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Canadian Atlantic Fisheries Scientific Advisory Committee

Comité scientifique consultatif des pêches canadiennes dans l'Atlantique

CAFSAC Research Document 92/61

CSCPCA Document de recherche 92/61

Why Was Inshore Capelin (*Mallotus villosus*) Spawning Delayed During 1991?

by

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Abstract

The water temperatures in the Newfoundland-Labrador area during 1991 were anomalously cold and the spawning of capelin on Newfoundland east and northeast coast beaches was delayed one month. This paper explored the relationship between time of spawning and water temperature and mean size of fish in the population. There was a significant negative relationship between day of spawning, as measured by day of the year that 25,000 lb of cumulative catch was recorded in capelin trap nets, and May water temperatures, 0-20 m, at Station 27 (1983-91). There were no significant relationships between spawning time and January-April water temperatures. There was a significant negative relationship between spawning date and mean length of capelin. May temperature and length of fish as independent variables were entered into a stepwise multiple regression analysis with spawning date as the dependent variable. Temperature entered first and the two variables combined explained 87% of the variation in spawning date.

Based on this analysis, cold water temperatures and smaller mean size are related to later spawning. Clearly 1991 was an abnormal year; within the range of values in this analysis, the May temperature was as low as the lowest previous May temperature (1984), the time of spawning was the latest and mean length was the smallest.

Résumé

En 1991, les températures des eaux de la région de Terre-Neuve et du Labrador ont été anormalement froides et le frai du capelan sur les plages de l'est et du nord-est de Terre-Neuve s'est trouvé retardé d'un mois. Dans le présent document, on étudie le lien entre la période de frai et la température de l'eau ainsi que la taille moyenne des poissons de la population. Un rapport négatif important est établi entre le jour de frai, fixé au jour durant lequel les prises cumulatives des parcs à capelan ont atteint 25 000 lb, et les températures de l'eau en mai, à 0,20 m, à la station 27 (1983-1991). Aucun rapport négatif digne de considération n'apparait entre la date du frai et la longueur moyenne du capelan. Les températures en mai et la longueur du poisson ont été incluses, comme variables indépendantes, dans une analyse de régression multiple séquentielle, la date de frai constituant la variable dépendante. Le taux de 87 % de variation dans la date du frai s'explique par les températures introduites en premier et par les deux variables combinées.

En se fondant sur l'analyse en question, on peut établir un lien entre les basses températures de l'eau et la diminution de la taille moyenne des poissons. L'année 1991 apparait nettement anormale. Signalons que dans la gamme des valeurs servant à l'analyse, la température en mai équivalait à la plus basse des températures enregistrés antérieurement en mai (1984), et que la période de frai et la longueur moyenne étaient respectivement la plus tardive et la plus petite de toutes.

Introduction

Water temperature has often been cited as an important environmental variable affecting capelin (Mallotus villosus) biology. Temperature has been invoked to explain, for example, variations in growth and maturation rate (Winters and Campbell 1974), later than normal fishing seasons in 1984 and 1985 (Nakashima and Harnum 1985, 1986), final spawning location on the Southeast Shoal (Carscadden and Frank 1989), variations in survival during early life history stages and subsequent survival (Leggett et al. 1984), and migration patterns in the Barents Sea (Tjelmeland 1987).

The water temperatures in the Newfoundland-Labrador area during 1991 were anomalously cold (Narayanan et al. 1992) and the spawning of capelin on Newfoundland east and northeast coast beaches was delayed by up to one month (Nakashima and Slaney 1992). In this paper, we use exploratory correlation analysis to examine the hypothesis that the timing of capelin spawning is related to water temperatures during the months preceding spawning. Specifically cold temperatures would be expected to result in slower maturation and later spawning. We also explore the hypothesis that the timing of the spawning is affected by the size of the capelin in the spawning stock. Nakashima (1983) presented preliminary evidence that larger females spawn first during the spawning run. In this paper, we enlarge on this observation and test the hypothesis that the overall timing of spawning will be influenced by the size structure of the population. A spawning population composed of larger fish would be predicted to mature faster and spawn earlier than a population composed of smaller fish.

Data Sources

Water Temperature

We used mean monthly temperatures integrated over 0-20 m depth from Station 27 (47°32'50"N, 52°35'10"W), 3.7 km off Cape Spear near St. John's, Newfoundland.

Timing of Spawning

Two sources of data were available to indicate either spawning time or arrival of capelin near beaches. Observations on mean spawning time at Bryant's Cove, Conception Bay were made by personnel from McGill University from 1978 to 1988 (Table 1).

We also used data from trap nets in Conception and Trinity Bays, collected as part of the capelin logbook program. Initial selection was based on persistence of individual fishermen in the fishery over the longest possible period including fishing during 1991. Using this criteria we retained 9 fishermen, 5 from Conception Bay and 4 from Trinity Bay (Table 2) with a data series from 1983 to 1991. For each fisherman, we used the day of the year when 25,000 lb. of cumulative catch was recorded as indicative of arrival of capelin near the spawning beach. The mean dates for the traps and Bryant's Cove mean spawning dates were correlated ($r = 0.91$, $n = 6$).

Size Structure of Mature Population

Overall mean lengths derived from sampling of the catch of the commercial fishery inshore in Div. 3L were used as an indicator of the size structure of the population. Data from all gear components, beach seine, purse seine and trap were combined (Table 1).

Results

The relationships (Table 3) between trap catches and mean monthly temperatures indicated that the correlation coefficient was significant ($r = -0.82$, $n = 9$) only for May (Fig. 1). The 1991 value for trap catch is clearly unusual when compared to the previous year's values.

None of the relationships between commercial length and temperature were significant (Table 3). However, the relationship (Table 3) between trap catch and commercial length was significant ($r = -0.78$, $n = 9$) (Fig. 2).

Temperature and commercial length as independent variables were then entered into a stepwise multiple regression analysis with trap catch as the dependent variable. The May temperature entered first and the two variables combined explained 87% of the variation (Table 4). The overall relationship between temperature, length and day of year of trap catch is given in Figure 3.

Discussion

Based on these analyses, the arrival of capelin to the spawning beaches is related to water temperatures prior to spawning and size structure of the population. Cold water temperatures and smaller mean size are related to retardation in spawning. Clearly 1991 was an abnormal year; within the range of values in this analysis, the May temperature was as low as the lowest previous May temperature (1984), the time of spawning was the latest and mean length was the smallest.

The relationship between spawning time, water temperature and age structure has also been reported (Lambert 1987, Ware and Tanasichuk 1989) for herring, *Clupea harengus*, another demersal spawner. Herring stocks are characterized by several year-classes and repeat spawning, in contrast to capelin where few age-classes and minimal repeat spawning is the case. Thus, Lambert's (1987) argument that several age-classes maturing at different rates result in stability through the production of several cohorts of larvae may not be obviously applicable to capelin. However, Ware and Tanasichuk (1989) discuss timing of spawning in relation to egg and larval mortality and growth rate. Given the relationships between environment and survival of capelin eggs and larvae (Frank and Leggett 1981a, b) and subsequent recruitment (Leggett et al. 1984), the ability to account for variations in the timing of spawning may also be useful in explaining recruitment variation.

The results here are preliminary and other data sources can be explored. For example, being able to predict spawning time or at least arrival of capelin near shore, especially in unusual years, would be a distinct advantage to the fishery. Although the best correlation was with May temperature, a longer lead time would be more useful. Data from offshore acoustic surveys may also provide information on length composition that would be potentially useful for prediction of mean length of the mature population.

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Table 1. Capelin data used in analysis of spawning time variation. Trap and BC are day of the year values for trap catches and Bryant's Cove - see text for details. CL is mean length (mm) of capelin in commercial catch in Div. 3L.

Year	Trap	BC	CL
1978		167	
1979		159	
1980		176	160
1981		166	168
1982		180	178
1983	170.3	170	174
1984	179.6	182	177
1985	180.2	178	167
1986	168.5	169	172
1987	170.6	165	178
1988	171.2	169	175
1989	168.3		175
1990	173.1		173
1991	201.9		163

Table 2. Dates that catches of 25,000 lb of capelin reached in individual traps in Conception and Trinity Bays. Day of year and standard deviation in parenthesis.

	Conception Bay					Trinity Bay				
	F_1	F_2	F_3	F_4	F_5	F_6	F_7	F_8	F_9	
Year	Harbour Grace	Bristols Hope	Carbonear	Western Bay	Holyrood	Chance Cove	Heart's Cont.	Winterton	Dildo	Mean (SD)
1983	June 19 (170)	June 20 (171)	June 22 (173)	–	June 17 (168)	–	June 20 (171)	June 21 (172)	June 16 (167)	170.3 (2.13)
1984	27 (179)	July 1 (183)	30 (182)	June 21 (173)	July 3 (185)	June 25 (177)	24 (176)	25 (177)	July 2 (184)	179.6 (4.13)
1985	28 (179)	June 29 (180)	29 (180)	28 (179)	4 (185)	29 (180)	28 (179)	28 (179)	June 30 (181)	180.2 (1.92)
1986	19 (170)	–	16 (167)	16 (167)	June 21 (172)	19 (170)	18 (169)	17 (168)	14 (165)	168.5 (2.20)
1987	20 (171)	June 19 (170)	19 (170)	20 (171)	20 (171)	20 (171)	–	20 (171)	19 (170)	170.6 (0.52)
1988	23 (175)	23 (175)	18 (170)	20 (172)	21 (173)	16 (168)	19 (171)	17 (169)	16 (168)	171.2 (2.73)
1989	18 (169)	17 (168)	21 (172)	18 (169)	19 (170)	14 (165)	15 (166)	18 (169)	16 (167)	168.3 (2.12)
1990	24 (175)	21 (172)	25 (176)	21 (172)	23 (174)	22 (173)	21 (172)	21 (172)	21 (172)	173.1 (1.54)
1991	July 26 (207)	July 27 (208)	July 4 (185)	July 20 (201)	July 24 (205)	July 24 (205)	July 20 (201)	July 22 (203)	July 26*	201.9 (7.28)

* Trap put in, small catch and removed the next day. Not included in calculation.

Table 3. Correlation coefficients (r) for various relationships tested. Trap and CL as in Table 1 (*p $\leq$ .05, **p $\leq$ 0.01).

Mean temperatures during the month of	CL	Trap
January	-0.17	0.40
February	-0.26	-0.30
March	0.31	-0.43
April	0.06	-0.59
May	0.12	-0.82**
Trap	-0.78*	

Table 4. Statistics for stepwise multiple regression.

Maximum R-square Improvement for Dependent Variable TRAP

Step 1 Variable MAY Entered R-square = 0.66615450 C(p) =84629.04065?

	DF	Sum of Squares	Mean Square	F	Prob>F
Regression	1	606.22723975	606.22723975	13.97	0.0073
Error	7	303.81276025	43.40182289		
Total	8	910.04000000			

Variable	Parameter Estimate	Standard Error	Type II Sum of Squares	F	Prob>F
INTERCEP	184.26150263	3.12223534	151163.14412184	3482.88	0.0001
MAY	-7.61770649	2.03826430	606.22723975	13.97	0.0073

Bounds on condition number: 1.0000, 1.0000

The above model is the best 1 variables model found.

Step 2 Variable CL Entered R-square = 0.87498597 C(p) =31689.632754

	DF	Sum of Squares	Mean Square	F	Prob>F
Regression	2	796.27222805	398.13611403	21.00	0.0020
Error	6	113.76777195	18.96129532		
Total	8	910.04000000			

Variable	Parameter Estimate	Standard Error	Type II Sum of Squares	F	Prob>F
INTERCEP	377.83768975	61.17936169	723.21707915	38.14	0.0008
MAY	-5.44116558	1.51250602	245.39045386	12.94	0.0114
CL	-1.13482354	0.35845457	190.04498830	10.02	0.0194

Bounds on condition number: 1.2604, 5.0417

The above model is the best 2 variables model found.

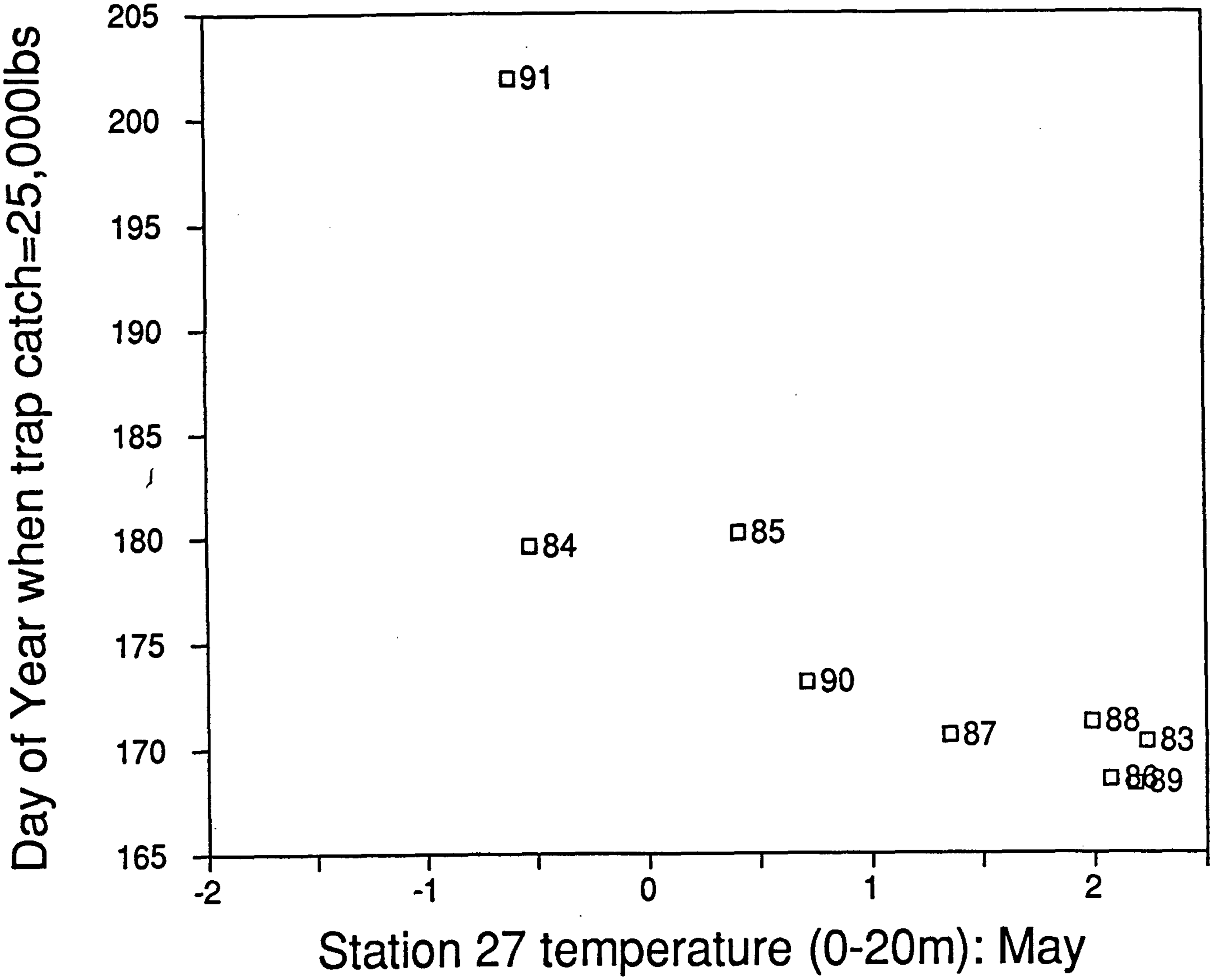

Fig. 1. Relationship between spawning time (day of year when trap catch = 25,000 lb) and May temperature, 0-20 m, at Station 27.

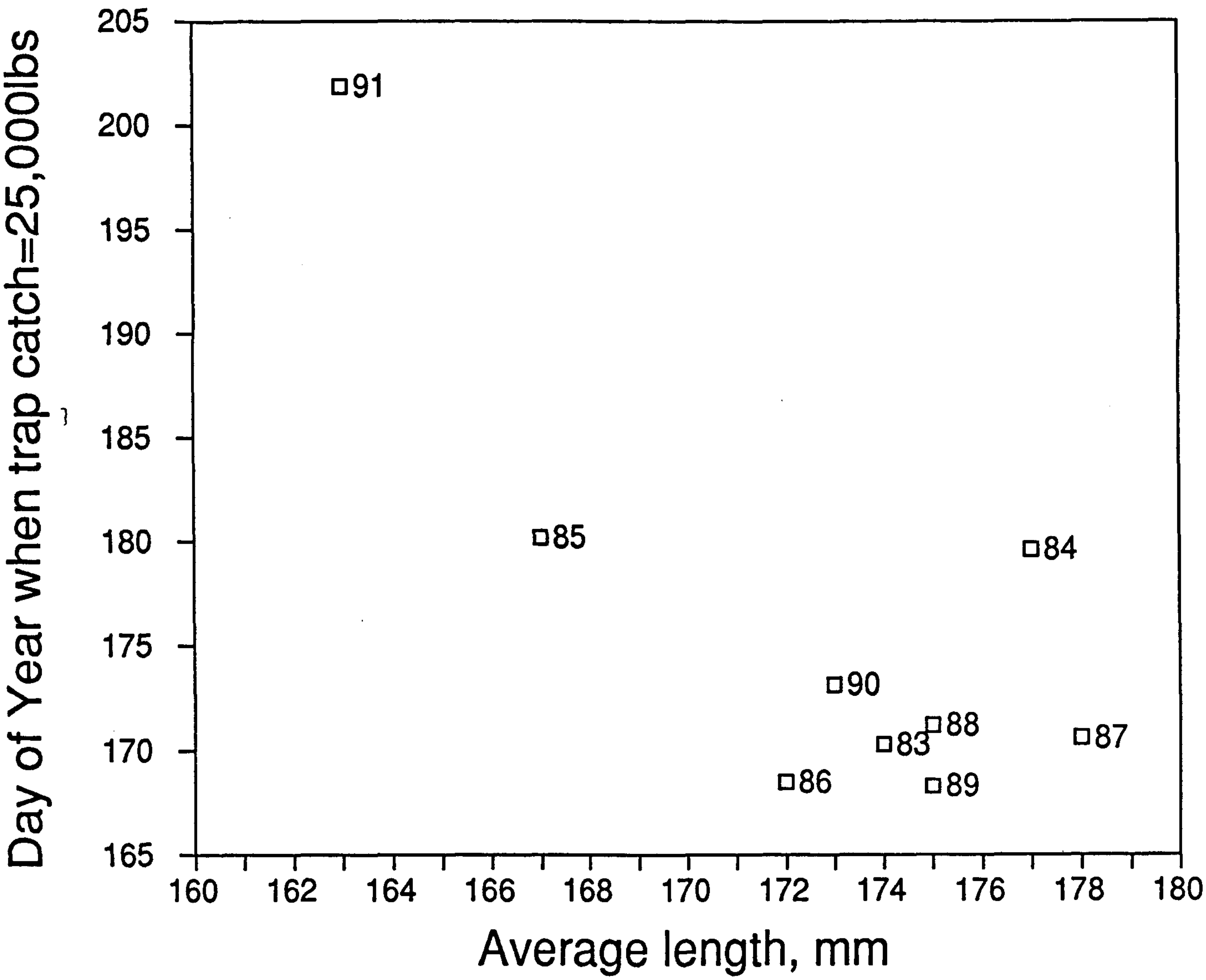

Fig. 2. Relationship between spawning time (day of year when trap catch = 25,000 lb) and average length (mm) of fish in the spawning population.

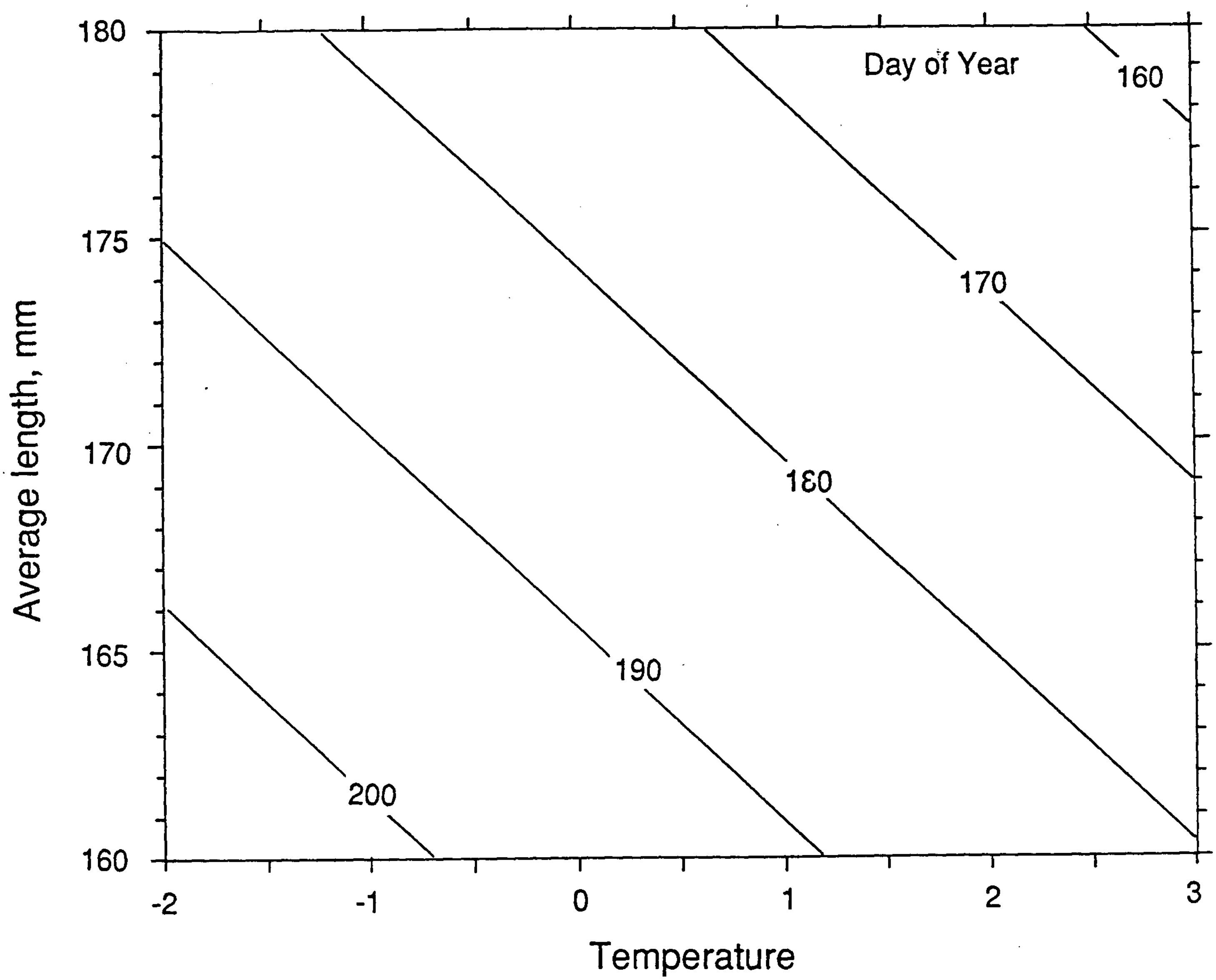

Fig. 3. Relationship between temperature, length and spawning data (day of the year when trap catch = 25,000 lb) from multiple regression relationships from Table 4.