.

Discussion

Squid distribution on the Grand Bank during survey periods is related to the existance of favourable warm temperature conditions (Frost and Thompson, 1932; Hodder, 1964; Mercer, MS 1974; Mercer and Paulmier, MS 1974; Hurley, MS 1980b). Highest catches have historically occurred on the southwest slope of the Bank, associated with high bottom temperatures (greater than 5°C in 1978 and 1979) and steep surface isotherms (Hurley, MS 1980). Steep sea surface isotherms represent the boundary between the cold Labrador current and outreaches of the warm Gulf Stream. This mixture of water masses has been termed the Slope Water Current (Mann, 1967). Hurley, (MS 1980) has noted that surface features of currents in this part of the Grand Bank reflect flow patterns and temperature fields existing at greater depths. Yearly occurrence of squid on the southwest slope of the Grand Bank is related to development of favourable conditions in the area through seasonal variations in flow patterns of the related currents.

June 9-30 has been identified as the optimum time for pre-season surveys. During this period catch rates on the Grand Bank are closely related to mean bottom temperature and positive catch rates occur even in years of low temperatures. Relationships before the June 9-30 period are statistically significant but no catches occurred for the majority of years for which data are available. This, and the fact that catches often did not occur even in years of very high mean bottom temperature suggest that sets conducted before June 9 are too early for squid to have reached the survey area in some years. This could be due to yearly variations in the timing of spawning or incursion of warm water into the survey area. Survey sets conducted later than June 30 also appear unreliable. During July high catch rates occur independent of bottom temperature. High catch rates for all years during July 8-14 indicate that squid may concentrate in the survey area by this time, even in years of low abundance. Squires (1957) noted that yearly variation in late season catch rates was much lower than early season figures.

Catch rates in the survey area during June 9-30 are directly associated with levels of later inshore abundance. Although this relationship does not constitute a basis for prediction, it could serve to provide a general indication of inshore abundance from survey results. Catch rates during June 9-30 surveys may reflect yearly variation in population abundance. High catch rates associated with incursion of warm water on the southwest slope of the Grand Bank at this time may reflect earlier conditions which were favourable for spawning or survival of young stages. Variations in yearly estimates of inshore abundance may reflect fluctuations in actual population abundance or yearly variations in that portion of the population which becomes available to the inshore fishery. Hydrographic conditions on the Grand Bank have been cited as a possible factor affecting yearly variations in the extent of inshore migration (Ennis, MS 1978). Hodder (1964) noted that squid availability inshore in 1958 was low despite an apparent abundance of squid over oceanic depths in that year.

High catch rates and mean bottom temperatures for 1972 and 1974 are indicative of higher levels of abundance than were estimated for those years. Thus it is possible that population abundance was relatively high during these years but some over-riding factor restricted inshore migration. Record high May-June number of icebergs drifting south of latitude 48°N during these years may reflect unfavourable environmental conditions which prevented inshore migration. High iceberg number was associated with several other years of low inshore availability. Yearly fluctuations in number of icebergs probably indicate yearly variation in the pattern of Labrador Current flow (Scobie, 1975; Soule and Morse, 1958; Templeman et al., 1978). A greater number of icebergs south of latitude 48°N would be expected in years when the Labrador Current is cold and flowing strongly under the influence of northerly winds (Hurley, MS 1980b).

Mean January sea surface temperatures in the area south of Newfoundland in the general vicinity of the Gulf Stream-Slope water current seems also to reflect approximate yearly levels of population abundance. Young Illex have been captured in these water masses in winter-spring surveys as early as February (Fedulov and Froerman, MS 1980). Thus, January environmental conditions such as temperature in this area could have considerable direct effect on spawning success or survival of young stages.

As also indicated from June catch rates, mean January sea surface temperatures for 1972 and 1974 are indicative of higher levels of abundance than were observed inshore in those years. This further supports the theory that 1972 and 1974 were examples of years of relatively high population abundance with inshore migration restricted by unfavourable environmental conditions.

Acknowledgments

Our appreciation is extended to the many staff members of the Department of Fisheries and Oceans who participated in the surveys used in this study, especially Mr. P. Beck who helped to organize and participated in 1978, 1979 and 1980 surveys. Thanks are extended to Mr. G. King and Mr. H. Mullett who prepared the diagrams. Provision of sea surface temperature data by Mr. W. B. Bailey, Maritime Command Headquarters is acknowledged. Helpful comments and suggestions provided by Dr. G. H. Winters, Mr. V. M. Hodder, Mr. J. A. Moores, and Dr. G. R. Lilly were also appreciated. Our thanks also go to Mr. J. Drew who helped process the data and Mr. D. Stansbury who assisted with statistical analysis.

References

Au, D. MS 1975. Considerations on squid (Loligo and Illex) population and recommendations for rational exploitation. ICNAF Res. Doc. 75/61.

Crowell, Lt. D.W. MS 1974. Report of the International Ice Patrol Service in the North Atlantic Ocean. Season of 1973. CG-188-28, 42 + X p.

Efanov, V. M., and M. D. Puzhakov. MS 1975. Size composition, growth, mortality rate and condition of short-finned squid (Illex) stocks in west Atlantic. ICNAF Res. Doc. 75/58.

Ennis, G. P. MS 1978. A review of the fishery for squid and the general biological characteristics of the species, Illex illecebrosus, in the Newfoundland area. In. N. Blach, T. Amaratunga and R. K. O'Dor (Eds.). Proceedings of the Workshop on the Squid Illex illecebrosus. Fish and Mar. Serv. Tech. Rep. No. 833.

Fedulov, P. P., Yu. M. Froerman. MS 1980. Effect of abiotic factors on distribution of young shortfin squid, Illex illecebrosus (LeSueur, 1821). NAFO SCR Doc. 80/VI/98, Ser. No. N153, 22 p.

Frost, N., and H. Thompson. 1932. The squids. Ann. Rept. Nfld. Fish. Res. Comm., 1(4): 25-33.

Hodder, V. M. 1964. Prospects for the Newfoundland squid fishery in 1964. Fish. Canada, 17(1): 16-18.

Hurley, G. V. 1980a. Recent developments in the squid (Illex illecebrosus) fishery of Newfoundland, Canada. Mar. Fish. Rev. 42(7-8): 15-22.

MS 1980b. An examination of criteria for the short-term forecasting of inshore abundance of squid (Illex illecebrosus) at Newfoundland. NAFO SCR Doc. 80/II/5, Ser. No. N031, 18 p.

ICNAF. 1978. Report of Standing Committee on Research and Statistics (STACRES). Special Meeting on Squid, February 1978. ICNAF Redbook 1978: 21-33.

Kashara, S. 1975. Angling of Japanese common squid off Japan and the actual state of forecast about sea conditions for fishing. Prog. Rep. Squid Fish. Survey World (5): 101-111 (Trans. Fish. and Aquat. Sci. Canada No. 4564).

Ketchen, Lt. H. G., and M.S.T.I. C.W. Jennings. MS 1977. Report of the International Ice Patrol Service in the North Atlantic Ocean. Season of 1976. CG-188-31, 82 p.

Knutson, Lt. K.N., and Lt. T. J. Neill. MS 1978. Report of the International Ice Patrol Service in the North Atlantic Ocean. Season of 1977. CG-188-32, 44 + XXII p.

Mann, C. R. 1967. The termination of the Gulf Stream and the beginning of the North Atlantic Current. Deep Sea Res. 14: 337-59.

Mercer, M. C. MS 1966. Squid investigations. Fish. Res. Board Can. Biol. Sta. St. John's, Newfoundland Circ. 13: 42-48.

MS 1973. Distribution and biological characteristics of the ommastrephid squid Illex illecebrosus (LeSueur) on the Grand Bank, St. Pierre Bank and Nova Scotian Shelf (Subareas 3 and 4) as determined by otter-trawl surveys 1970-72. ICNAF Res. Doc. 73/79, Ser. No. 3031, 11 p.

Mercer, M. C., and G. Paulmier MS 1974. Distribution and biological characteristics of short-finned squid (Illex illecebrosus) on the continental shelf of Subareas 3 and 4 in May-June 1973. ICNAF Res. Doc. 74/87, Ser. No. 3323, 11 p.

Mesnil, B. 1977. Growth and life cycle of squid, Loligo pealei and Illex illecebrosus, from the Northwest Atlantic. ICNAF Sel. Pap. No. 2: 35-69.

Scobie, Lt. R. W. 1975. International Ice Patrol Operations 1972 - Why so many icebergs? ICNAF Spec. Publ. No. 10: 79-93.

Soule, F. M., and R. M. Morse. 1958. Physical oceanography of the Grand Bank region and the Labrador Sea in 1957. Report of the International Ice Observation and Ice Patrol Sevice in the North Atlantic Ocean - season of 1957. Bull. U.S. Cst. Guard, No. 43: 81-131.

Squires, H. J. 1957. Squid Illex illecebrosus (Lesueur) in the Newfoundland fishing area. J. Fish. Res. Board Can. 14(5): 693-728.

MS 1959. Squid inshore in Newfoundland and on the Grand Bank, 1953-58. Prog. Rep. Dept. Atlantic Coast Sta., Fish. Res. Board Can. 72: 23-26.

1967. Growth and hypothetical age of the Newfoundland bait squid, Illex illecebrosus illecebrosus. J. Fish. Res. Board Can., 24(26): 1209-1217.

Super, Cdr. A. D., and Lt. D. W. Crowell. MS 1975. Report of the International Ice Patrol Service in the North Atlantic Ocean. Season of 1974. CG-188-29, 62 p.

Super, Cdr. A. D., Lt. H. G. Ketchen and M.S.T.I. C. W. Jennings. MS 1976. Report of the International Ice Patrol Service in the North Atlantic Ocean. Season of 1975. CG-188-30, 77 p.

Templeman, W. 1966. Marine resources of Newfoundland. Bull. Fish. Res. Board Can., No. 154, 170 p.

Templeman, W., V. M. Hodder, and R. Wells. 1978. Age, growth, year-class strength and mortality of haddock, *Melanogrammus aeglefinus*, on the southern Grand Bank and their relation to the haddock fishery of this area. ICNAF Res. Bull. No. 13: 31-52.

U. S. Coast Guard Commander, International Ice Patrol. MS 1979. Report of the International Ice Patrol Service in the North Atlantic Ocean. Season of 1978. CG-188-33, 39 p.

MS 1980. Report of the International Ice Patrol Service in the North Atlantic Ocean. Season of 1979. CG-188-34, 29 + XXXIV p.

MS. 1981. Report of the International Ice Patrol Service in the North Atlantic Ocean. Season of 1980. CG-188-35, 39 p.

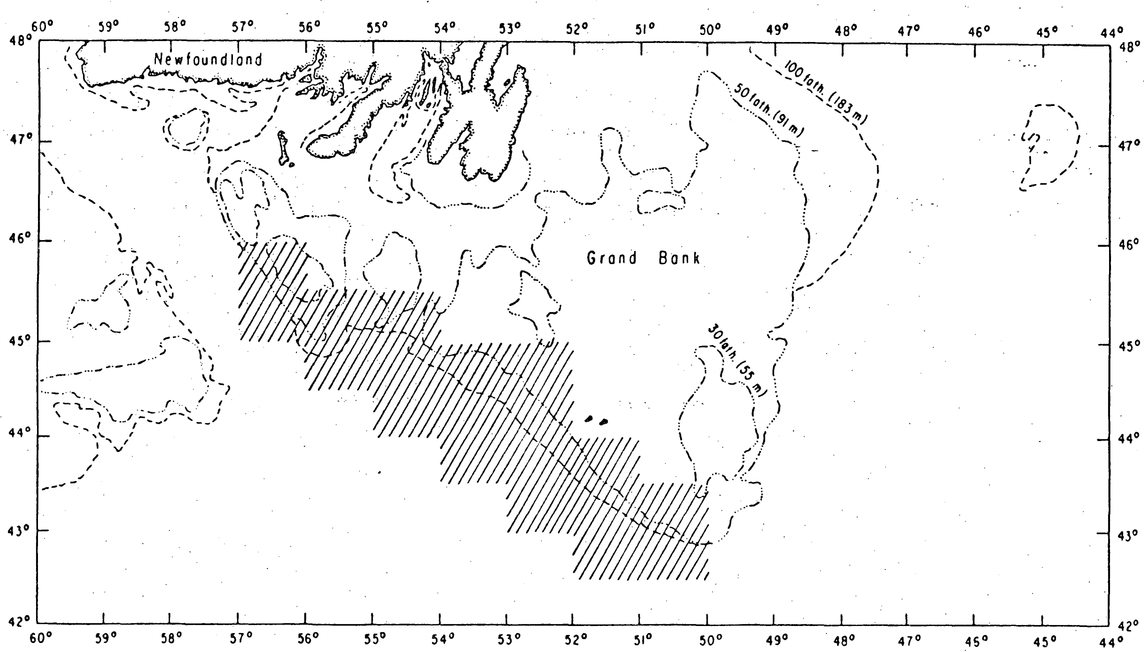

Fig. 1. Map showing survey area (shaded). Catch rates and mean bottom temperatures were derived only from sets conducted within this area.

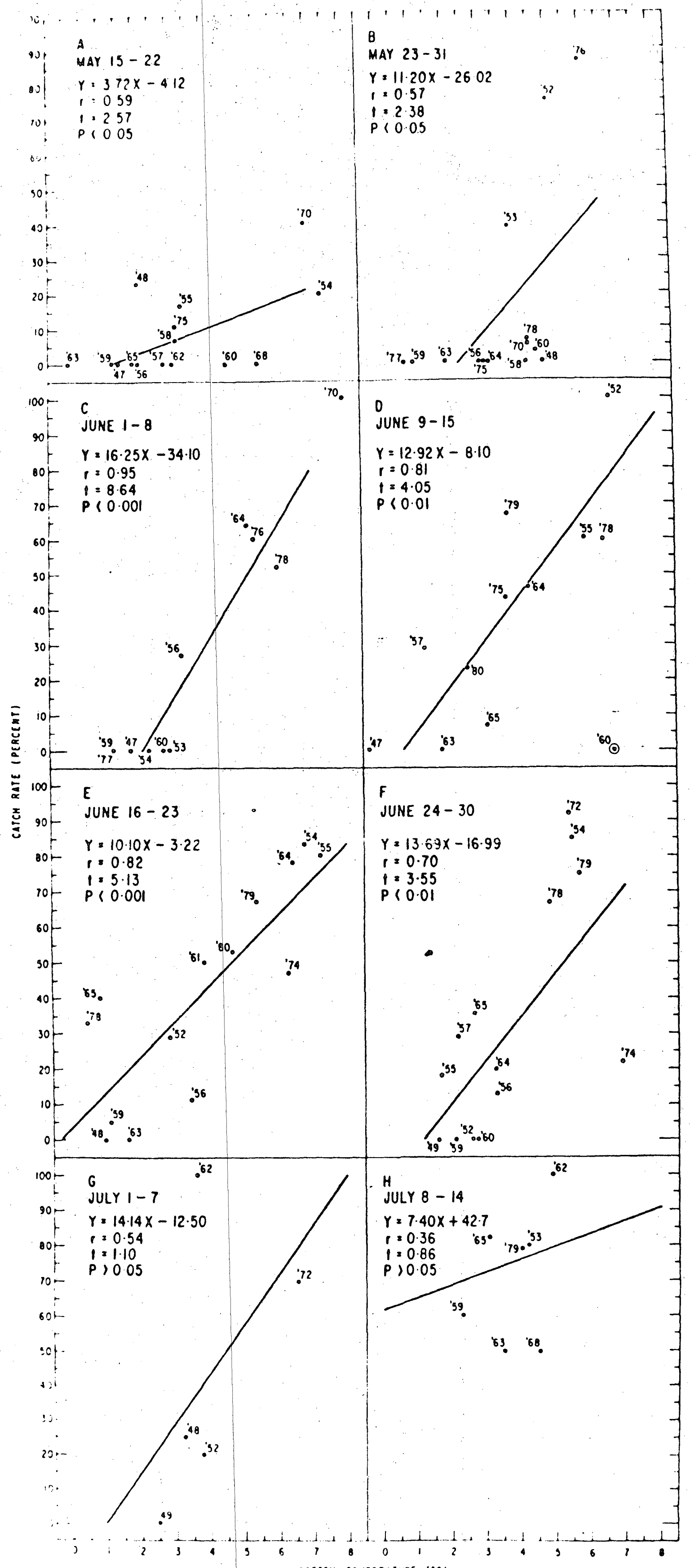

Fig. 2. Relationships between catch rate (percent positive trawling time) and mean bottom temperature for 6-8 day intervals within the May 15-July 14 survey period since 1948. (Anomalous 1960 value in Fig. 2D, based on only 4 sets, excluded from correlation analysis).

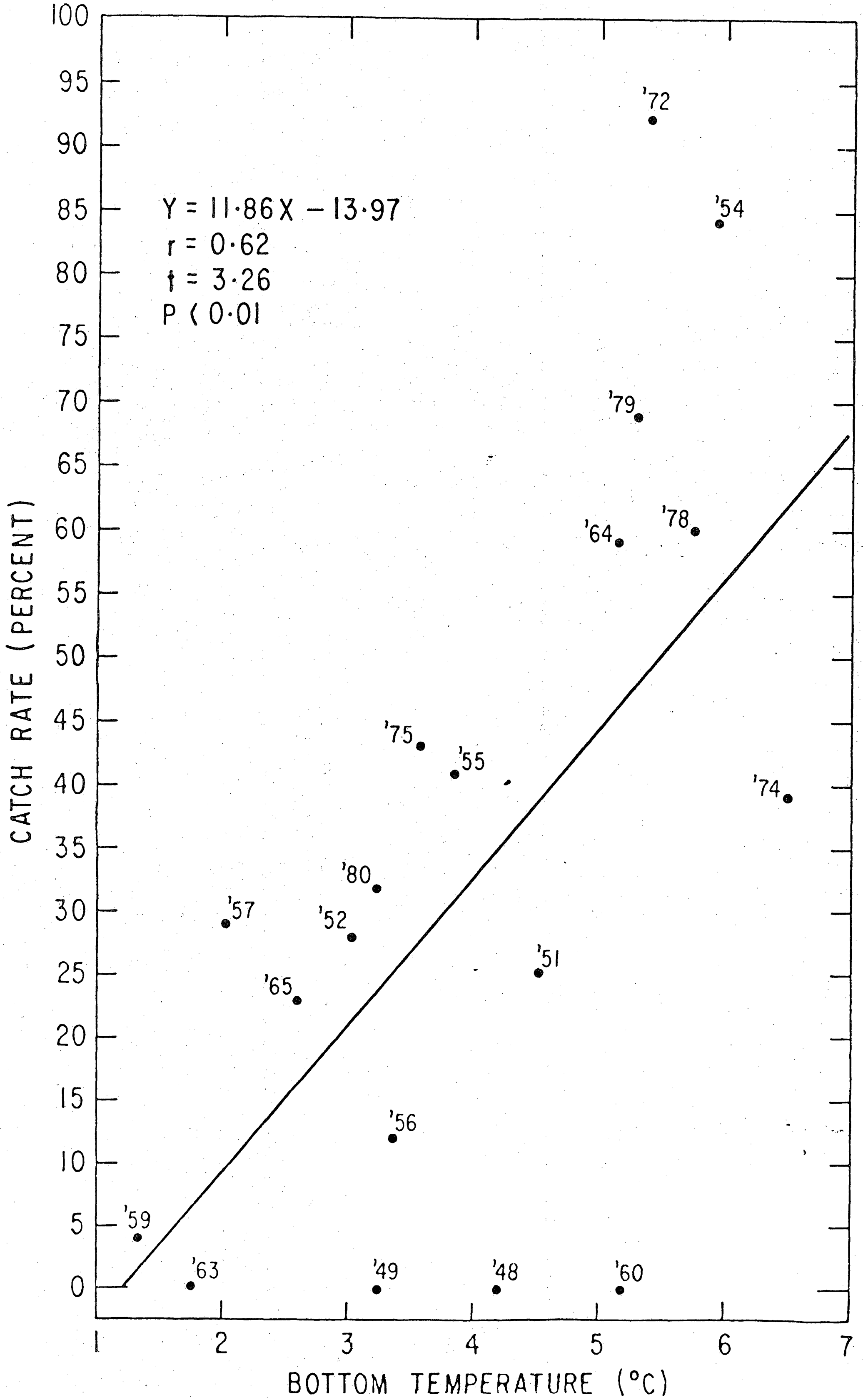

Fig. 3. Relationships between catch rate (percent positive trawling time) and mean bottom temperature from June 9-30 survey sets since 1948.

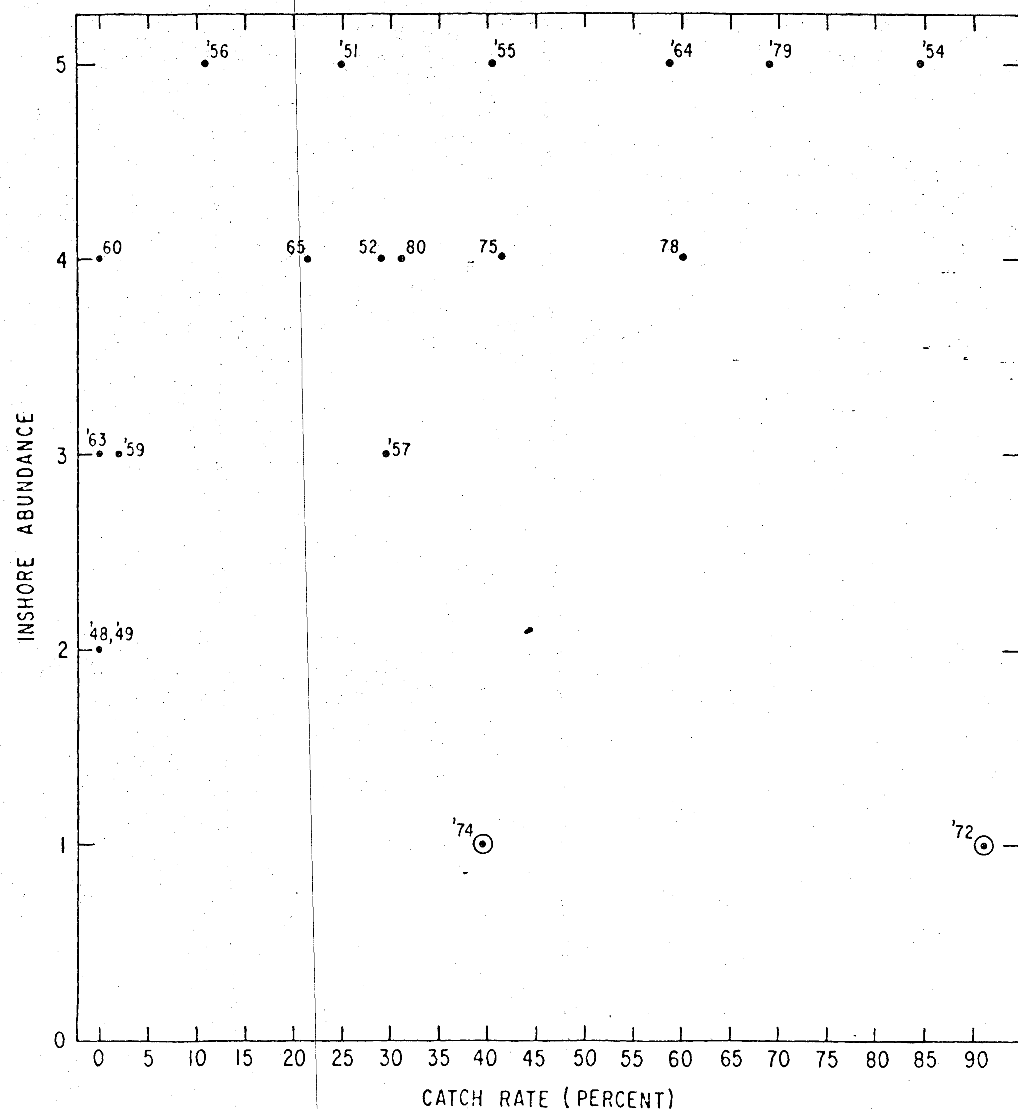

Fig. 4. Relationship between qualitative estimates of inshore squid abundance at Newfoundland and June 9-30 catch rates (percent positive trawling time) since 1948 (τ = 0.53, P < 0.01).

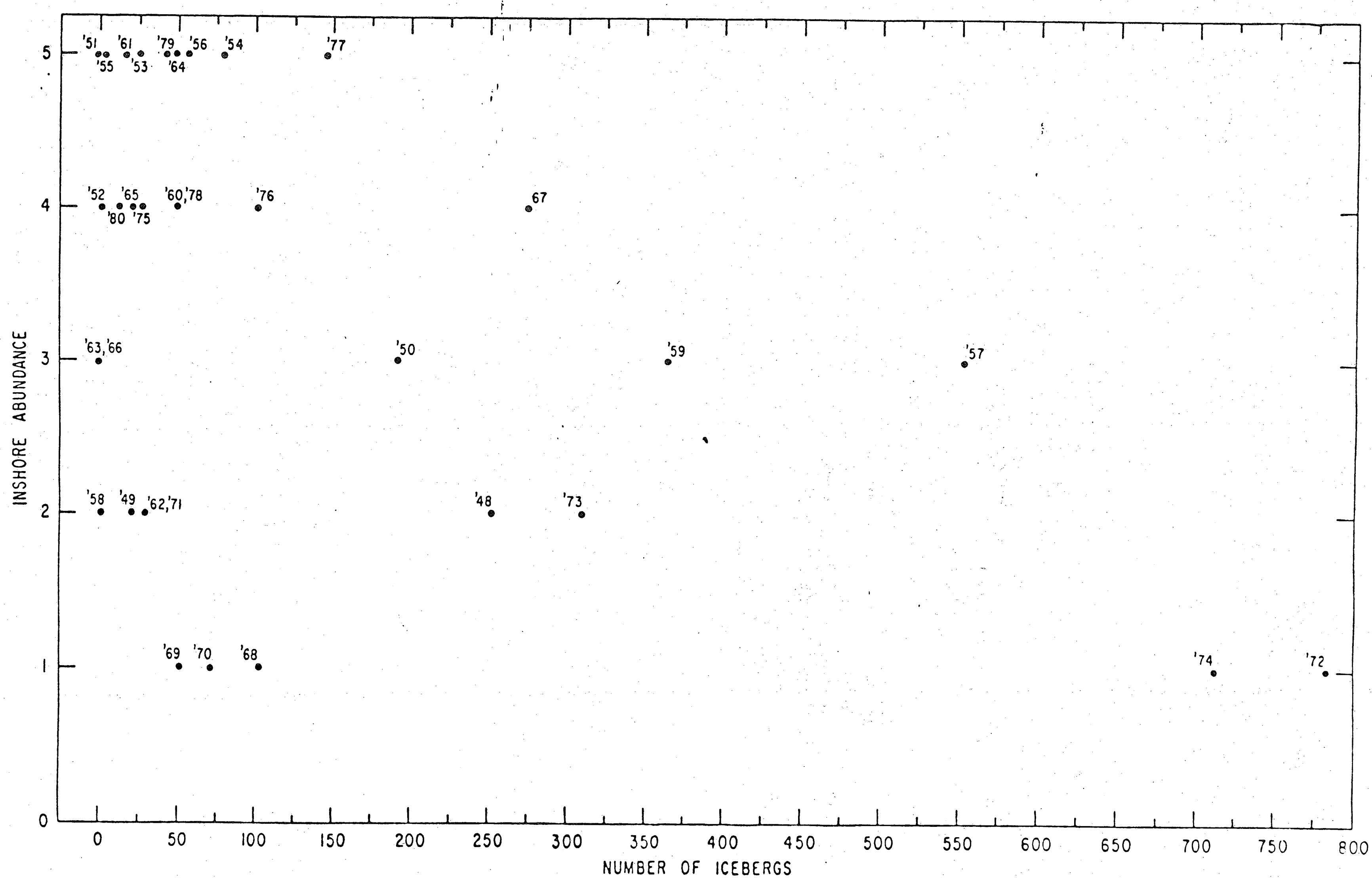

Fig. 5. Relationship between qualitative estimates of Newfoundland inshore squid abundance and number of icebergs south of latitude 48°N during May-June since 1948.

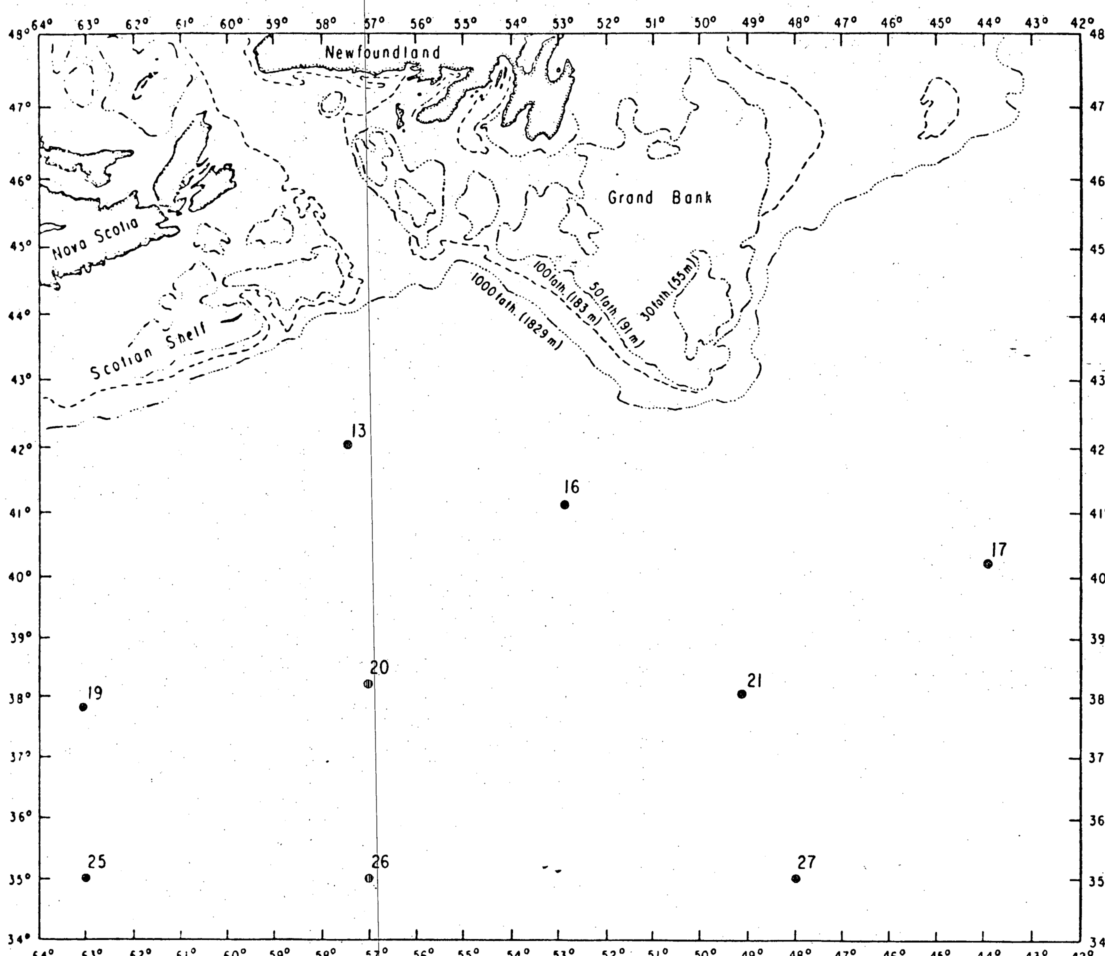

Fig. 6. Map showing location of stations from which 1962-80 January mean surface temperatures shown in Fig. 7 were derived.

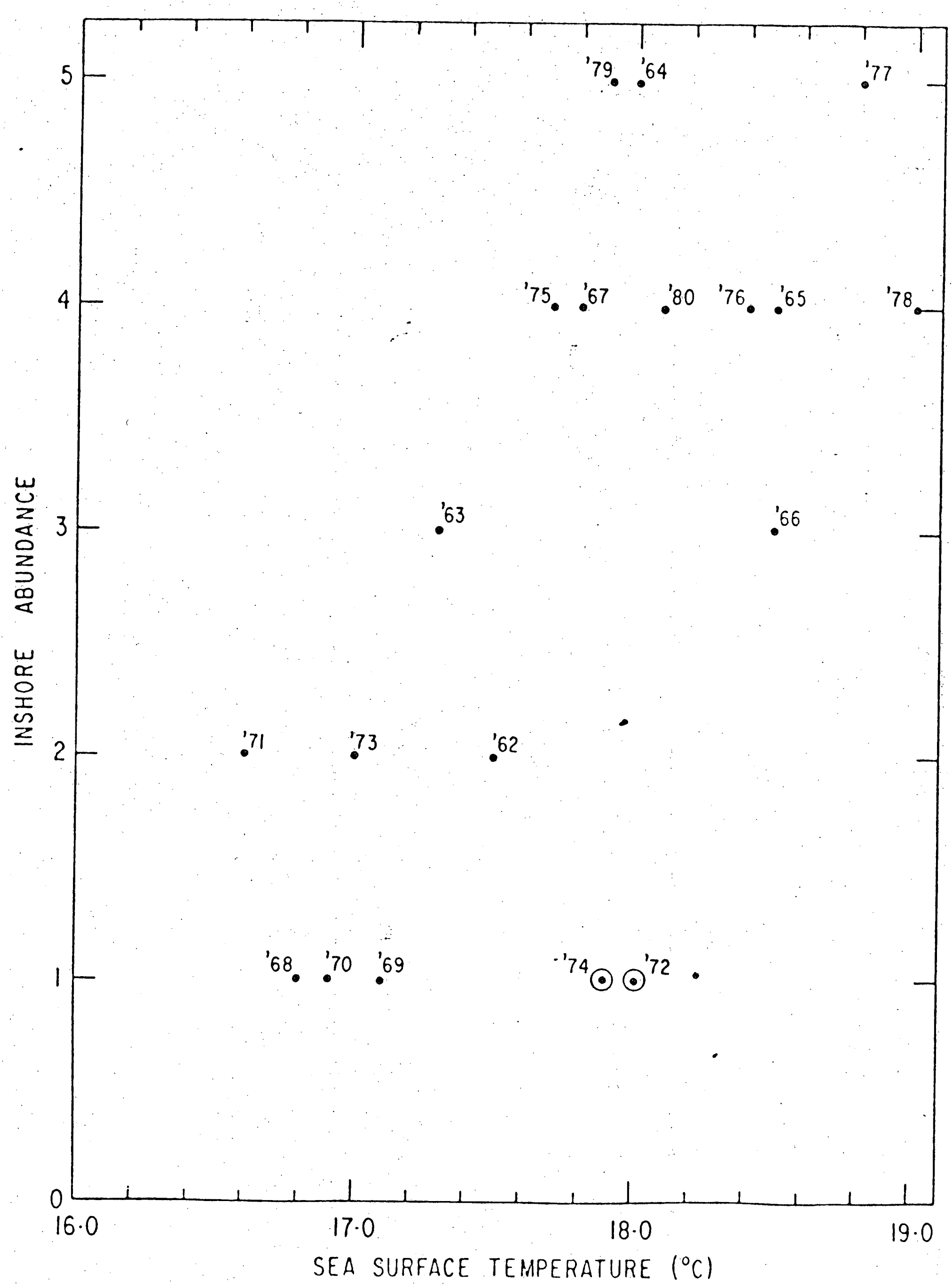

Fig. 7. Relationship between qualitative estimates of Newfoundland inshore squid abundance and means of January mid-monthly observations of sea surface temperature in the vicinity of the Gulf Stream-Slope water masses, 1962-1980 ($r = 0.46$, $P < 0.01$).