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The Spawning Season of Pacific Cod on the West Coast of Canada

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ABSTRACT

Foucher, R. P., and S. J. Westrheim. 1990. The spawning season of Pacific cod on the west coast of Canada. Can. MS Rep. Fish. Aquat. Sci. 2072: 25 p.

The spawning season of Pacific cod in British Columbia is primarily January-March, based on 46,106 trawl-caught specimens sampled during 1976-85 at processing plants. Gonad development for both sexes was similar among four areas, but occurred later in the northernmost area (north Hecate Strait). Spawning was apparently determinate and essentially complete by May in north Hecate Strait, and by April elsewhere. Considerable variability was found among hauls and among years within months. A maximum likelihood technique used to fit a curve to the proportion spawned by day of year showed that there was no overlap among the four areas in parameters which describe the rate and timing of the point at which 50% had spawned. Elsewhere in the north Pacific Ocean, cod spawning was also determinate, the season was relatively short and only slightly later in the higher latitudes. In contrast, Atlantic cod are batch spawners, and the seasons are protracted in all areas.

RÉSUMÉ

Foucher, R. P., and S. J. Westrheim. 1990. The spawning season of Pacific cod on the west coast of Canada. Can. MS Rep. Fish. Aquat. Sci. 2072: 25 p.

En Colombie-Britannique, le frai de la morue du Pacifique a lieu principalement en janvier-mars, d'après l'examen dans les usines de transformation de 46 106 spécimens capturés au chalut entre 1976 et 1985. Le développement des gonades chez les sujets des deux sexes était semblable dans quatre régions, mais il était retardé dans la région située le plus au nord (partie nord du détroit d'Hécate). Apparemment, le frai est déterminé et essentiellement complet dès mai dans le partie nord du détroit d'Hécate et dès avril ailleurs. On a constaté de considérables variations d'un trait de chalut à l'autre et d'une année à l'autre, à des mois correspondants. Il a été établi grâce à une technique du maximum de vraisemblance pour l'ajustement d'une courbe à la proportion de sujets qui ont frayé un jour donné, qu'il n'y a pas de superposition des valeurs des paramètres mesurés dans les quatre régions, paramètres qui décrivent le taux et le moment où 50% des sujets ont frayé. Ailleurs dans le Pacifique nord, le frai de la morue est également déterminé et la saison est relativement courte et un peu retardée seulement aux latitudes supérieures. Par contraste, la morue de l'Atlantique fraie en mars et les saisons sont très courtes partout.

INTRODUCTION

The spawning season for Pacific cod (Gadus macrocephalus) off western Canada has been generally acknowledged to be January-March based on limited studies in the Strait of Georgia (Area 4B) (Ketchen 1961) and Hecate Strait (Areas 5C and 5D) (Thomson 1962) (Figure 1). The first systematic attempt at documentation began with field studies during 1975-76 (Westrheim 1977). These produced a seven-stage scale of gonad-condition criteria for each sex which was specifically designed for field work, at sea or dockside.

Available data have not previously been examined to determine the timing of spawning. Here we present results from the dockside sampling during 1976-85, and utilize a statistical procedure to describe and define the parameters associated with spawning. Timing and duration of spawning are compared with previous studies of Pacific cod in British Columbia and elsewhere, as well as with Atlantic cod (Gadus morhua).

MATERIALS AND METHODS

Materials used to determine the spawning season of Pacific cod in B.C. waters were based on samples collected in processing plants from 1976-85. All fish were trawl-caught, in areas 4B, 3C-N, 5C and 5D (Figure 1). Limited data were available during November-March from Areas 5A and 5B (Queen Charlotte Sound), because trawling is inhibited due to inclement weather and the lack of safe harbours near the trawling grounds. Cod production was negligible in Areas 3D and 5E, presumably due to unsatisfactory habitat--narrow and generally rock continental shelf. Canadian trawling effort was nil or negligible in areas south of 3C-N (3C-S is the U.S. portion of Area 3C) or north of 5E.

Within Area 5D (Figure 2), White Rocks-Bonilla Ground (hereafter referred to as White Rocks) is the predominant source of Pacific cod during January-March, but Two Peaks-Butterworth Ground (hereafter referred to as Two Peaks) accounted for as much as 20% in five years of the study period (Table 1) and therefore data were examined for each ground.

Gonad-condition criteria (Table 2) were developed in field studies conducted during April, July, and October 1975, and February 1976 in the areas which are the major sources of Pacific cod (3C-N and 5C/D) (Westrheim 1977). Data including length (fork length to the nearest centimeter), sex and gonad condition were collected from a stratified sample. This consisted of the first 10 specimens encountered per sex per selected 1-cm, length interval (17,20,23, etc.), except that all specimens greater than

71 cm were included. Maturity stages were assessed by macroscopic inspection of gonads.

Dockside sampling involved applying the criteria developed at sea to Pacific cod in samples routinely collected for size and sex ratio from all areas in British Columbia. Data were assembled by month and area and the incidences of gonad stages were calculated in percent. Spawning season was estimated by inspection of the relative incidences of the pre- and post-spawning stages.

To further define the duration of spawning time in each area, a maximum likelihood method (Welch and Foucher 1988) was used to fit an ogive to the plot of the proportion of stages 6 + 7 on day of year. The ogive formula was:

$$I(x_i) = 1/[1 + (a/x_i)e^{-bxi}],$$

where, $I(x_i)$ = proportion of gonad stages 6 + 7 on day i, and a and b are parameters of the ogive.

The ogive formula was used to estimate the day of year at which 50% and 90% of the fish had spawned.

Two interpretations of the uncertainty regions reported later are possible--the 95% confidence region and the 5% plausibility region. Welch and Foucher (1988) provided the following definition: "A 95% confidence region indicates that range of parameter values containing the true parameter values with 95% probability, given that H_o is true. In contrast, the 5% plausibility region indicates that region within which any individual parameter estimate has at least 5% of the maximum likelihood of representing the data." See Welch and Foucher (1988) for further details.

RESULTS

General

During 1976-85, gonad development was assessed for 46,106 Pacific cod (Table 3). Of these, 35,494 (18,285 males and 17,209 females) were mature (stages 3-7). Among areas, the number of mature cod was 5,390 in Area 4B, 9,657 in Area 3C-N, 6,291 in Area 5C and 14,156 in Area 5D. This study, involving numerous port samples taken in all seasons, has shown that spawning is confined to the winter period.

Trawlers generally followed the seasonal bathymetric movements of Pacific cod. They tended to concentrate their effort, and obtain the highest catch rates in areas where the fish might be more concentrated for feeding or spawning activity.

Spawning Season

Among months, years combined. Gonad development in both sexes was similar among areas, except that development was slightly slower, or more prolonged, in Area 5D (Table 3). For females, spawning was essentially complete by May (stages 6 + 7 = 97%) in Area 5D, and by April (92-100%) elsewhere. The one female recorded as being in stage 5 in August 1978 is unexplained. Based on the increases in proportion of stage 6 and 7 ovaries (Table 3), the principal spawning months were February-March in all areas with development starting earliest in Area 5C (Figure 3). The high proportion indicated as spawned in January in areas 4B and 3C-N is composed completely of stage 7 (resting) fish with none in stage 6. These are likely fish that were not yet showing observable development for the coming spawning period and should not be regarded as having spawned. Spawning is most prolonged in Area 5D where 20% had not yet spawned by April.

Among grounds in Hecate Strait, incidences of stages 6 + 7 were 85% for males and 83% for females on Two Peaks Ground, and 71% for males and 76% for females on White Rocks Ground in April (Table 4). In May, comparable values were 97 and 96% on Two Peaks Ground, and 100% for both sexes on White Rocks Ground. No appreciable difference was evident between the two grounds.

Based on the maximum likelihood estimates for females, the spawning season was later in Area 5D than in the other three areas (Figure 4, Table 5). The estimated day of year at which 50% of the female cod had completed spawning was 76 (March 17) for Area 5D, compared to 63 (March 4) for Area 4B, 68 (March 9) for Area 3C-N, and 58 (February 22) for Area 5C. Spawning duration was also longer in Area 5D. The estimated day of year at which 90% of females had spawned was 51 days after the day at which 50% had spawned in Area 5D, compared to 28 days for Area 5C, 33 days for Area 3C-N, and 22 days for Area 4B.

The plausibility regions are quite narrow in all cases (Figure 4). Furthermore, the among-area plot (Figure 5) of slope on day of year, for 50% completion of spawning, suggests that: (1) Area 4B has the shortest spawning season (steepest slope); (2) Area 5D has the longest spawning season (latest day of year at 50% completion, and shallowest slope); and (3) each area is unique with respect to the two variables (no overlap among plausibility regions).

Among years, within months. Gonad-condition within specific months varied among years (Table 6). For example, in

February, the incidence of stage-5 females ranged from 0 to 26% in Area 4B; 33-63% in Area 3C-N; 14-37% in Area 5C; and 7-50% in Area 5D. More detailed interannual comparisons were not possible, because of incomplete data.

Among hauls. Gonad condition, by ground, varied among research-vessel hauls from Area 3C-N during February-March 1978 (Harling et al. 1978). On Amphitrite Bank, the principal spawning ground in Area 3C-N, relatively large catch rates of cod (603-3794 fish/h) occurred for three hauls. For mature cod (stages 3-7), the incidence of condition 6 and 7 gonads, by sex, by haul, was:

		Males		Females	
Haul	Date	%	N	%	N
1	Feb 28	68	214	67	273
2	Feb 28	26	235	21	71
8	Mar 2	68	214	77	273

DISCUSSION

Pacific cod in northern Hecate Strait (Area 5D) spawn later than elsewhere in British Columbia waters. The earliest spawning is in southern Hecate Strait (Area 5C). The substantial difference between Areas 5C and 5D may reflect some degree of stock delineation within Hecate Strait. In the 1975-76 study in British Columbia, the principal month of spawning was estimated to be February off Southwest Vancouver Island, and March in Hecate Strait (Westrheim 1977). The among-year differences are of uncertain significance because of the degree of variation even among hauls in the same area and month.

The spawning season of Pacific cod in British Columbia waters is relatively short, principally February-March. Elsewhere in the North Pacific Ocean, spawning seasons are slightly later in the higher latitudes, and somewhat earlier in the lower latitudes off Asia (Table 7). Throughout the North Pacific Ocean, the spawning season occurs within the period December-May. In contrast, the Atlantic cod (Gadus morhua) exhibits a relatively prolonged spawning season, even within regions. In the Northeast sector the spawning season is February-September, while in the Northwest sector, the comparable time is February-December (Table 7). The probable reason for the difference is the fact that this species is a batch spawner (Sorokin 1957; May 1967). Kjesbu (1989) reported that individual tank-reared Atlantic cod spawned for about 50-60 days at intervals of 62-78 h. In contrast, local, unpublished studies of egg diameter-frequency distributions show Pacific cod to be a determinate spawner.

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Table 1. Canadian landings (t) of Pacific cod from Area 5D and selected grounds therein, January-March 1977-85.

Year	5D[a] (t)	Two Peaks[b] (t)	Two Peaks[b] (%)	White Rocks[b] (t)	White Rocks[b] (%)	TP + WR (%)
1977	260	64	24.6	150	57.7	82.3
1978	250	63	25.2	169	67.6	92.8
1979	413	45	10.9	362	87.7	98.6
1980	1,115	336	30.1	716	64.2	94.3
1981	510	71	13.9	308	60.4	74.3
1982	342	33	9.6	301	88.0	97.6
1983	736	89	12.1	564	76.6	88.7
1984	428	87	20.3	326	76.2	96.5
1985	365	133	36.4	228	62.5	98.9
Total	4,419	921	20.8	3,124	70.7	91.5

[a] From annual publications, beginning with Smith (1978) and ending with Leaman (1986).
[b] From Foucher (1987).
TP = Two Peaks = Two Peaks + Butterworth;
WR = White Rocks = White Rocks + Bonilla.

Table 2. Criteria for maturity condition of Pacific cod gonads. (Source: Westrheim 1977, Table 12)

Stage	Testis	Ovary
1. Immature	string-like, translucent	small, translucent
2. Maturing	small, some proportionally large convolutions, translucent to white	small, colouring
3. Mature	large, convolutions firm, whitening	large, opaque, creamy, blood
4. Mature	large, convoluted white	large, eggs visible, creamy yellow
5. Mature (ripe)	large, milt running, white	large, eggs translucent
6. Mature (spent)	medium, convolutions flaccid, bloodshot	medium, flaccid, bloodshot
7. Mature (resting)	small, convolutions firm, translucent red, or tan	small, firm, black or grey

Table 3. Mean percentage of gonad conditions, among months, years combined, for mature male and female Pacific cod landed from Areas 4B, 3C-N, 5C, and 5D, January-December 1976-85. (T = trace = <1%)

Month	Years[a]	Males 3	4	5	6	7	N[b]	Females 3	4	5	6	7	N[b]	Total N[b]
Area 4B														
Jan	6	12	75	0	0	13	478	48	30	T	0	21	323	801
Feb	5	2	67	14	8	9	816	10	59	9	8	15	875	1,691
Mar	3	2	9	12	65	14	774	0	12	10	61	18	814	1,588
Apr	2	1	0	1	30	69	137	0	0	0	1	99	93	230
May	0	-	-	-	-	-	-	-	-	-	-	-	-	0
Jun	0	-	-	-	-	-	-	-	-	-	-	-	-	0
Jul	0	-	-	-	-	-	-	-	-	-	-	-	-	0
Aug	1	0	0	0	0	100	57	0	0	2	0	98	58	115
Sep	2	0	0	0	0	100	78	0	0	0	0	100	101	179
Oct	4	4	0	0	0	96	113	0	0	0	0	100	98	211
Nov	5	64	2	0	0	34	157	6	1	0	0	93	192	349
Dec	5	59	9	0	0	32	141	18	1	1	0	80	85	226
Total							2,751						2,639	5,390
Area 3C-N														
Jan	1	5	57	18	9	11	163	15	28	33	0	24	136	299
Feb	5	2	26	53	18	1	2,260	1	33	41	20	4	1,688	3,948
Mar	4	0	7	46	45	2	2,159	1	24	33	41	1	1,494	3,653
Apr	7	0	1	3	19	78	707	0	2	1	12	85	617	1,324
May	2	0	2	2	10	87	162	0	0	0	0	100	155	317
Jun	0	-	-	-	-	-	-	-	-	-	-	-	-	0
Jul	0	-	-	-	-	-	-	-	-	-	-	-	-	0
Aug	0	-	-	-	-	-	-	-	-	-	-	-	-	0
Sep	0	-	-	-	-	-	-	-	-	-	-	-	-	0
Oct	1	0	0	0	0	100	15	0	0	0	0	100	26	41
Nov	1	80	17	0	0	3	35	28	3	0	0	70	40	75
Dec	0	-	-	-	-	-	-	-	-	-	-	-	-	0
Total							5,501						4,156	9,657

[a] numbers of years of sampling.
[b] numbers of specimens examined.

Table 3. (Continued).

Month	Years[a]	Males 3	4	5	6	7	N[b]	Females 3	4	5	6	7	N[b]	Total N[b]
							Area 5C							
Jan	4	8	89	2	T	1	479	18	34	42	3	5	390	869
Feb	5	4	52	16	17	12	663	5	36	22	19	19	734	1,397
Mar	2	0	18	9	47	26	191	0	6	19	20	55	251	442
Apr	5	T	4	4	18	75	804	0	5	4	16	76	769	1,573
May	3	0	T	0	5	95	260	0	1	1	1	98	242	502
Jun	3	0	0	T	T	99	244	0	0	T	0	100	292	536
Jul	2	0	0	0	T	100	205	0	0	0	0	100	173	378
Aug	1	0	0	0	2	98	54	0	0	0	0	100	46	100
Sep	1	0	0	0	0	100	119	6	0	0	0	94	81	200
Oct	1	0	0	0	0	100	38	0	0	0	0	100	35	73
Nov	1	79	11	0	0	9	53	95	0	0	0	5	61	114
Dec	1	60	35	0	0	5	43	89	0	0	3	8	64	107
Total							3,153						3,138	6,291
							Area 5D							
Jan	4	17	75	3	0	6	493	39	45	7	1	8	664	1,157
Feb	7	3	67	18	7	6	1,283	12	47	24	10	7	1,314	2,597
Mar	3	T	43	10	23	24	980	3	24	23	26	24	1,011	1,991
Apr	6	0	8	14	22	56	1,536	T	9	11	18	62	1,591	3,127
May	6	0	1	3	17	79	524	T	2	1	21	76	517	1,041
Jun	3	0	0	1	2	97	224	0	1	0	1	98	231	455
Jul	3	T	0	0	T	99	374	0	0	0	0	100	378	752
Aug	2	0	0	1	1	99	254	0	0	0	0	100	249	503
Sep	3	5	0	0	0	95	450	23	0	0	0	77	481	931
Oct	1	12	0	0	0	88	58	35	0	0	0	65	55	113
Nov	4	70	7	0	0	23	511	73	0	0	0	27	601	1,112
Dec	3	68	15	0	0	18	193	64	8	0	0	28	184	377
Total							6,880						7,276	14,156
Grand total							18,285						17,209	35,494

Table 4. Mean percentage of gonad conditions, among months, years combined, for mature male and female Pacific cod landed from Two Peaks and White Rocks grounds, January-December 1977-85. (T = trace = <1%)

Month	Years[a]	Male 3	4	5	6	7	N[b]	Female 3	4	5	6	7	N[b]	Total N[b]
Two Peaks Ground														
Jan	1	12	88	0	0	0	34	11	55	3	0	32	38	72
Feb	4	1	79	5	10	5	312	0	46	38	9	7	291	603
Mar	1	0	39	7	29	25	75	0	43	2	33	23	61	136
Apr	3	0	10	5	1	84	602	0	3	14	2	81	745	1,347
May	5	0	1	2	25	72	327	T	3	1	26	70	329	656
Jun	3	0	0	1	2	97	224	0	1	0	1	98	231	455
Jul	3	1	0	0	T	99	272	0	0	0	0	100	248	520
Aug	2	0	0	T	1	99	198	0	0	0	0	100	192	390
Sep	3	1	0	0	0	99	337	20	0	0	0	80	363	700
Oct	0	-	-	-	-	-	-	-	-	-	-	-	-	-
Nov	0	-	-	-	-	-	-	-	-	-	-	-	-	-
Dec	0	-	-	-	-	-	-	-	-	-	-	-	-	-
White Rocks Ground														
Jan	4	17	74	2	0	7	859	41	45	7	1	7	626	1,485
Feb	6	3	66	18	6	6	915	15	47	20	11	7	978	1,893
Mar	3	T	47	10	19	24	795	4	22	25	23	25	863	1,658
Apr	5	T	12	17	31	40	415	0	18	6	24	52	421	836
May	1	0	0	0	4	96	45	0	0	0	0	100	65	110
Jun	0	-	-	-	-	-	-	-	-	-	-	-	-	0
Jul	1	0	0	0	0	100	102	0	0	0	0	100	130	232
Aug	1	0	0	0	0	100	56	0	0	0	0	100	57	113
Sep	2	18	0	0	0	82	113	34	0	0	0	66	118	231
Oct	1	12	0	0	0	88	58	35	0	0	0	65	55	113
Nov	4	74	4	0	0	22	411	73	0	0	0	27	601	1,012
Dec	3	68	15	0	0	18	193	64	8	0	0	28	184	377

[a] Numbers of years of sampling.
[b] Numbers of specimens examined.

Table 5. Maximum-likelihood estimates for day of year at which spawning is 50% and 90% complete for Pacific cod in Areas 4B, 3C-N, 5C, and 5D, 1977-85.

Area	N[a]	Day of year at: 50% complete	90% complete	-ln(L)[b]
4B	9,143	63	85	866
3C-N	10,764	68	101	2125
5C	7,405	58	96	921
5D	20,008	76	127	2376
Total	47,320			

[a] Number of specimens examined.
[b] Value of the likelihood function at maximum.

Table 6. Percentage of gonad conditions, by area, by selected months, by year, for mature male and female Pacific cod, 1977-85.

Month	Year	Male 3	4	5	6	7	N[a]	Female 3	4	5	6	7	N[a]	Total N[a]
							Area 4B							
Jan	1978	14	84	0	0	1	206	34	57	0	0	9	120	326
	1979	22	74	0	0	4	23	57	7	0	0	36	14	37
	1980	12	52	0	0	35	113	40	14	0	0	45	99	212
	1981	0	92	0	0	8	13	50	0	0	0	50	8	21
	1982	5	81	0	0	15	108	76	20	1	0	3	71	179
	1983	33	60	0	0	7	15	82	0	0	0	18	11	26
Feb	1977	1	14	84	1	0	87	5	65	26	4	0	81	168
	1978	5	74	10	5	6	132	12	70	2	3	13	162	294
	1979	1	66	5	14	15	392	2	53	10	14	22	419	811
	1980	0	82	7	5	5	112	11	66	9	5	10	128	240
	1985	2	94	2	0	2	93	48	47	0	0	5	85	178
Nov	1977	97	0	0	0	3	36	5	0	0	0	95	19	55
	1978	81	6	0	0	13	48	7	0	0	0	93	74	122
	1979	41	0	0	0	59	46	9	0	0	0	91	58	104
	1981	50	8	0	0	42	12	0	0	0	0	100	7	19
	1982	7	0	0	0	93	15	3	3	0	0	94	34	49
Dec	1978	68	32	0	0	0	37	92	8	0	0	0	12	39
	1979	34	0	0	0	66	50	4	0	0	0	96	46	96
	1980	58	4	0	0	38	26	0	0	0	0	100	13	39
	1981	91	0	0	0	9	23	40	0	0	0	60	5	28
	1982	100	0	0	0	0	5	0	0	11	0	89	9	14
							Area 3C-N							
Feb	1977	0	9	77	14	0	592	0	40	37	23	0	575	1,167
	1978	0	28	49	20	2	967	0	35	41	16	8	675	1,642
	1982	3	39	39	18	1	272	4	18	50	27	2	288	560
	1983	10	41	29	19	2	281	3	43	33	18	3	98	379
	1984	1	24	47	24	3	148	0	8	63	13	15	52	200
Apr	1977	0	0	9	91	0	78	0	11	2	87	0	84	162
	1978	0	0	0	16	84	58	0	0	0	0	100	47	105
	1979	0	0	0	6	94	50	0	2	0	2	97	59	109
	1980	0	9	2	0	89	47	0	0	14	0	86	28	75
	1981	0	0	0	16	84	62	0	0	0	0	100	42	104
	1982	0	1	4	3	92	119	0	1	2	0	97	106	225
	1985	0	0	3	12	85	293	0	0	0	0	100	251	544

[a] Number of specimens examined.

Table 6. (Continued).

Month	Year	Male						Female						Total
		3	4	5	6	7	N[a]	3	4	5	6	7	N[a]	N[a]
							Area 5C							
Feb	1978	19	16	35	28	1	99	5	20	37	24	15	117	216
	1979	2	52	21	13	12	163	1	45	19	33	3	194	357
	1980	1	58	19	8	15	113	3	49	14	5	29	116	229
	1982	0	87	10	2	2	120	9	64	22	2	2	95	215
	1983	2	45	1	30	22	168	8	16	22	17	38	212	380
Apr	1977	0	0	15	85	0	59	0	13	9	79	0	56	115
	1978	1	2	7	13	78	196	0	7	4	6	83	168	364
	1980	0	4	2	14	80	373	0	4	2	19	74	337	710
	1982	1	0	2	5	92	86	0	1	0	1	98	98	184
	1983	0	12	0	12	76	90	0	3	9	0	88	110	200
							Area 5D							
Feb	1978	4	56	15	20	4	91	31	30	14	18	7	102	193
	1979	2	46	35	12	5	155	6	66	10	17	1	166	321
	1980	1	76	14	5	5	371	3	79	7	6	6	348	719
	1982	7	68	4	0	21	85	45	36	7	4	8	74	159
	1983	1	80	3	11	5	298	14	13	50	15	9	363	661
	1985	8	68	18	0	6	227	10	47	31	2	9	216	443
Apr	1977	0	3	40	54	4	219	0	31	11	53	4	166	385
	1978	0	6	6	31	57	202	2	8	3	19	69	178	380
	1979	0	17	11	19	52	150	0	15	3	28	55	195	345
	1980	0	1	11	5	82	74	0	10	5	5	80	99	173
	1983	0	10	7	6	78	768	0	4	14	6	76	877	1,645
May	1977	0	0	8	92	0	37	2	14	0	76	8	51	88
	1978	0	2	2	19	77	115	0	2	2	27	69	130	245
	1979	0	1	0	0	99	101	0	0	0	1	99	106	207
	1980	0	1	0	12	87	132	0	1	0	26	73	89	221
	1981	0	2	0	29	69	49	0	0	0	0	100	57	106
	1983	0	0	10	6	84	90	0	0	4	11	86	84	174

Table 7. Spawning times, by location, for Pacific and Atlantic cod.

Location	Time	Source
	Northeast Pacific Ocean	
Juan de Fuca Strait (Area 4A)	Jan-Mar	Karp (1982)
Georgia Strait & Juan de Fuca Strait (Area 4B)	Feb-Mar	This paper
S.W. Vancouver Is. (Area 3C-N)	ca. Feb Feb-Mar	Westrheim (1977) This paper
Hecate Strait (Areas 5C+5D)	ca. Mar Feb-Mar	Westrheim (1977) This paper
Gulf of Alaska	Feb-Apr	Hirschberger & Smith (1983)
N. Bering Sea	Jan-Mar	Svetovidov (1949)[a]
	Northwest Pacific Ocean	
Gulf of Anadyr	? -Apr	Moiseev (1953)
Olyutorskii Bay	? -May	
Kronotskii Gulf	Jan-Mar	
Komandorski Islands	Jan-May	
S.E. Kamchatka	Mar-May	
W. Kamchatka	Mar-May	
Peter-the-Great Bay	Feb-Apr	
W. Sakhalin	Jan-Mar	
Japan[b]	Dec-Mar	Mishima (1984)
S.E. Korea	Dec-Jan	Moiseev (1953)

[a] Cited by Musienko (1970).
[b] Includes Hokkaido, and East and West Honshu north of about 36° N. latitude.

Table 7. (Continued).

Location	Time	Source
	Northeast Atlantic Ocean	
European waters	Feb-Sep	Hardy (1978)
	Northwest Atlantic Ocean	
Labrador	May-Nov	Hardy (1978)
Newfoundland	Mar-Aug	
Gulf of St. Lawrence	May-Nov	
Nova Scotia	Mar, Jun-Dec	
Bay of Fundy	Jan-May, Nov	
"Canadian coast"	Feb-Dec	Scott & Scott (1988)
Gulf of Maine	Nov-Apr	Hardy (1978)
"New England coast"	Jul-Apr	
Massachusetts	Sep-Apr	
Rhode Island	Jan-May	
North Carolina	Sep-Jun	

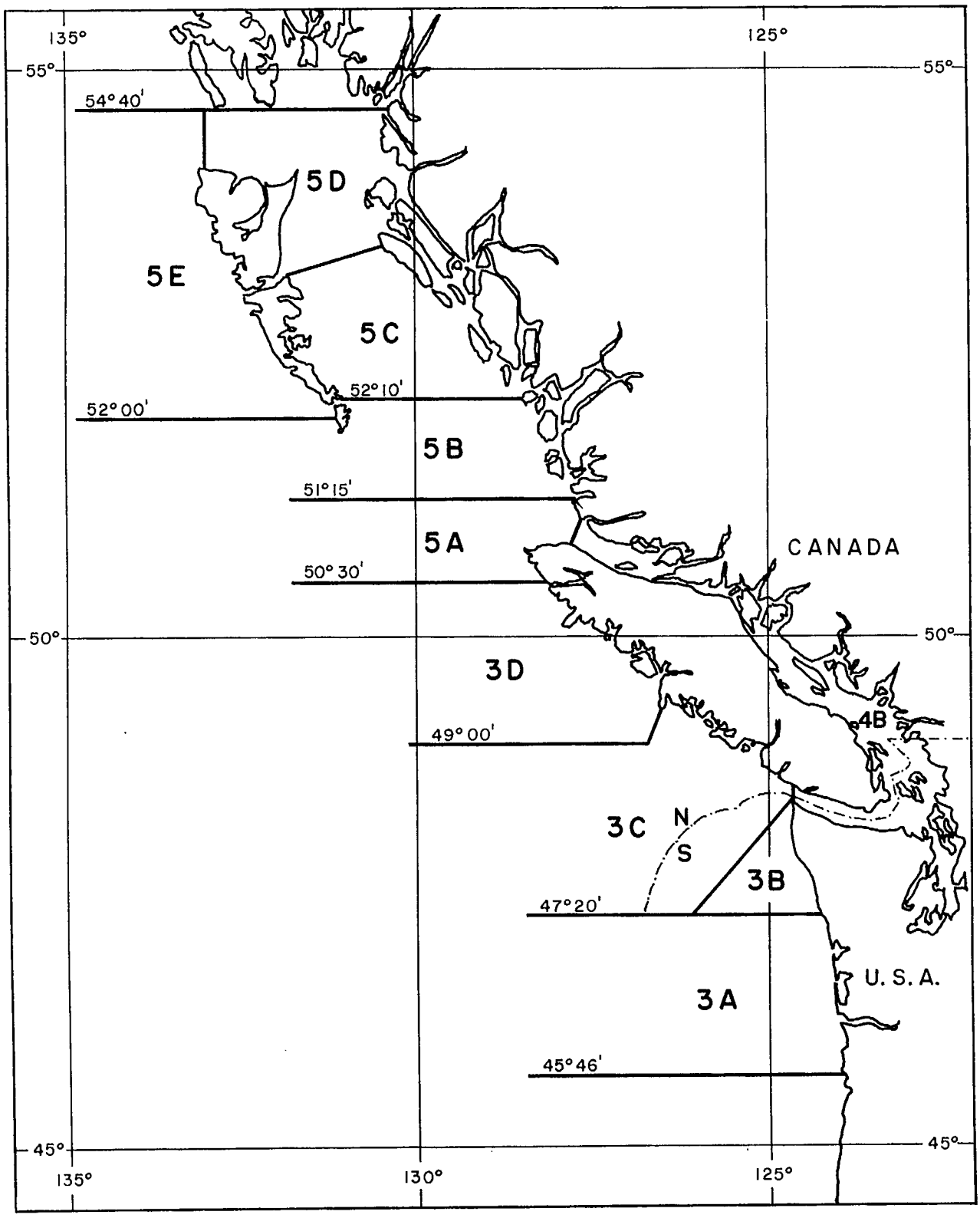

Fig. 1. International statistical areas for groundfish off western Canada.

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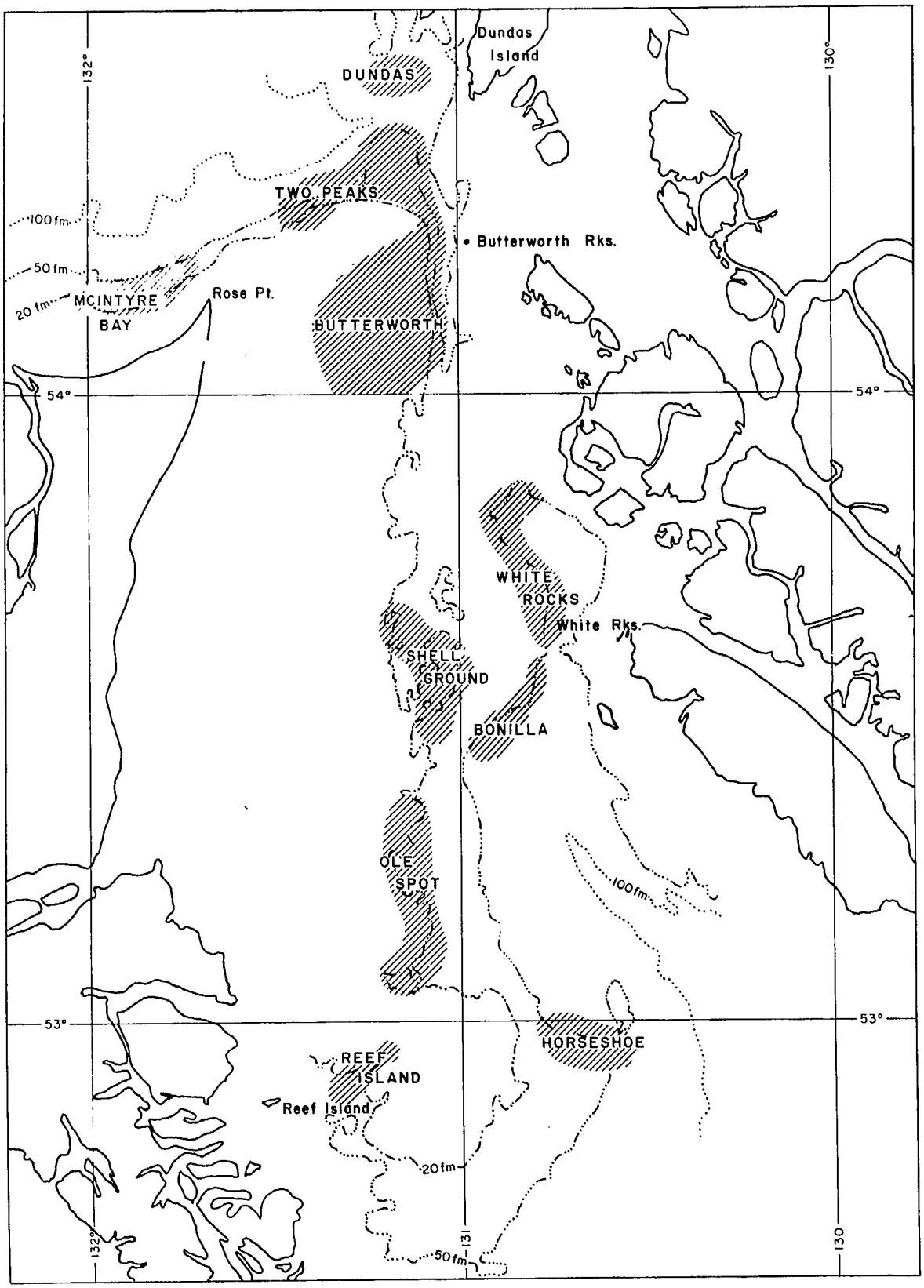

Fig. 2. Major trawling grounds for Pacific cod in Hecate Strait (Areas 5C and 5D).

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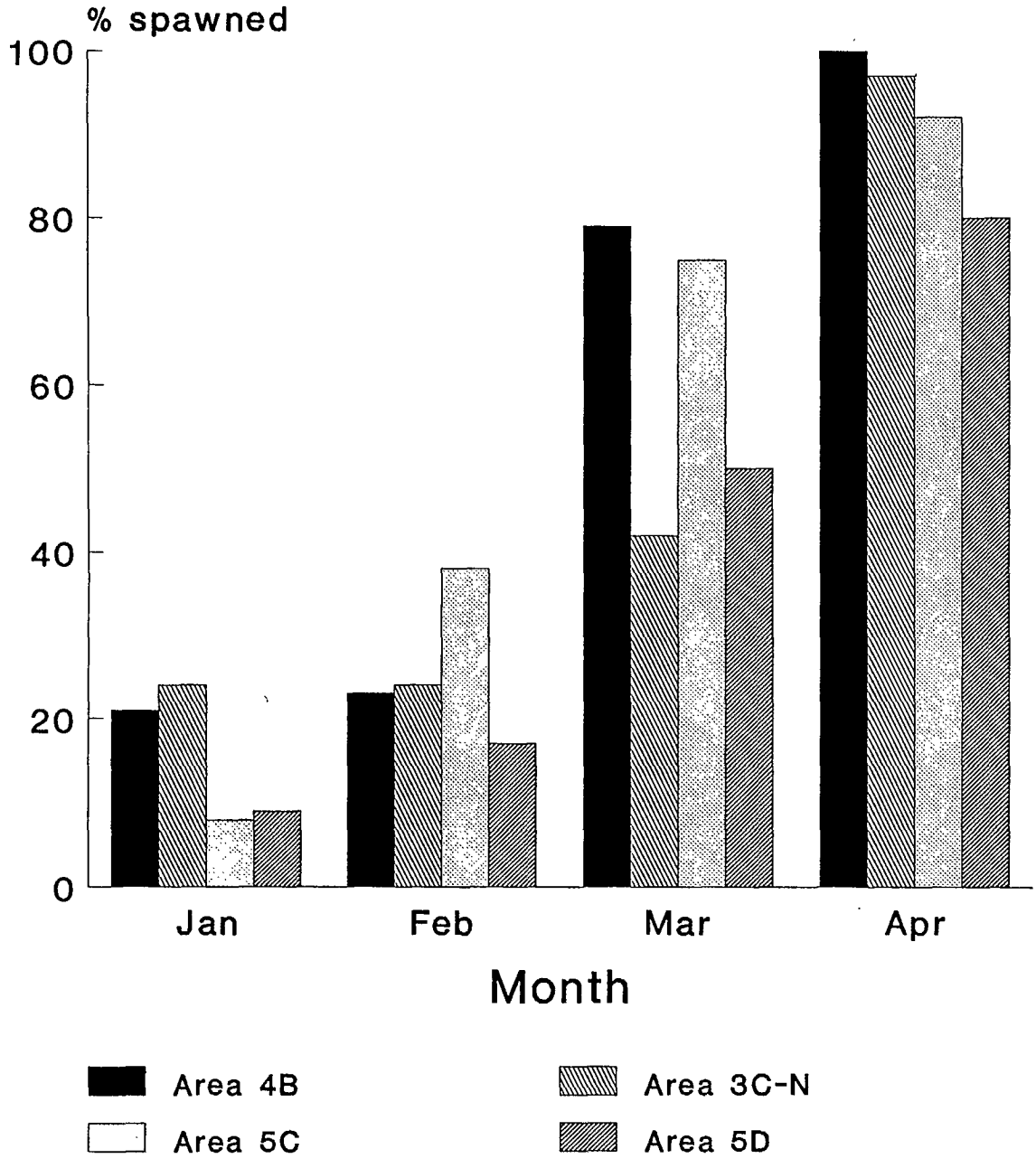

Fig. 3. Percentage of female Pacific cod spawned by month by area.

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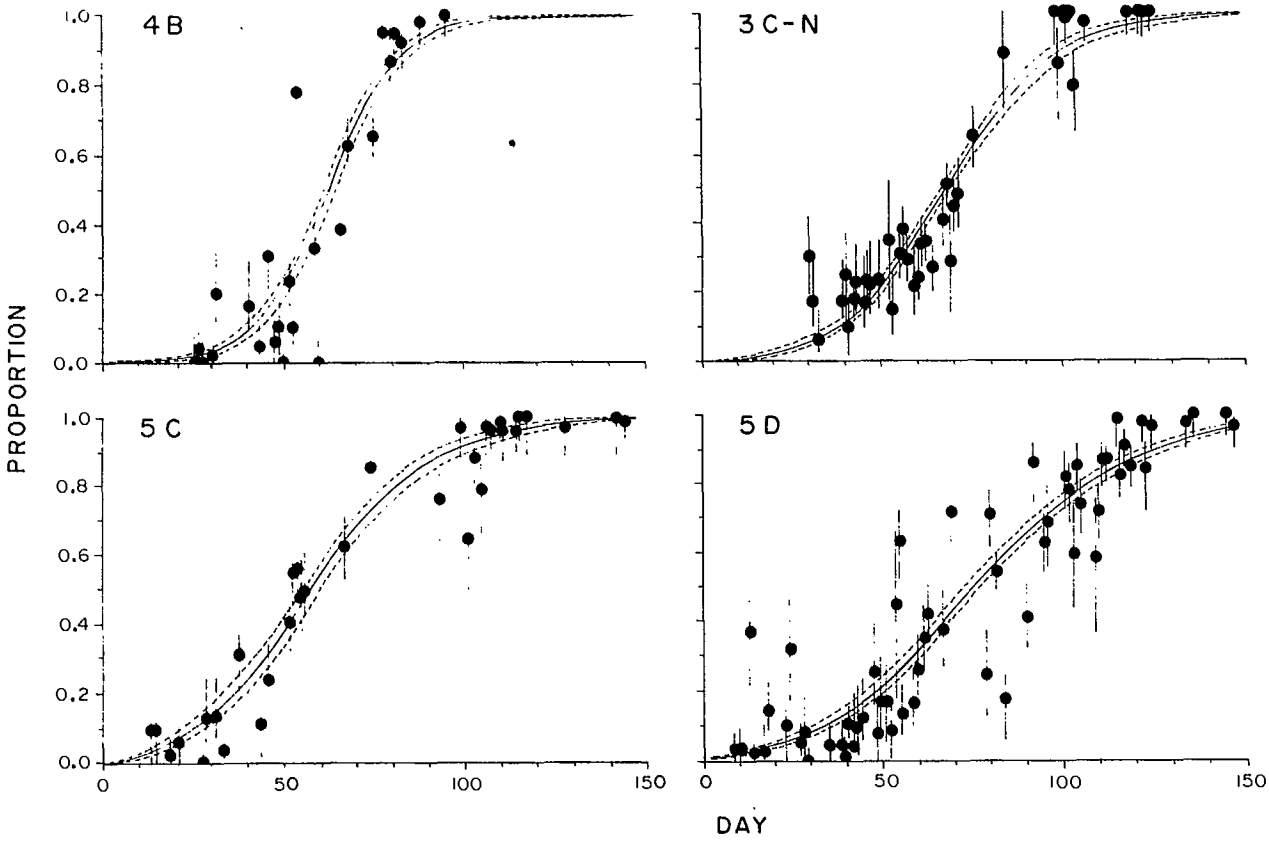

Fig. 4. Relationship between proportion of ovary conditions 6 + 7 and day of year for Pacific cod in Areas 4B, 3C-N, 5C and 5D. (Vertical lines indicate the 95% confidence intervals around the mean percentages. Area between dashed lines indicates the 5% plausibility region around the curve, fitted by maximum likelihood.)

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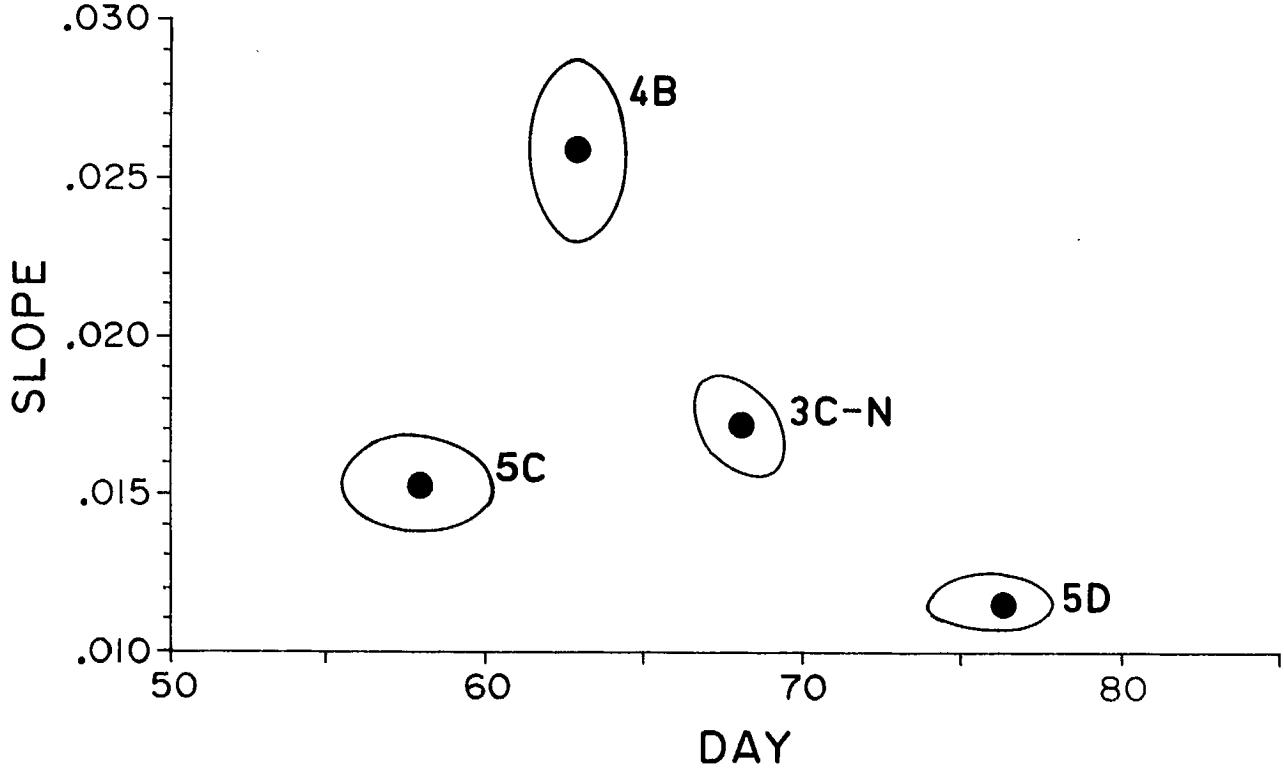

Fig. 5. Relationship between slope at day of year of 50% spawning completion (ovary conditions 6 + 7) and day of year at 50% spawning completion for female Pacific cod in Areas 4B, 3C-N, 5C, and 5D. (Open ellipses around the black dots represent the 5% plausibility regions.)