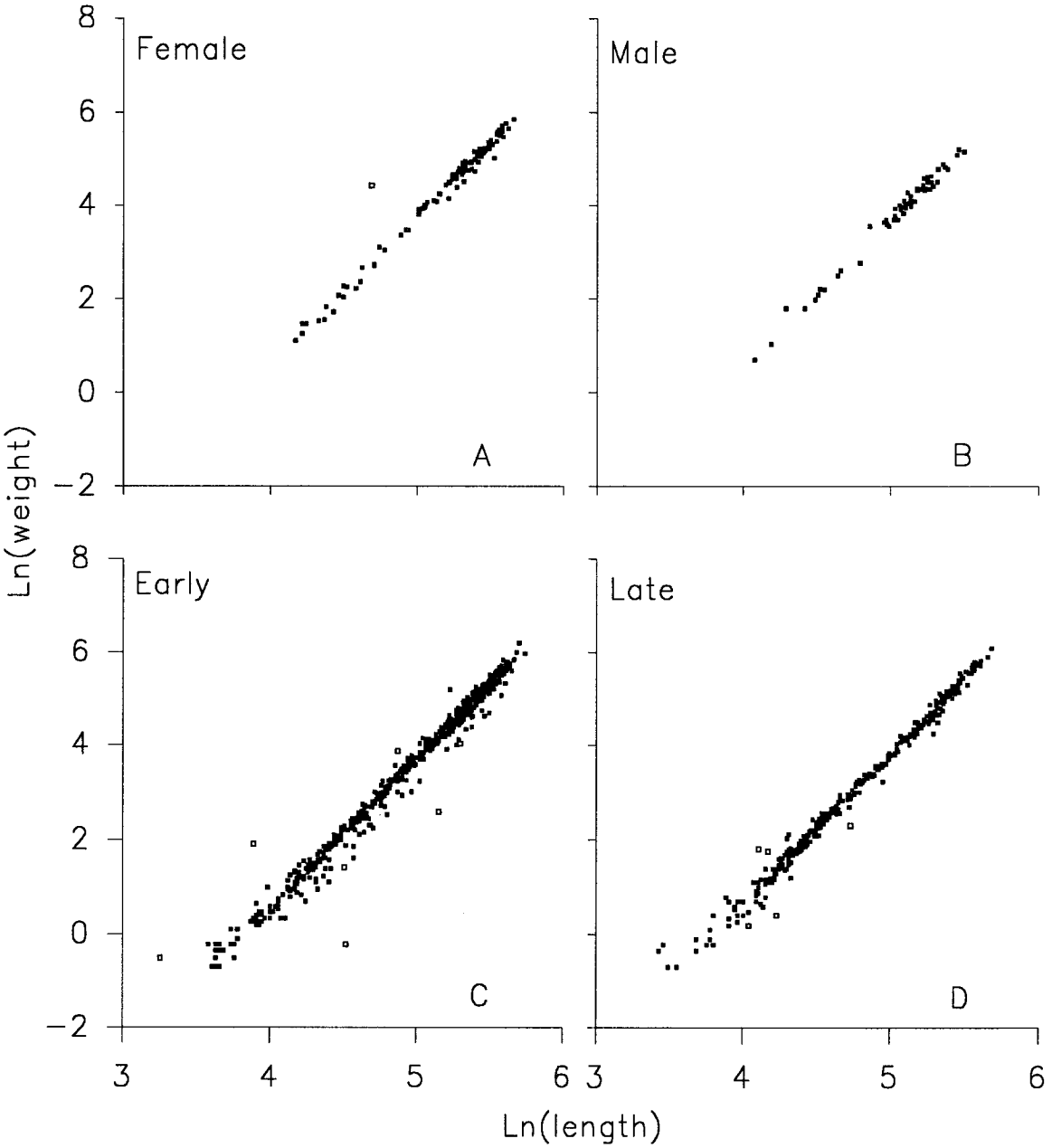

FIGURE 6.39.— Log-transformed weight-length data (□ = outliers) for comparisons between sexes (A, B) in July and between seasons (C, D). Seasonal data are from early (July 9-31) and late (August 27-September 14) time periods.

TABLE 6.14.— Seasonal fish condition comparisons for Arctic flounder for all years combined and for individually sampled years. Asterisks (*) indicate significant changes in condition.

		Slopes		Intercepts		
Group	N	b(SE)	P-values	$\log_e a$(SE)	P-values	r^2
			All years			
Early	679	3.18 (0.02)		-12.22 (0.09)		0.98
Late	541	3.16 (0.01)		-11.97 (0.07)		0.98
			P = 0.28		P = 0.0001	*
	Without outliers		P = 0.07		P = 0.0001	*
			1989			
Early	52	3.12 (0.04)		-11.80 (0.21)		0.99
Late	236	3.12 (0.02)		-11.75 (0.08)		0.99
			P = 0.97		P = 0.002	*
	Without outliers		P = 0.25		P = 0.0003	*
			1990			
Early	335	3.17 (0.02)		-12.13 (0.10)		0.99
Late	138	3.17 (0.02)		-12.15 (0.19)		0.98
			P = 0.54		P = 0.0001	*
	Without outliers		P = 0.0006		P = 0.0001	
			1991			
Early	261	3.21 (0.04)		-12.42 (0.18)		0.97
Late	138	3.17 (0.02)		-12.09 (0.12)		0.99
			P = 0.48		P = 0.0001	*
	Without outliers		P = 0.66		P = 0.0001	*

TABLE 6.15.— Condition comparisons in overwintering Arctic flounder for the winters of 1989-90, and 1990-91. Asterisks (*) indicate significant changes in condition.

		Slopes		Intercepts		
Group	*N*	*b*(SE)	*P*-values	$\log_e a$(SE)	*P*-values	r^2
			1989 - 1990			
Fall	109	3.10 (0.02)		-11.67 (0.12)		0.99
Spring	335	3.17 (0.02)		-12.13 (0.10)		0.99
			P = 0.09		*P* = 0.0001	*
	Without outliers		*P* = 0.04		*P* = 0.001	
			1990 - 1991			
Fall	133	3.19 (0.04)		-12.15 (0.19)		0.98
Spring	261	3.21 (0.04)		-12.42 (0.18)		0.97
			P = 0.78		*P* = 0.0001	*
	Without outliers		*P* = 0.002		*P* = 0.0001	

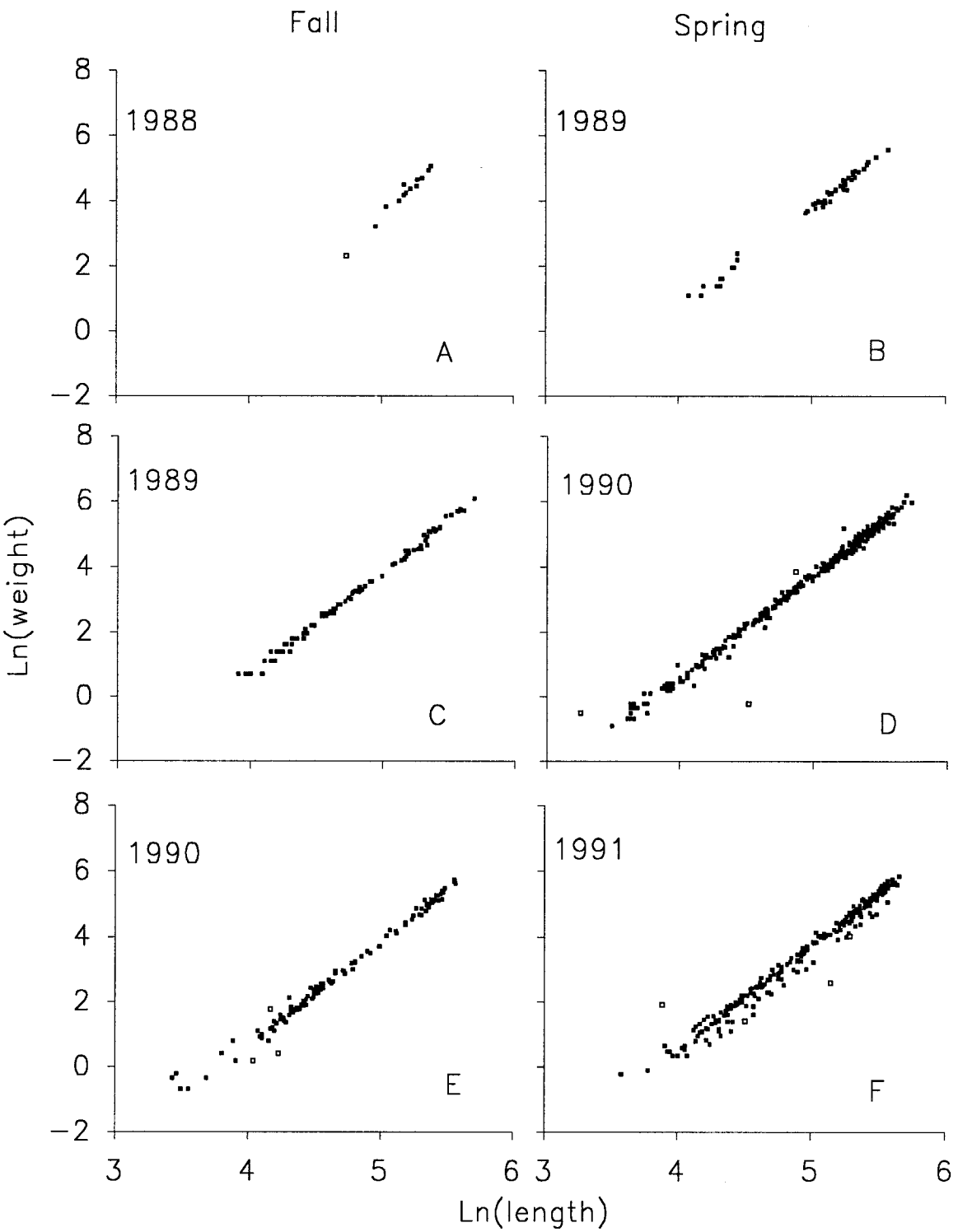

FIGURE 6.40.— Log-transformed weight-length data (□ = outliers) for three comparisons, winter 1988-89, 1989-90, and 1990-91.

TABLE 6.16.— Spatial condition comparisons for Arctic flounder collected in July for all years combined and sampled years individually. In 1988 and 1989 sample sizes were too small to analyze separately, but were included in the overall analyses. Asterisks (*) indicate significant differences in condition.

		Slopes		Intercepts			
Group	N	b(SE)	*P*-values	$\log_e a$(SE)	*P*-values	r^2	Pairwise results
			All years				
Beaufort Lagoon	269	3.16(0.01)		-12.10(0.07)		0.99	B
Kaktovik/Jago	248	3.20(0.03)		-12.30(0.13)		0.99	A
Simpson Cove	158	3.14(0.02)		-12.02(0.12)		0.99	A,B
			P = 0.02		P = 0.01		
Without outliers			P = 0.23		P = 0.004	*	
			1990				
Beaufort Lagoon	109	3.16(0.02)		-12.09(0.11)		0.99	A
Kaktovik/Jago	131	3.16(0.02)		-12.05(0.10)		0.99	B
Simpson Cove	89	3.15(0.02)		-12.07(0.11)		0.99	A,B
			P = 0.06		*P* = 0.29		
Without outliers			*P* = 0.99		*P* = 0.01	*	
			1991				
Beaufort Lagoon	106	3.09(0.04)		-11.74(0.20)		0.98	
Kaktovik/Jago	95	3.31(0.06)		-13.04(0.33)		0.96	
Simpson Cove	58	3.17(0.08)		-12.22(0.37)		0.97	
			P = 0.019		*P* = 0.0001		
Without outliers			*P* = 0.0012		*P* = 0.0001		

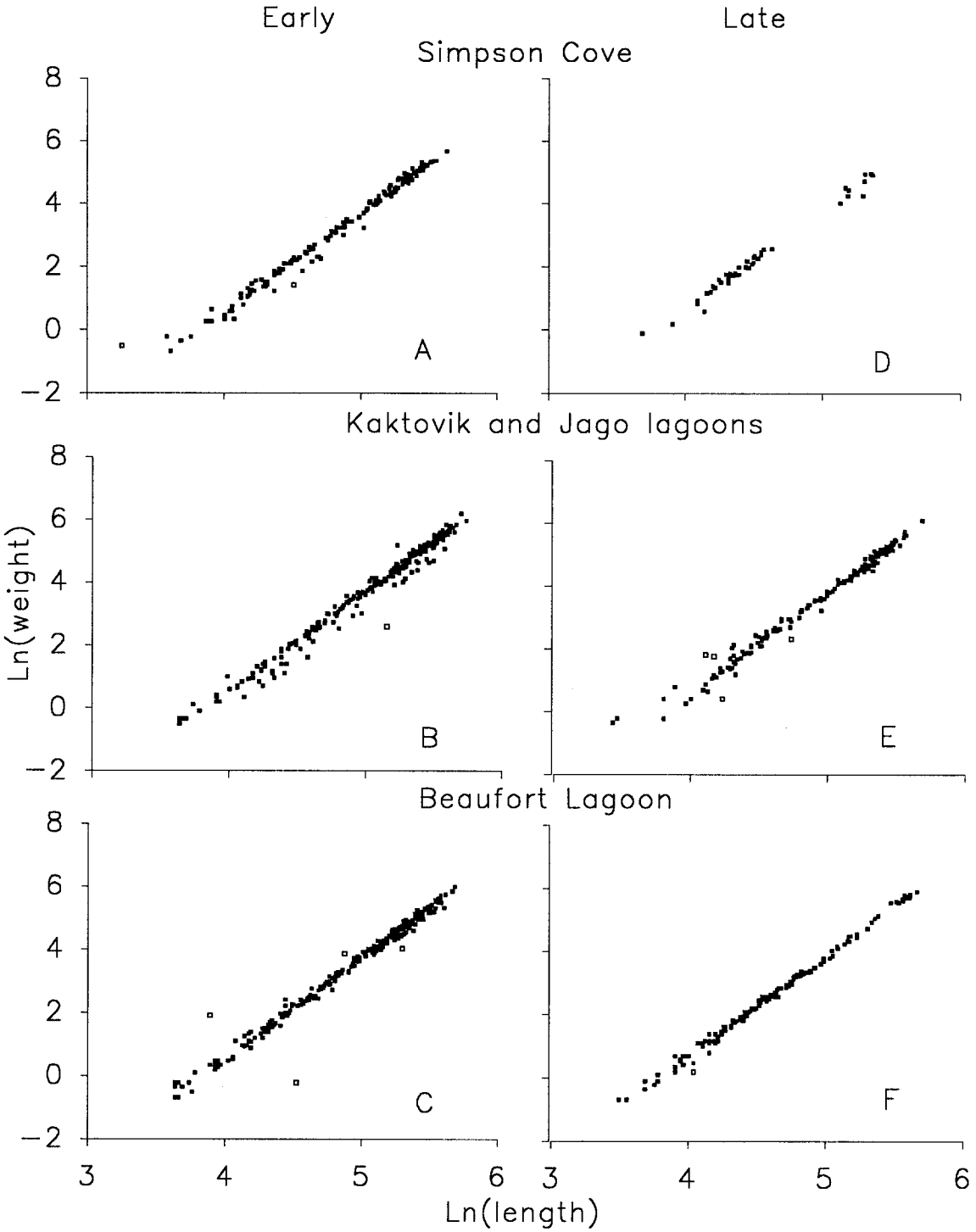

FIGURE 6.41.— Log-transformed weight-length data (□ = outliers) for among-area comparisons, early (July, first column) and late (after August 27, second column) of each year. Plots are compared down the columns.

TABLE 6.17.— Spatial condition comparisons for Arctic flounder collected after August 27 for all years combined, 1989, and 1991. Sample sizes in 1988 and 1990 were inadequate for separate analyses, but were included in the pooled sample. Asterisks (*) indicate significant differences in condition.

		Slopes		Intercepts			
Group	N	b(SE)	P-values	$\log_e a$(SE)	P-values	r^2	Pairwise results
			All years				
Beaufort Lagoon	142	3.18 (0.02)		-12.09 (0.08)		0.99	B
Kaktovik/Jago Lagoon	168	3.19 (0.02)		-12.14 (0.12)		0.99	A
Simpson Cove	44	3.15 (0.05)		-11.99 (0.24)		0.99	A
			P = 0.75		P = 0.07		
Without outliers			P = 0.78		P = 0.01	*	
			1989				
Beaufort Lagoon	58	3.16 (0.02)		-11.94 (0.11)		0.99	
Kaktovik/Jago Lagoon	36	3.23 (0.04)		-12.36 (0.20)		0.99	
			P = 0.11		P = 0.003	*	
Without outliers			P = 0.11		P = 0.003	*	
			1991				
Beaufort Lagoon	61	3.19 (0.02)		-12.16 (0.11)		0.99	
Kaktovik/Jago Lagoon	58	3.24 (0.04)		-12.44 (0.19)		0.99	
			P = 0.90		P = 0.28		
Without outliers			P = 0.29		P = 0.02	*	

indicated Beaufort Lagoon fish condition was higher than Kaktovik and Jago lagoons and lower than Simpson Cove. Plots of transformed data showed data from Simpson Cove were sparse, clustered differently, and dissimilar to other areas (Figure 6.41D). We observed similar results from within-year comparisons. Due to low sample sizes, we dropped Simpson Cove data from the analyses for 1989 and 1991.

Annual differences.— We detected significant differences in condition among years in all July analyses with the exception of the Kaktovik and Jago lagoons analysis with outliers removed (Table 6.18). The pooled pairwise analyses indicated that fish condition in 1991 differed from that seen in 1989 or 1990. Intercept values indicated that 1991 fish had lower condition than the other two years. Within Beaufort Lagoon, pairwise comparisons indicated that 1990 was different from 1989 and 1991. Intercepts at Beaufort Lagoon indicated fish from 1990 had lower condition than those from other years. Kaktovik Lagoon and Simpson Cove results indicated that fish from 1990 had higher condition than those from 1991. Plots of transformed data showed large differences in both the size range and size distribution of data from sampled fish (Figure 6.42).

We found significant differences in condition among years with areas pooled and within Beaufort Lagoon (Table 6.19). For pooled data pairwise comparisons indicated that 1991 was different from 1989 and 1990. Intercept values indicated that fish condition was lowest in 1991. Plots of transformed data showed similar size ranges and dispersion of observations among the years (Figure 6.43). The presence or absence of outliers did not change statistical results. Within Beaufort Lagoon only 1989 and 1991 had adequate sample sizes for comparative analyses. Fish condition was lower in 1991 than in 1989. In Kaktovik and Jago lagoons either no differences in condition was detected, or, when outliers were discarded, differences in slope precluded statements about condition.

Age and Growth

Arctic flounder collected during July in 1988, 1989, and 1990 ranged from 1 to 18 years of age and from 48 to 277 mm TL. Age-2 fish occurred most frequently (21%, N = 47), with age-10 fish second in frequency (19%, N = 40). The overall mean age was 7 years (N = 215, SE = 0.2) and the overall mean length was 163 mm TL (N = 215, SE = 4.1, Table 6.20). Overlap of length ranges between year classes was considerable, indicating variable growth among individuals and less distinctions in length among years. Plots of overall mean length at age showed nearly steady growth increases (Figure 6.44). This contrasts with our other target species, which exhibited declining growth rates as the fish aged.

We found no significant differences in mean lengths at age among areas (Table 6.21). Among years, significant differences in mean lengths were indicated only at age 10 between 1991 and the other years (Table 6.22). Average length of 10-year-old Arctic flounder was greater in 1991 than that in either 1989 or 1990. Overall age and length frequencies showed bimodal distributions (Figure 6.44). Lengths peaked between 50 and 150 mm TL and at 200 mm TL. Ages peaked at age-2 and 10. The modes at 200 mm TL probably

TABLE 6.18.— Annual condition comparisons for Arctic flounder collected in July for all sampling areas combined and sampling areas individually. In some analyses years were dropped when sample sizes were below minimum (N=32). Asterisks (*) indicate significant differences in condition.

		Slopes		Intercepts			
Group	N	b(SE)	P-values	$\log_e a$(SE)	P-values	r^2	Pairwise Results
			All areas				
1989	52	3.12 (0.04)		-11.80 (0.21)		0.99	A
1990	312	3.18 (0.02)		-12.17 (0.07)		0.99	A
1991	255	3.16 (0.03)		-12.19 (0.16)		0.97	B
			P = 0.65		P = 0.0001	*	
	Without outliers		P = 0.23		P = 0.0001	*	
			Beaufort Lagoon				
1989	52	3.12 (0.04)		-11.80 (0.21)		0.99	A
1990	100	3.19 (0.03)		-12.25 (0.14)		0.99	B
1991	106	3.10 (0.04)		-11.74 (0.20)		0.98	A
			P = 0.10		P = 0.02	*	
	Without outliers		P = 0.26		P = 0.0002	*	
			Kaktovik and Jago lagoons				
1990	126	3.17 (0.02)		-12.11 (0.12)		0.99	
1991	93	3.28 (0.07)		-12.85 (0.33)		0.96	
			P = 0.08		P = 0.0001	*	
	Without outliers		P = 0.01		P = 0.0001		
			Simpson Cove				
1990	86	3.16 (0.02)		-12.08 (0.12)		0.99	
1991	56	3.14 (0.06)		-12.09 (0.27)		0.98	
			P = 0.79		P = 0.008	*	
	Without outliers		P = 0.97		P = 0.001	*	

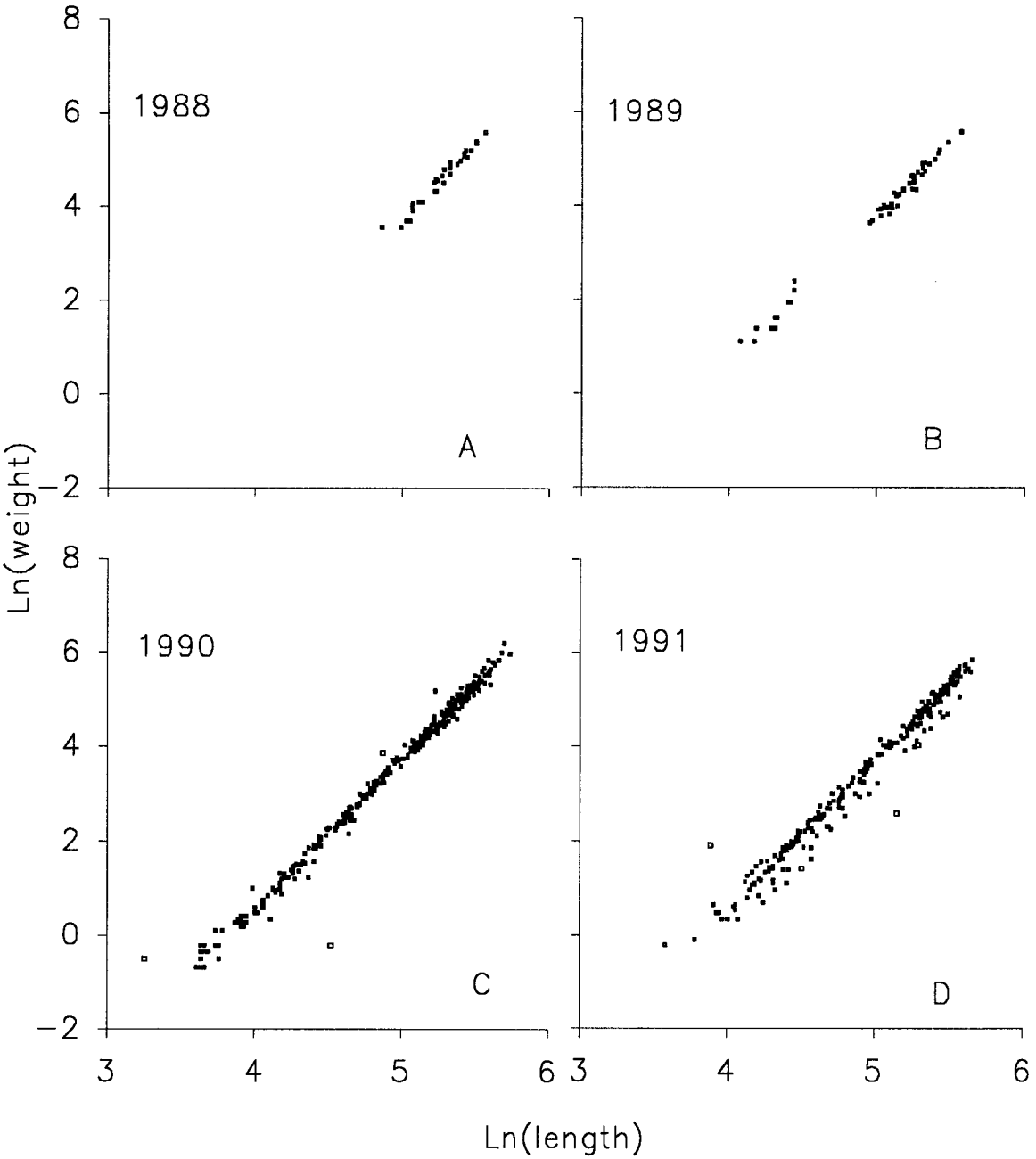

FIGURE 6.42.— Log-transformed Arctic flounder weight-length data (□ = outliers) collected during July in all areas for comparisons among-years.

TABLE 6.19.— Annual condition comparisons for Arctic flounder collected after August 27 for all sampling areas combined, Beaufort Lagoon and the Kaktovik/Jago Lagoon complex separately. In some analyses years were dropped when sample sizes were below the minimum (N=32). Asterisks (*) indicate significant differences in condition.

		Slopes		Intercepts			
Group	N	b(SE)	P-values	$\log_e a$(SE)	P-values	r^2	Pairwise results
			All areas				
1989	94	3.16 (0.02)		-11.94 (0.10)		0.99	A
1990	119	3.18 (0.03)		-12.10 (0.15)		0.99	A
1991	133	3.18 (0.03)		-12.14 (0.12)		0.99	B
			P = 0.75		P = 0.0004	*	
	Without outliers		P = 0.34		P = 0.0001	*	
			Beaufort Lagoon				
1989	58	3.16 (0.02)		-11.94 (0.11)		0.99	
1991	61	3.19 (0.02)		-12.17 (0.11)		0.99	
			P = 0.36		P = 0.0001	*	
	Without outliers		P = 0.36		P = 0.0001	*	
			Kaktovik and Jago lagoons				
1989	36	3.23 (0.04)		-12.36 (0.20)		0.99	
1990	69	3.14 (0.05)		-11.82 (0.20)		0.98	
1991	59	3.18 (0.05)		-12.16 (0.24)		0.99	
			P = 0.51		P = 0.07		
	Without outliers		P = 0.04		P = 0.0005		

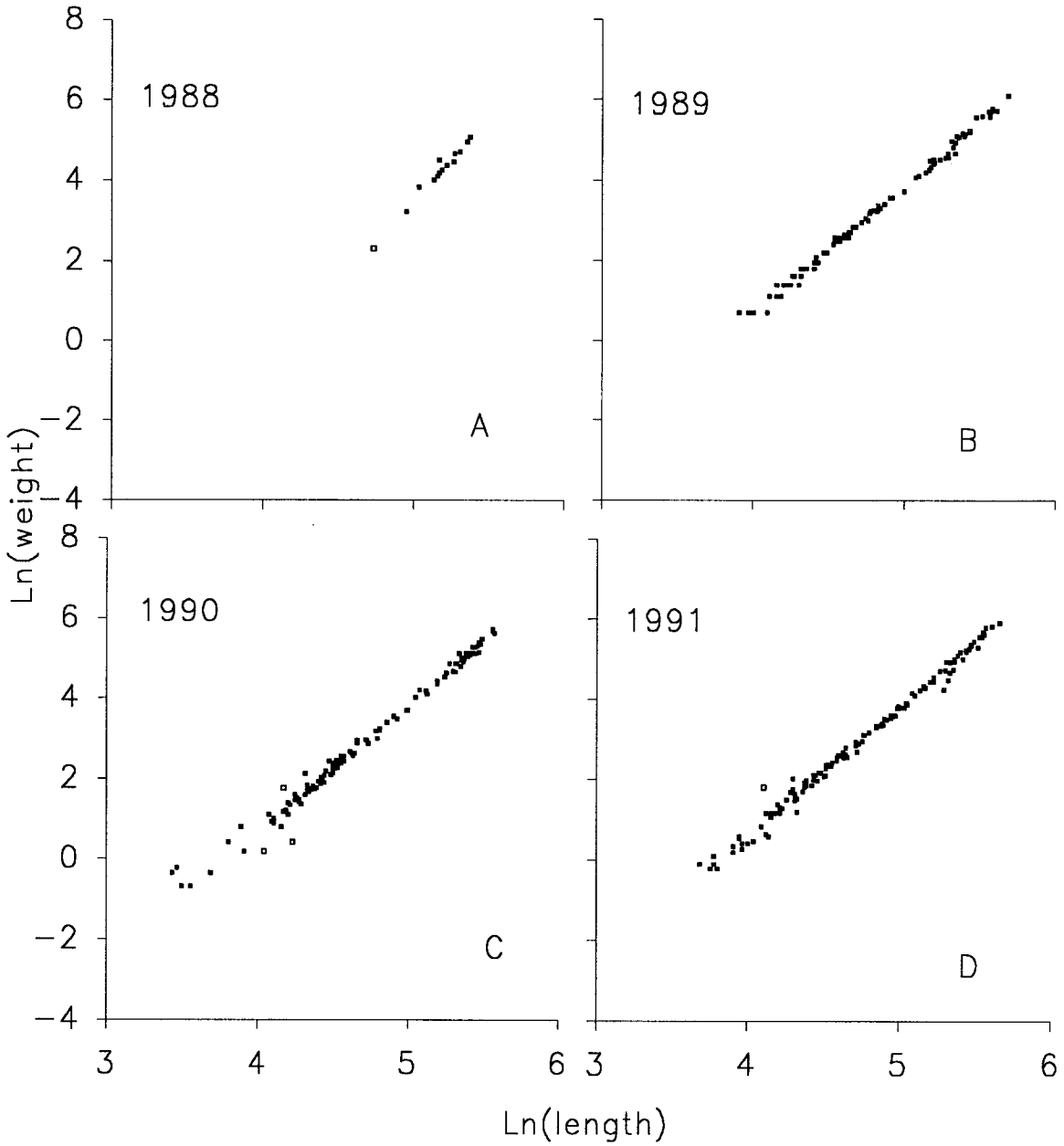

FIGURE 6.43.– Log-transformed Arctic flounder weight-length data (□ = outliers) collected after August 27 in all areas for comparison among-years.

TABLE 6.20.— Mean length at age (SE) and ranges for Arctic flounder collected during July, all years and areas pooled.

Age	*N*	Length (SE)	Range
1	4	63(9)	36-109
2	47	85(4)	48-206
3	20	109(5)	73-170
4	17	142(5)	90-198
5	3	141(14)	119-167
6	1	129(--)	--
7	6	181(10)	144-225
8	8	181(6)	152-216
9	28	198(6)	109-245
10	40	198(4)	142-259
11	19	232(7)	121-265
12	14	231(8)	182-272
13	4	232(12)	204-262
14	2	256(11)	245-267
15	1	248(--)	--
16	0	--	--
17	0	--	--
18	1	277(--)	--
	N = 215	$\bar{x}$ = 163	

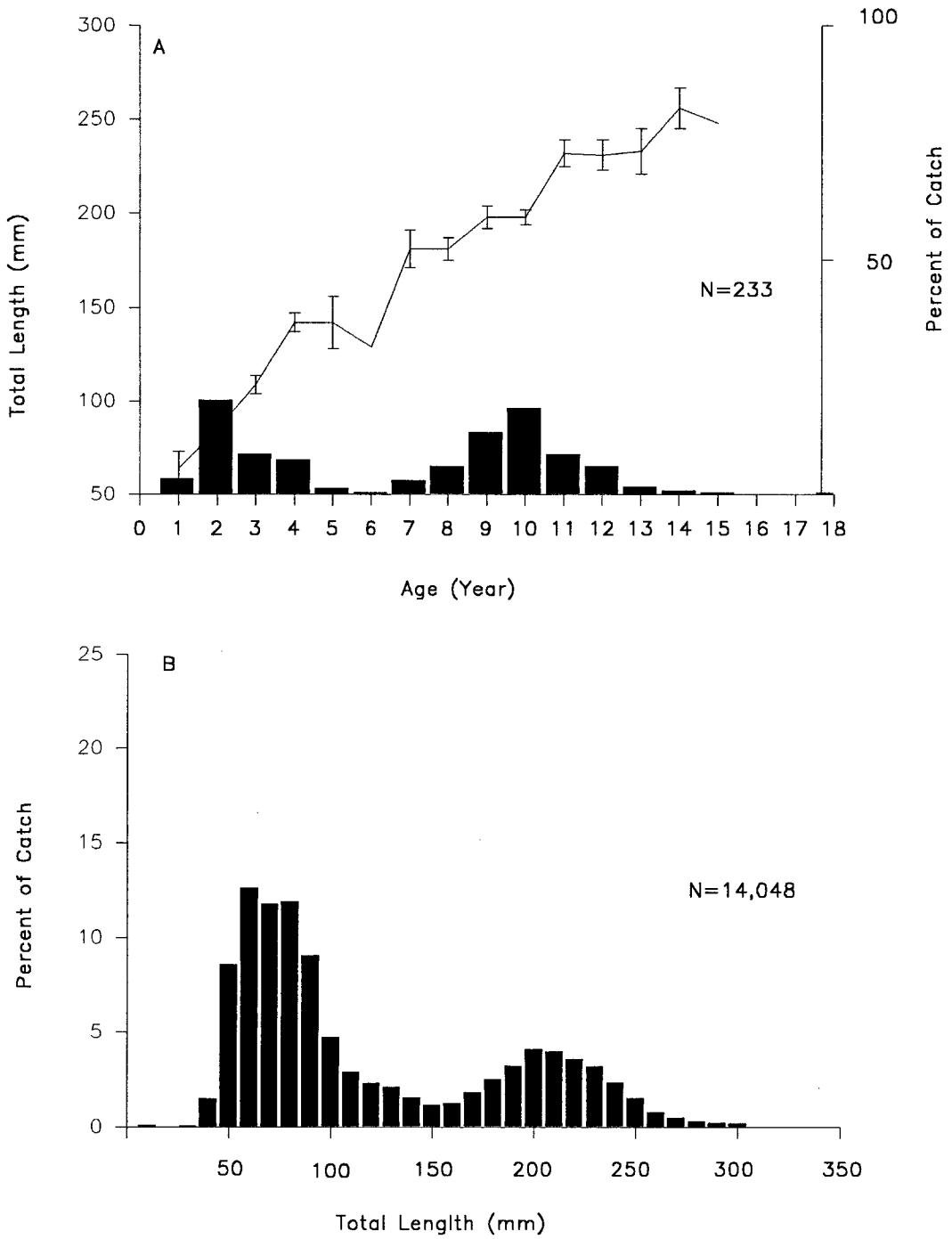

FIGURE 6.44.– Mean length at age (±SE), age frequencies (A) and standard fyke net length frequencies (10 mm intervals, B) for Arctic flounder collected during July, years and areas pooled.

TABLE 6.21.— Mean lengths at age (SE) and among-area analysis for Arctic flounder collected during July, 1988, 1989, and 1991. Similar letters represent no significant difference between those means at that age.

	Simpson Cove			Kaktovik Lagoon			Jago Lagoon			Beaufort Lagoon		
Age	*N*	$\bar{x}$(SE)		*N*	$\bar{x}$(SE)		*N*	$\bar{x}$(SE)		*N*	$\bar{x}$(SE)	
1	2	74(17)	A	0	--		0	--		2	89(21)	A
2	11	94(12)	A	0	--		0	--		36	82(3)	A
3	12	106(8)	A	0	--		0	--		8	113(7)	A
4	3	149(6)	A	0	--		0	--		14	140(6)	A
5	1	119(--)		0	--		0	--		2	153(14)	
6	0	--		1	129(--)		0	--		0	--	
7	2	164(5)	A	0	--		0	--		4	189(17)	A
8	2	159(7)	A	1	159(--)		1	205(--)		4	198(6)	
9	6	184(10)	A	2	192(36)	A	6	219(9)	A	14	192(10)	A
10	5	209(7)	A	2	191(5)	A	0	--		33	196(5)	A
11	5	234(7)	A	2	230(6)	A	0	--		12	231(12)	A
12	2	244(7)	A	0	--		0	--		12	229(9)	A
13	1	235(--)		0	--		0	--		3	232(17)	A
14	0	--		1	245(--)		0	--		1	267(--)	
15	0	--		0			0	--		1	248(--)	
16	0	--		0			0	--		0	--	
17	0	--		0			0	--		0	--	
18	1	277(--)		0			0	--		0	--	

TABLE 6.22.— Mean lengths at age (SE) and among-year analysis for Arctic flounder collected during July, areas pooled. Similar letters represent no significant difference between those means at that age.

	1988				1989				1991			
Age	*N*	$\bar{x}$(SE)	Range		*N*	$\bar{x}$(SE)	Range		*N*	$\bar{x}$(SE)	Range	
1	0	--	--		0	--	--		4	81(12)	57-109	
2	0	--	--		12	76(2)	59-85	A	35	88(5)	48-206	A
3	0	--	--		0	--	--		20	109(5)	73-170	
4	0	--	--		0	--	--		17	142(14)	90-198	
5	0	--	--		0	--	--		3	142(14)	119-167	
6	1	129(--)	--		0	--	--		0	--	--	
7	1	159(--)	--		0	--	--		2	184(16)	168-200	
8	4	174(7)	152-216	A	3	186(23)	144-225	A	2	208(7)	201-215	A
9	11	202(9)	147-249	A	2	189(18)	171-206	A	9	200(13)	109-245	A
10	3	200(6)	187-227	A	8	187(9)	164-241	A	16	221(6)	184-259	B
11	2	234(5)	225-243	A	21	179(5)	142-220	A	14	232(10)	121-265	A
12	0	--	--		3	234(15)	212-264	A	14	231(8)	182-272	A
13	0	--	--		0	--	--		4	233(12)	204-262	
14	1	245(--)	--		0	--	--		1	267(--)	--	
15	0	--	--		0	--	--		1	248(--)	--	
16	0	--	--		0	--	--		0	--	--	
17	0	--	--		0	--	--		0	--	--	
18	0	--	--		0	--	--		1	277(--)	--	

corresponded to 10-year-old fish. The 50-150 mm TL mode may correspond to the peak at age-2, but based on length at age analysis, is more likely representative of age-1 Arctic flounder.

The data stratified by area showed bimodal distributions in lengths and ages similar to the overall plot, except for fish collected in Kaktovik and Jago lagoons. Low sample sizes from these latter areas prevented interpretation of age frequency distributions (Figure 6.45; Table 6.21). Data stratified by years indicated bimodal distributions similar to those in the overall distributions except for 1988 (Figure 6.46). During that year, fish less than 50 mm TL were present. These very small fish probably were young-of-the-year recruiting into the sampled population. In 1989, the first length mode between 50 and 150 mm TL was smaller than that observed in 1991 (Figure 6.46).

Movements

We tagged and released a total of 995 Arctic flounder in Arctic Refuge coastal waters between 1988 and 1991. Of these fish, we recaptured 58 (6%) (Table 6.23). Nine fish were recaptured in areas other than where tagging occurred, and 49 fish were recaptured within the original tagging area. Thirty-nine of the recaptured fish had been tagged in previous field seasons. We documented movement of nine Arctic flounder among the sampling areas both east and west from where tagging occurred. Of these fish, four moved between Simpson Cove and the Kaktovik/Jago lagoon complex (three east and one west). The remaining five moved within the Kaktovik/Jago lagoon complex (four moved east and one west). We did not document movement of tagged Arctic flounder east of Jago Lagoon or between Pokok Bay and Beaufort Lagoon.

Environmental Influences on CPUE

Simpson Cove.— Arctic flounder were most abundant in Simpson Cove during July and the first week of August in 1988-91, although they were present in diminishing densities throughout each sampling season. This intraseasonal trend of diminishing CPUE included large daily variations, but was generally coincident with decreasing water temperatures and increasing temperatures. Daily catch rates at net station SC04, in particular, were strongly positively correlated with temperature and negatively correlated with salinity (Figure 6.47). At net station SC01 we detected similar relationships during 1988 and 1991. We observed higher CPUE, higher temperatures, and lower salinities at net station SC04 when compared to net station SC01 (Figure 6.48). This relationship underscored the positive association between Arctic flounder CPUE and water temperature. When pooled over net stations, daily catch rates were again strongly associated with temperature during all four sampling years (Table 6.24). Wind components were only weakly associated with Arctic flounder daily catch rates, for both net station and area-wide data (Tables 6.24, 6.25). Strong correlations between CPUE and hydrographic variables in 1988 may be misleading due to the small sample size for the analyses (N = 10).

Kaktovik Lagoon.— We caught Arctic flounder in Kaktovik Lagoon throughout the 1988-91 sampling seasons. While CPUE was generally higher at net station KL05, temperature and salinity regimes between the two Kaktovik Lagoon net stations were similar (Figure 6.49). Temperature was the dominant variable in the more successful station-specific modelling efforts ($R^2 > 0.40$) except for

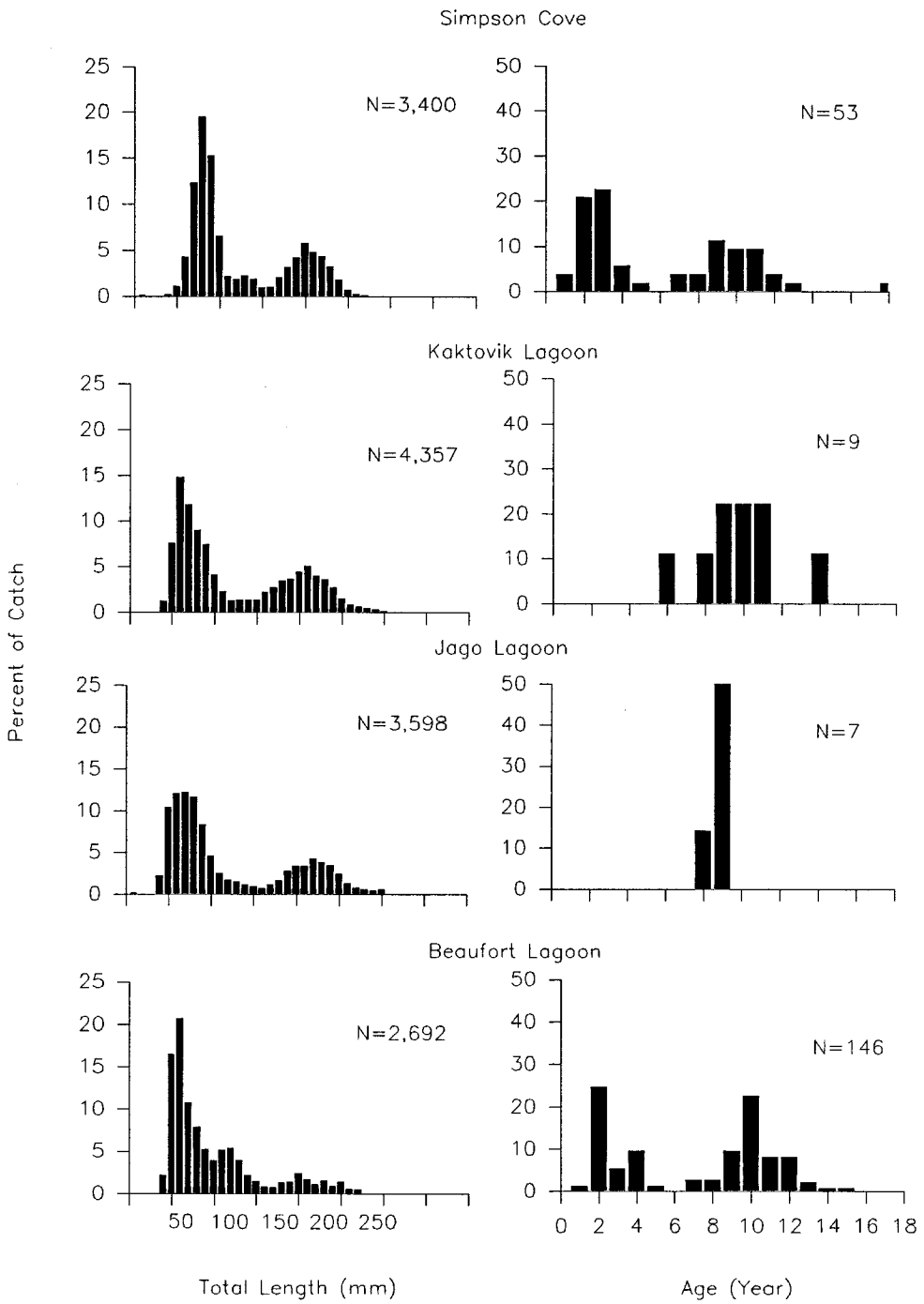

FIGURE 6.45.– Length frequencies (10 mm intervals) for standard fyke net catches and age frequencies for Arctic flounder collected during July with years pooled.

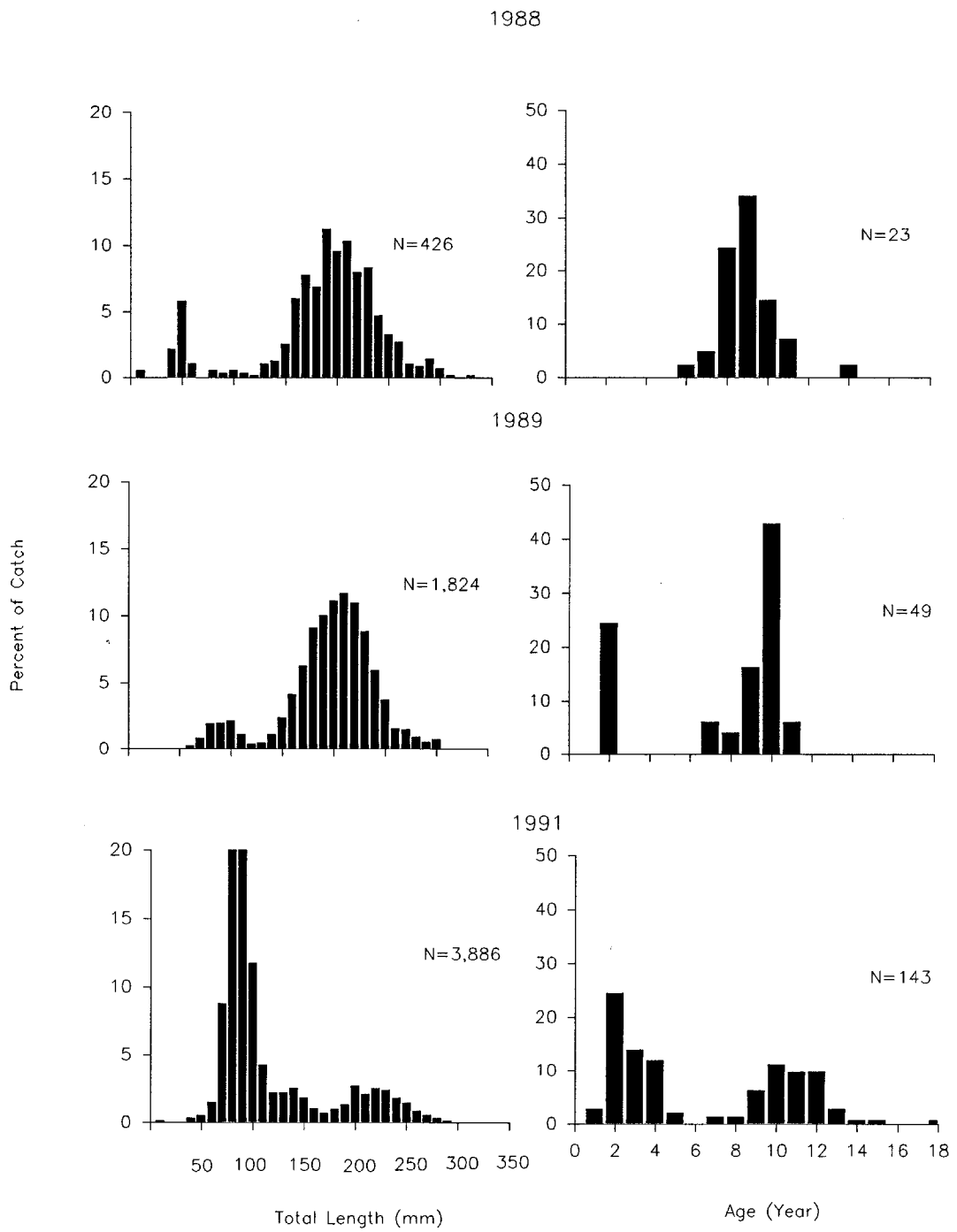

FIGURE 6.46.— Length frequencies (10 mm intervals) for standard fyke net catches and age frequencies for Arctic flounder collected during July with areas pooled.

TABLE 6.23.— Number of Arctic flounder tagged (N) and recaptured by location in Arctic Refuge coastal waters, 1988-91.

		Recapture area				
Tagging area	N	Simpson Cove	Kaktovik Lagoon	Jago Lagoon	Beaufort Lagoon	Pokok Bay
Simpson Cove	216	15	2	1	0	0
Kaktovik Lagoon	289	0	13	4	0	0
Jago Lagoon	240	1	1	12	0	0
Beaufort Lagoon	174	0	0	0	7	0
Pokok Bay	76	0	0	0	0	2

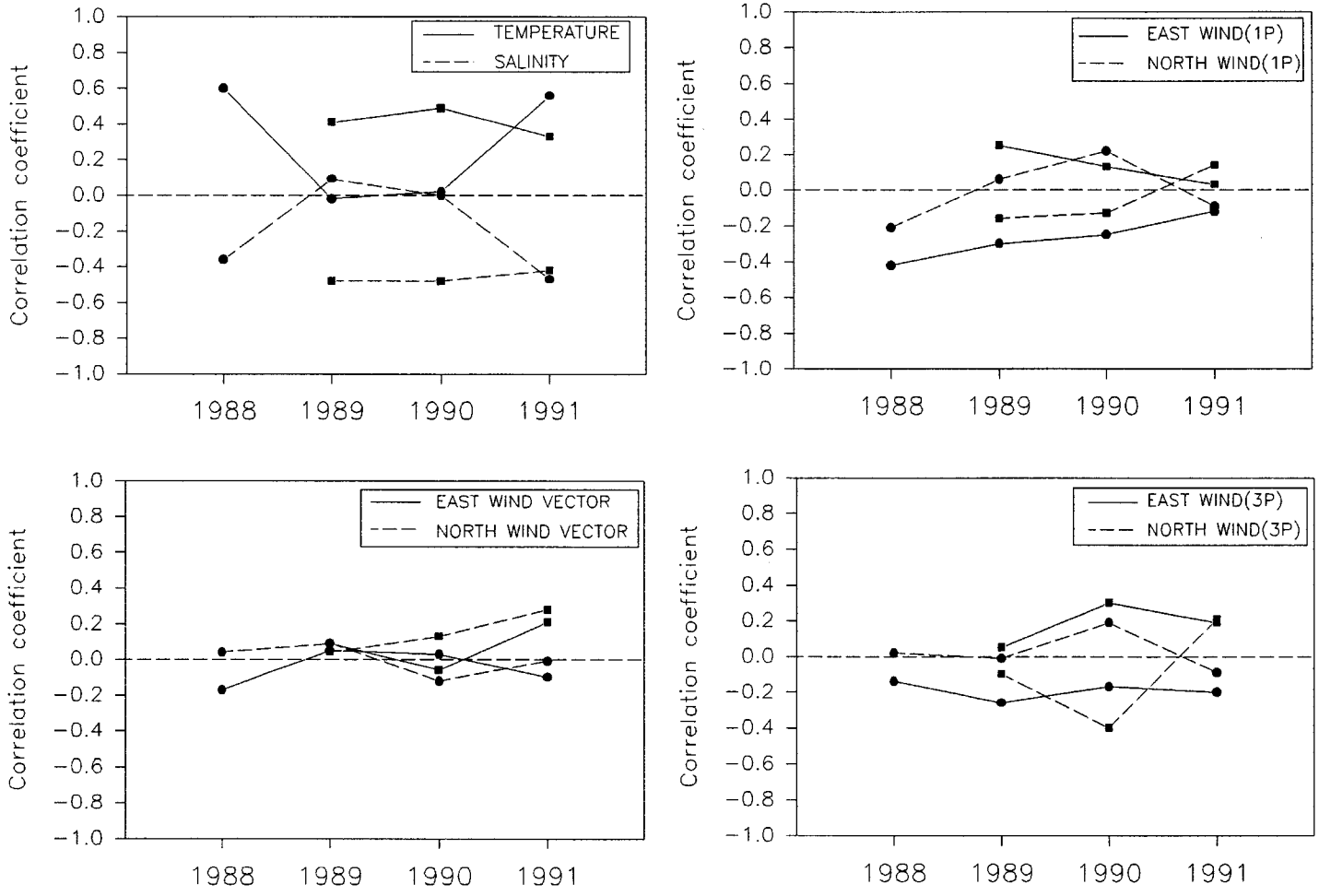

FIGURE 6.47.— Correlations between environmental variables and Arctic flounder CPUE from fyke net stations SC01 (•) and SC04 (▪) (1988-91) in Simpson Cove. [1P=mean wind vector for previous day; 3P=mean wind vector over 3 previous days].

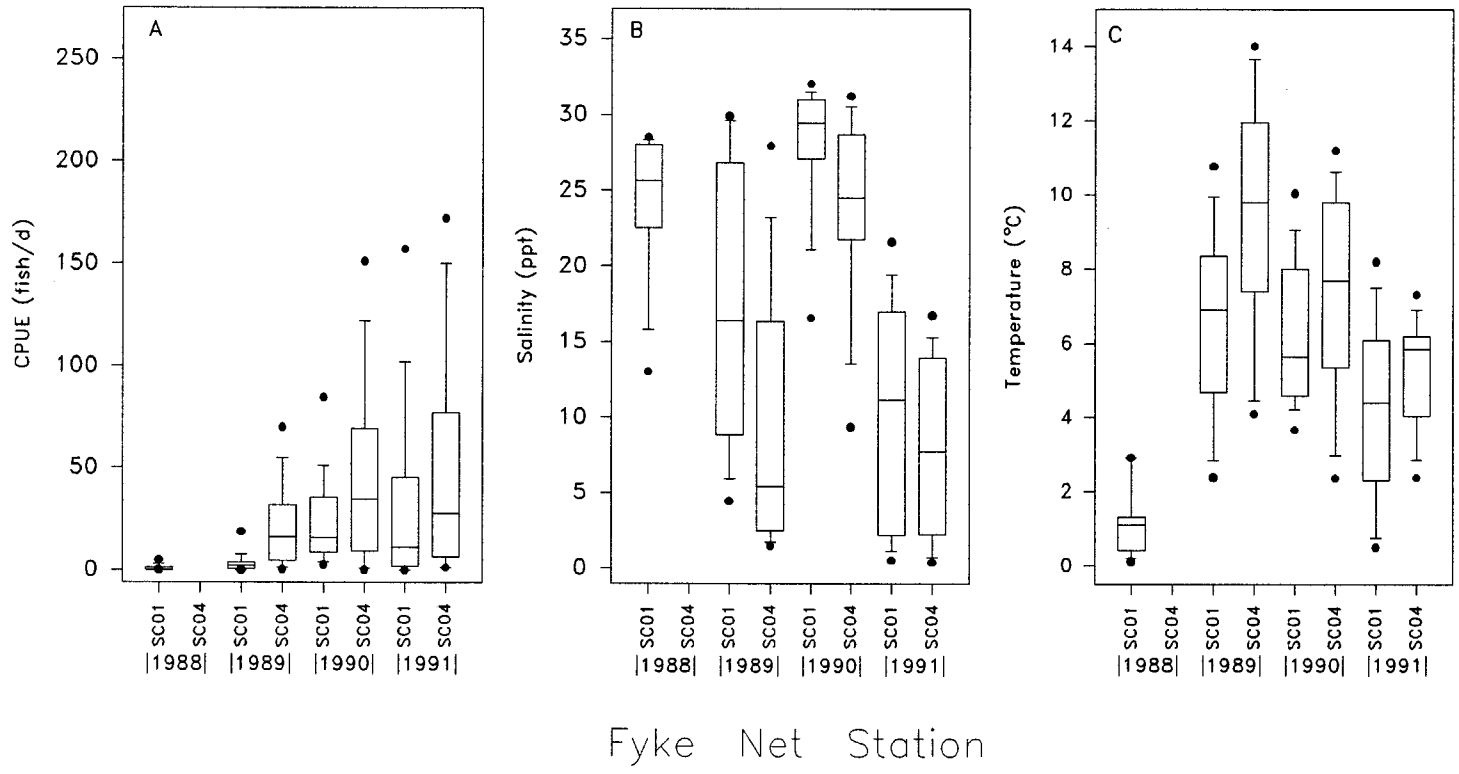

FIGURE 6.48.— Boxplots of (A) catch per unit effort for Arctic flounder, (B) salinity, and (C) temperature for Simpson Cove fyke net stations during 1988-91.

TABLE 6.24.— Environmental variables[a] influencing Arctic flounder CPUE (pooled over stations). Coefficient of partial correlation (r^2_p) for each effect and overall R^2 shown as determined by stepwise selection procedure.

Year	Environmental variable	r^2_p	R^2
	Simpson Cove		
1988	SAL	0.88	
	TEMP	0.86	
	NW	0.73	
	NW1P	0.49	0.94
1989	TEMP	0.28	
	NW	0.04	
	EW	0.04	0.32
1990	TEMP	0.27	0.27
1991	TEMP	0.47	
	SAL	0.05	0.48
	Kaktovik Lagoon		
1988	EW1P	0.10	
	TEMP	0.08	0.17
1989	TEMP	0.08	0.08
1990	SAL	0.09	0.09
1991	TEMP	0.50	
	EW1P	0.17	0.54
	Jago Lagoon		
1988	EW1P	0.14	
	SAL	0.12	
	NW1P	0.10	0.29
1989	TEMP	0.20	
	SAL	0.05	0.24
1990	TEMP	0.30	0.30
1991	EW	0.31	
	TEMP	0.20	0.41
	Beaufort Lagoon		
1990	EW3P	0.13	0.13
1991	NW1P	0.08	0.08
	Pokok Bay		
1988	TEMP	0.13	0.13

[a] EW=mean east wind vector; EW1P=mean east wind vector for previous day; EW3P=mean of east wind vector over 3 previous days; NW=mean north wind vector; NW1P=mean north wind vector for previous day; NW3P=mean north wind vector over 3 previous days; SAL=salinity(ppt); TEMP=temperature(C).

TABLE 6.25.— Environmental variables[a] influencing Arctic flounder CPUE (fish/d), followed by R^2 value of overall model. Parameter estimate is positive unless followed by "(-)". ("nv" = no eligible variables.)

Station	Year			
	1988	1989	1990	1991
Simpson Cove				
SC01	SAL TEMP NW NW1P(-) (0.95)	EW1P(-) (0.11)	nv	TEMP EW3P(-) (0.60)
SC04		SAL(-) (0.35)	TEMP (0.53)	TEMP (0.23)
Kaktovik Lagoon				
KL05	EW SAL(-) EW1 (0.82)	TEMP EW1P EW (0.59)	nv	TEMP EW1P (0.79)
KL10	nv	SAL EW3P(-) (0.17)	TEMP EW3P(-) (0.42)	TEMP NW1P EW1P (0.76)
Jago Lagoon				
JL12	nv	TEMP (0.32)	TEMP EW1P(-) (0.31)	EW1P (0.28)
JL14	NW3P EW3P (0.33)	SAL(-) (0.29)	TEMP (0.53)	EW1P SAL(-) (0.42)
Beaufort Lagoon				
BL02			TEMP NW1P NW3P(-) (0.68)	TEMP NW3P EW1P(-) (0.54)
BL04			TEMP(-) (0.37)	NW1P(-) SAL (0.39)
Pokok Bay				
PB01	NW1P(-) (0.12)			
PB02	TEMP EW1P NW1P (0.71)			

[a] EW=mean east wind vector; EW1P=mean east wind vector for previous day; EW3P=mean of east wind vector over 3 previous days; NW=mean north wind vector; NW1P=mean north wind vector for previous day; NW3P=mean north wind vector over 3 previous days; SAL=salinity(ppt); TEMP=temperature(C).

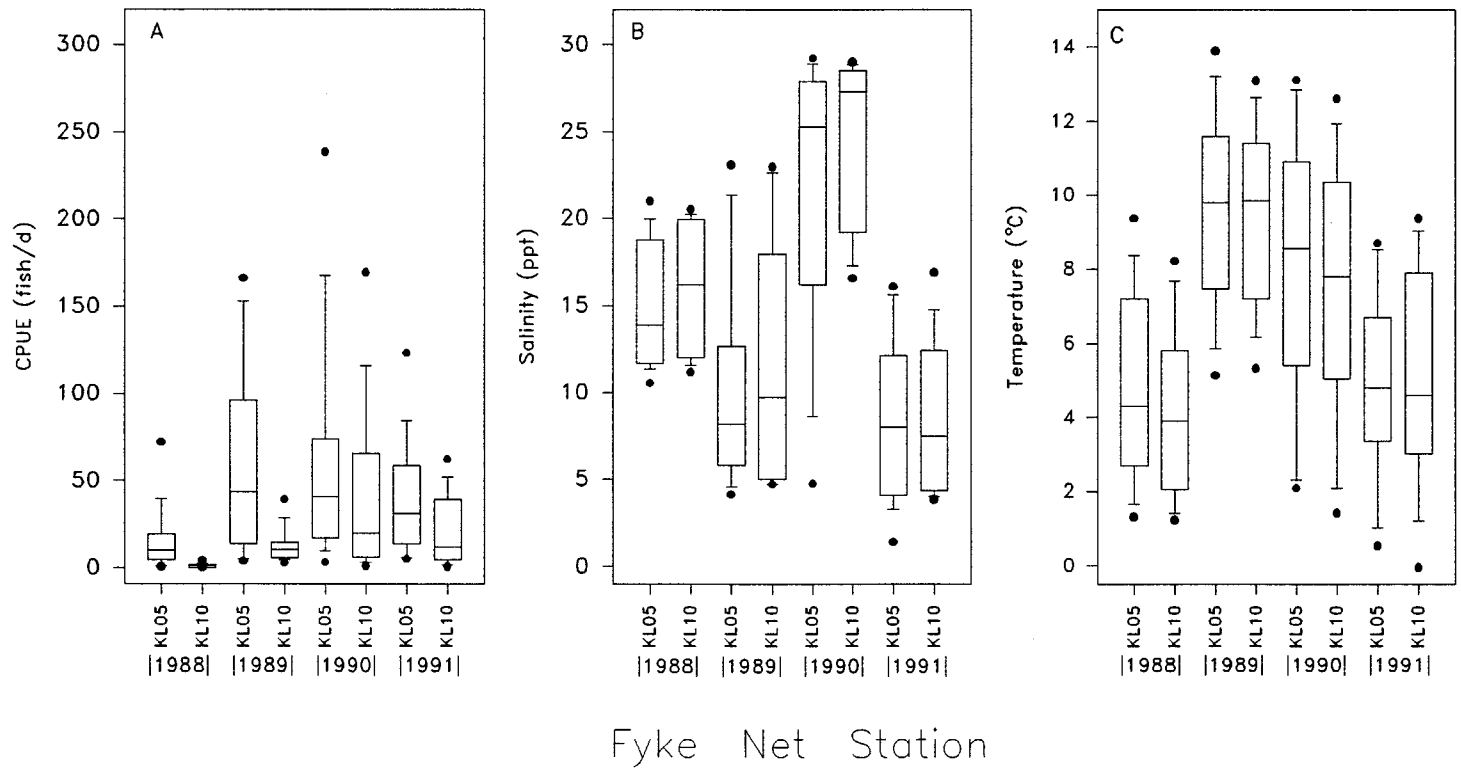

FIGURE 6.49.– Boxplots of (A) catch per effort for Arctic flounder, (B) salinity, and (C) temperature for Kaktovik Lagoon fyke net stations during 1988-91.

net station KL05 in 1988 when a negative correlation with salinity was present (Figure 6.50). Catch per unit effort at net station KL05 was also directly related to east wind components in 1988, 1989, and 1991 (Tables 6.24, 6.25). While correlations between CPUE and physical variables were variable at net station KL10 over the four year study period, relatively high daily catch rates were strongly correlated with water temperature in 1990 ($r^2 = 0.58$) and 1991 ($r^2 = 0.76$). We also detected a positive relationship between temperature and daily catch rates in the stepwise regression analyses (Table 6.25).

Jago Lagoon.— Arctic flounder daily catch rates in Jago Lagoon generally decreased as the sampling season progressed (Table 6.6), coincident with the gradual decrease in water temperatures and increase in salinities as the influence of coastal runoff diminished (Figure 6.51). Similar to other sampling areas, increased CPUE was associated with higher water temperatures for station-specific and pooled data (Table 6.24). We also identified an inverse relationship between salinity and CPUE by stepwise regression for net station JL14 in 1989 and 1991. An east wind component was positively related to 1991 daily catch rates at both Jago Lagoon net stations (Table 6.25).

Beaufort Lagoon.— Although temperature and salinity regimes were similar between net stations BL02 and BL04, daily catch rates at net station BL02 were higher in 1990, suggesting a location effect (Figure 6.52). The disparity in daily catch rates between net stations contributed to poor results for stepwise regression modelling efforts on pooled data ($R^2 \leq 0.13$). Station-specific results were most successful for net station BL02, where daily catch rates were primarily associated with water temperature for 1990 and 1991 (Table 6.24). A seasonal trend of decreasing daily catch rates near the end of the sampling season, coincident with decreasing temperatures, was primarily responsible for this association. North wind components were also associated with daily catch rates, although the direction of the effect varied. As such, an interpretation of causal mechanisms was unclear. High variation in daily catch rates remained difficult to correlate with short-term environmental influences.

Pokok Bay.— Synoptic environmental and CPUE sampling in Pokok Bay occurred over a relatively short period in late August and early September. Arctic flounder CPUE was higher early in the sampling season when water temperatures greater than 5°C and salinities were near 15 ppt. Similar to other sampling areas, CPUE was positively associated with water temperature and daily catch rates dropped as temperatures decreased in September. We detected the highest Arctic flounder daily catch rates at net station PB01 in late July, prior to collection of corresponding environmental data (Figure 6.15).

Discussion

Relative Abundance and Distribution

Our results suggest that the abundance of Arctic flounder along the Arctic Refuge coast varies more among years than among sampling areas. Year class

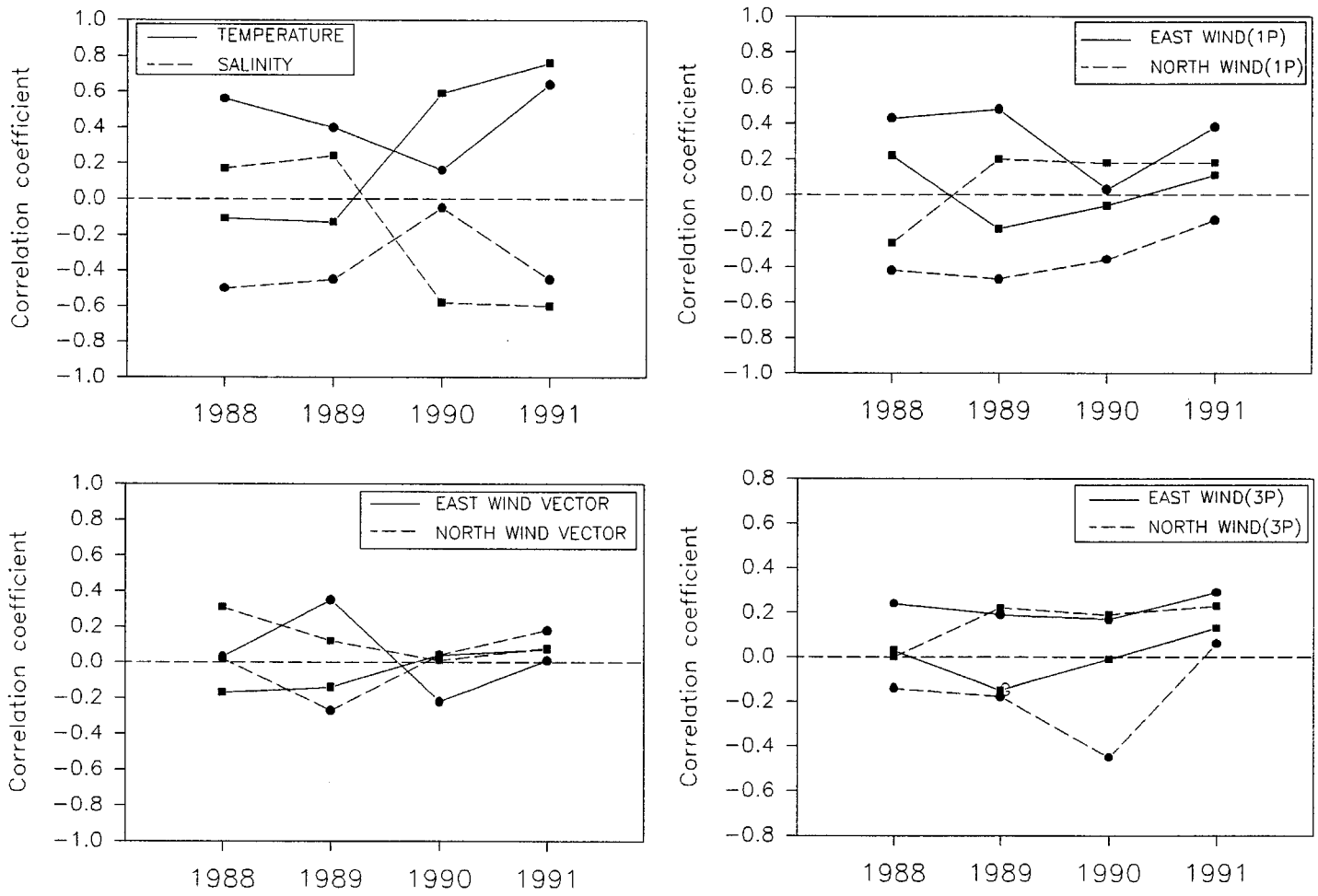

FIGURE 6.50.— Correlations between environmental variables and Arctic flounder CPUE from fyke net stations KL05 (•) and KL10 (▪) in Kaktovik Lagoon, 1988-91. [1P=mean wind vector for previous day; 3P=mean wind vector over 3 previous days].

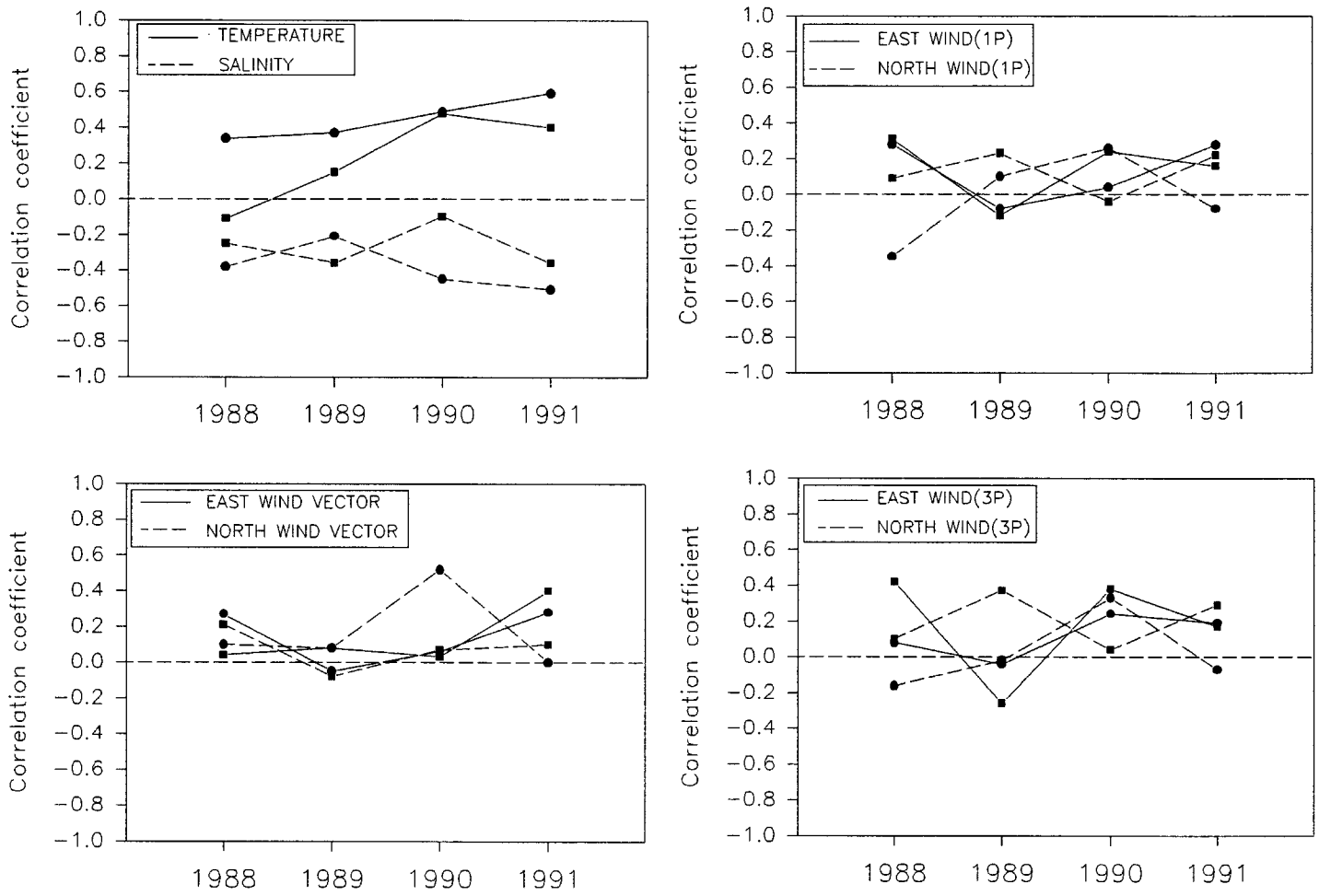

FIGURE 6.51.— Correlations between environmental variables and Arctic flounder CPUE from fyke net stations JL12 (•) and JL14 (▪) in Jago Lagoon, 1988-91. [1P=mean wind vector for previous day; 3P=mean wind vector over 3 previous days].

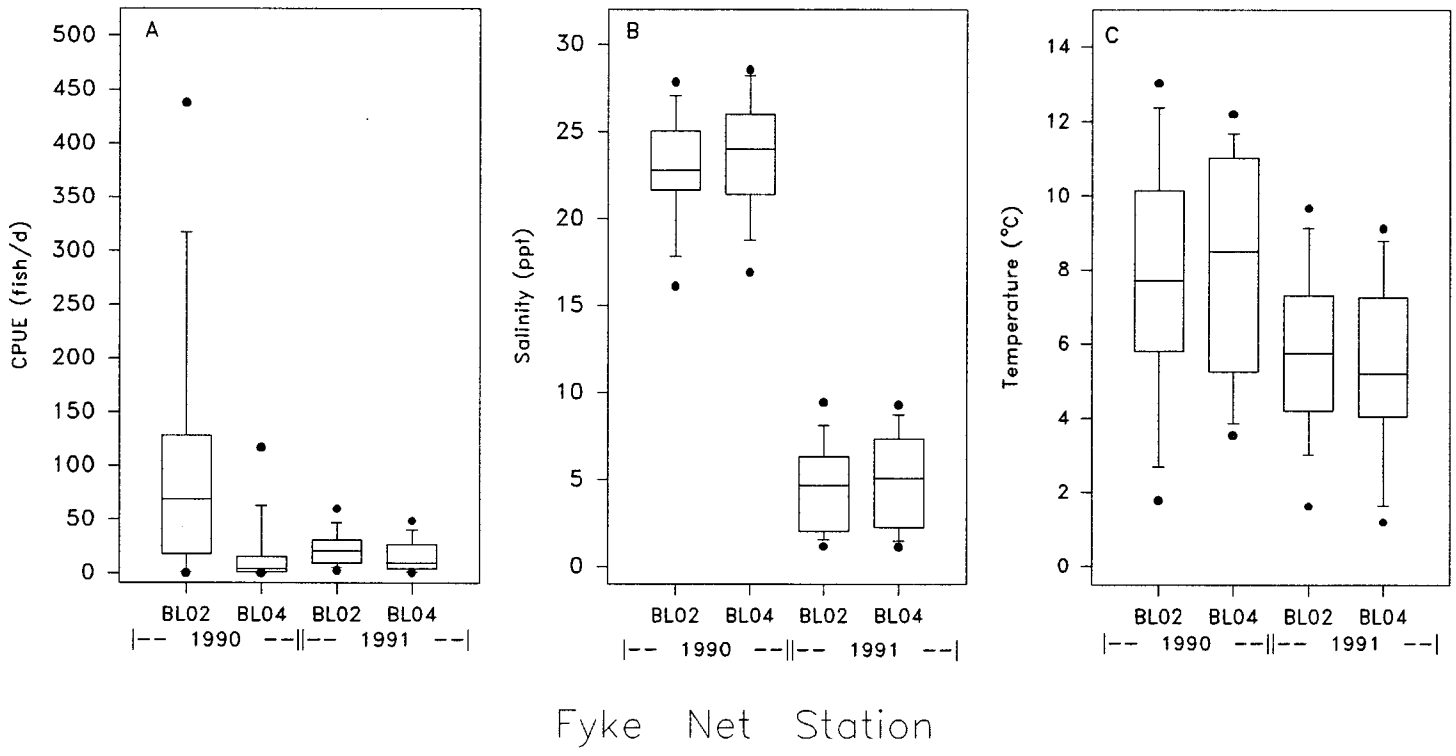

FIGURE 6.52.– Boxplots of (A) catch per effort for Arctic flounder, (B) salinity, and (C) temperature for Beaufort Lagoon fyke net stations during 1990-91.

strengths of Arctic flounder in the Barents Sea have varied widely (Kobelev 1989). If this condition is also true in the Beaufort Sea, high annual variation in abundance would result from the variable influence of the newly recruited age class. For example, Arctic flounder in the 50-80 mm TL interval were virtually absent in Kaktovik and Jago lagoons in 1988 and 1989, but were extremely abundant in 1990 and 1991. This suggests that reproductive success may have been much greater in the latter two years, a hypothesis which would account for both the large among-year variability and the relative ranking of mean annual catch rates.

Spatial and temporal variability in the relative abundance of Arctic flounder have been previously reported (Bond and Erickson 1989, 1991). Bond and Erickson (1989, 1991) observed fluctuations in daily catch rates at and among sampling sites in Phillips Bay, Yukon Territories (1985-86), and the Anderson River estuary, Northwest Territories (1989). During the latter part of each sampling season declines in daily catch rates were found to have occurred.

Our analyses detected significant variation among net stations and sampling areas. The higher daily catch rates at net station KL05 in 1988, 1989, and 1991, and in Kaktovik Lagoon in 1988 and 1989 suggest favorable conditions for Arctic flounder in these locations. The spatial differences found in relative abundance could have been a result of food item distributions (Bond and Erickson 1989) and/or a consequence of hydrographic conditions (see ***Environmental Influences on CPUE***).

Early summer inshore and late summer offshore movements of Arctic flounder resulting in declining daily catch rates have been reported (Bond and Erickson 1989). Data collected during our study appear to have annual temporal trends in support of this observation. Inshore movements appear to have been completed before sampling began (i.e. net station SC01, in 1990 and 1991, net station KL10 in 1988, 1990, and 1991). The difference found between some of the daily catch rates at the beginning and the end of the sampling season may result from offshore movement (i.e. net station KL05 in 1991, JL12 in 1989, and Simpson Cove in 1990). Deviations from these patterns could be due to movements having occurred at different times and rates in each sampling location and year.

Among-year comparisons indicate two trends. First, the 1988 sampling season had some of the lowest overall and within time period daily catch rates. Secondly, the daily catch rates were generally stable between years at some locations.

Although abundance varied, Arctic flounder were present along the Beaufort Sea coastline of the Arctic Refuge throughout the summer of each sampling season. This widespread distribution suggests that localized coastal development is unlikely to impact Arctic flounder populations through loss of critical habitat. Thus Arctic flounder represent a valuable indicator species. Regional absences of Arctic flounder subsequent to development may indicate significant alterations in coastal habitat conditions.

However, further sampling is necessary to identify the effects of inshore and offshore movements on localized relative abundance. In addition, a longer time series of data is necessary to identify factors affecting recruitment of Arctic flounder. This information would aid our ability to characterize annual variation, to discern development-related effects from natural variability, and to identify possible cyclic patterns of abundance.

Length Frequency Distributions

We documented bimodal length frequency distributions for Arctic flounder. The first mode, 50-150 mm TL, represented immature fish and the second mode, 200-250 mm TL, most likely represented mature fish. This species is thought to reach sexual maturity between 4 and 8 years of age (Kobelev 1989). According to our age and growth analysis (see ***Age and Growth***), Arctic flounder reach age-4 at an average length of 142 mm TL and age-10 at an average length of 200 mm TL. These mean lengths, 142 and 200 mm, are at the length-modal peaks of the length frequency distributions and probably distinguish immature from mature Arctic flounder. Like many marine fish species, juvenile fish commonly segregate from mature fish as a means of avoiding cannibalism (Valiela 1984).

During 1988 and 1989, we caught a higher percentage of large fish (200-250 mm TL) in Simpson Cove and Kaktovik and Jago lagoons; whereas we caught a higher percentage of small fish (50-150 mm TL) in 1990 and 1991. This change in length frequency distributions may by a result of inconsistent effort, but this is unlikely since we placed the fyke net stations in the same locations during all four years. A more likely explanation is that large Arctic flounders occurred more frequently in 1988 and 1989, whereas smaller fish were more numerous in 1990 and 1991. Possible mechanisms causing small Arctic flounder to become more abundant in these locations in 1990 and 1991 were not addressed by our sampling design. However, a possible causal factor such as changes in availability of suitable habitat could have influenced the distribution pattern for either adult or juvenile fish. The availability of suitable habitat can fluctuate due to changes in physical (i.e. water temperature and salinity) or biological (i.e. prey availability) parameters. Arctic flounder daily catch rates were positively correlated with temperature and negatively correlated with salinity within a given season (see ***Environmental Influences on CPUE***). Although we did not address the question of how environmental factors affect the CPUE of distinct size classes of Arctic flounder, salinity and temperature conditions may have been more suitable for larger fish in 1988 and 1989 and for smaller fish in 1990 and 1991. While we cannot answer the questions of causal relationships as they relate to distributions of different age classes, a longer-term project with specific objectives to study these mechanisms would clarify the trends in length frequency distributions.

Condition

Gender differences.— Gender differences are common and separate sampling of female and male fish for growth and condition are recommended (Bagenal and Tesch 1978; Anderson and Gutreuter 1983). Kobelev (1998) demonstrated sexual dimorphism in Arctic flounder in growth rates and age of sexual maturation (Kobelev 1989). Differences found between females and males confirm that

separate sampling by sex should continue for Arctic flounder.

Seasonal differences.— Higher Arctic flounder condition found in the later sampling period agree with expectations that Arctic fish feed, store energy, and develop gonadal tissue during the short summer open-water season. Spawning is thought to occur in January and February (Kobelev 1989). By September, substantial development of gonads would be required. Demonstrated temporal differences in condition suggest that comparative studies (i.e. among years or areas) consider sample timing to minimize variation. Multi-year studies should select the same short time frame to sample each year. Within one year, multiple sites need to be sampled simultaneously.

Overwintering.— Declines in condition are in agreement with current hypotheses that Arctic fish store energy during the summer and consume it in the winter. Spawning during the winter could also be a factor in overwinter decreases in condition (Kobelev 1989).

Spatial differences.— Differences found in Arctic flounder condition among areas in July must be interpreted in light of results indicating slope differences and those indicating no intercept differences; our results were mixed and difficult to interpret. No firm statements can be made. Efforts to select length intervals of similar slope may improve evidence one way or the other. In September results were more consistent and indicated spatial differences when outliers were discarded or no differences when outliers are retained (except during 1989). Differences are small, but still of concern when trying to minimize variation. Kobelev (1989) reported spatial differences in growth rates which might support these results. Conservative study design would dictate that future sampling be site specific if it is to be sensitive to changes in condition.

Annual differences.— Low condition of Arctic flounder in 1991, relative to 1989 and 1990, is consistent with patterns in other species from this study. High annual variation of environmental conditions is well documented in the Arctic. In 1991 the ice pack did not recede appreciably from the coast. Low condition could be associated with the ice pack through a number of direct or indirect mechanisms. Water temperatures were lower in 1991 (Figures 6.48, 6.49, 6.52). Wind-aided transport of food into nearshore areas from offshore (Craig 1984) could have been blocked by surface ice. Finally, shading by ice could reduce primary production in offshore areas. Although the specific mechanism is not known, annual variation must be accounted for if comparative studies are to be sensitive to changes in fish condition.

Age and Growth

Two strong age and length groups of Arctic flounder occurred during this study. The first group or mode represented juvenile fish and the second mode corresponded to adult fish (Kobelev 1989). A steady increase in overall mean length at age indicated continued growth after maturity. Arctic flounder mature at 3-4 years for males and 4-8 years for females (Kobelev 1989).

Results of our growth analyses were similar to those for Arctic flounder collected in the Barents Sea (Kobelev 1989). Kobelev reported mean lengths at

age for 3,598 Arctic flounder. When the sexes were pooled, those mean lengths were comparable to ours at ages 4-10. As with the population in the Barents Sea, Arctic flounder along the Beaufort Sea coast appear to grow very slowly. The mean annual increase in length increment was 14 mm for our population and 13 mm for those Arctic flounder in the Barents Sea (Kobelev 1989) for ages 1-14. Long lived, slow growing fish are typically more vulnerable to negative perturbations in their environment. As such Arctic flounder should be considered as important indicator species if development occurs in coastal areas of the Arctic Refuge.

Movements

Previous findings suggest that the movement of Arctic flounder is generally inshore/offshore and localized (Andriyashev 1954; Griffiths 1983; Craig 1984; Bond and Erickson 1989). Due to the study design the inshore/offshore movement described for this species cannot be inferred by our tag-recapture results. However, our results do appear to be consistent with the theory that movement of Arctic flounder along the coast is localized. The high incidence of recaptures occurring within the original tagging area suggest that Arctic flounder do not frequently move between the sampling areas. Movement of five Arctic flounder between Kaktovik and Jago lagoons can be attributed to the proximity and rather limited separation of these lagoons. The lagoons are adjacent to one another and separated by a peninsula of land, Manning Point, which narrows to three meters wide at its base. A small stretch of the peninsula becomes submerged during high water, aided by strong winds, connecting the lagoons. Fish have been observed moving over this spit during high water. Another travel route is Nelsaluk Pass connecting the two lagoons at the tip of the peninsula.

Although localized movement appears to be the norm, we documented Arctic flounder moving considerable distances along the coast. Four Arctic flounder moved between Simpson Cove and the Kaktovik/Jago lagoon complex, representing a minimum travel distance of approximately 60 km. There are at least two possible explanations for this movement. First, this long distance movement could be a rare occurrence. Only 0.4% of the tagged fish or 6.9% of the recaptured fish, not including movement between Kaktovik and Jago lagoons, moved "long" distances along the shoreline to other sampling areas. Secondly, movement of one Arctic flounder of the four that moved between the Kaktovik/Jago lagoon complex and Simpson Cove could be attributed to the unique wind and water conditions during the 1990 sampling season. This period was the only sampling season since 1987 in which winds were from the east and were relatively strong during July and August (LGL, 1991). This movement could also have been aided by currents that were caused by the prevailing easterly winds.

Further tag-recapture studies will be necessary to thoroughly examine Arctic flounder movement along the coast. To properly document movement, a multi-year tag and recapture study of Arctic flounder consisting of both inshore and offshore locations at specific sites along the coast is necessary.

Environmental Influences on CPUE

Arctic flounder exhibited an overall trend of decreasing CPUE towards the end of the summer sampling season as water temperatures dropped and salinities increased. This seasonal trend resulted in Arctic flounder CPUE being positively associated with temperature and negatively associated with salinity in both correlation and stepwise regression analyses. Whether this seasonal abundance pattern was a response to preferred thermohaline conditions or, alternatively, induced by trophic or reproductive stimuli remains unclear. Kobelev (1989) reports Arctic flounder in the Barents Sea do not move more than 40 km offshore and generally feed in shallow nearshore waters during summer. Our data suggest that higher numbers of Arctic flounder were present along the lagoon shorelines when water temperatures were near their summer maximums. This is consistent with the work of Bond and Erickson (1987) in the Yukon Territory, who found the highest summer concentrations of Arctic flounder at the warmest and least saline sampling stations in Phillips Bay, near the mouth of the Babbage River.

The nature of the relationship between CPUE and east winds observed in Kaktovik Lagoon is uncertain, but may be related to offshore conditions created by the upwelling which follows easterly winds (Hale 1991). Colder upwelled waters may induce movement into the more protected waters of Kaktovik Lagoon.

Vertical thermohaline isobars of the coastal lagoons suggest that benthic waters may be less affected by short-term weather events than are surface waters (Hale 1990). As such, daily movements of the substrate-oriented Arctic flounder may be less influenced by meteorologic events than those fishes inhabiting the upper water column. Salinity and temperature regimes for net stations within some sampling areas appeared to be similar, while daily catch rates were significantly different. The presence of this location effect was most noticeable in Kaktovik Lagoon in 1988 and 1989 and in Beaufort Lagoon in 1990, and suggests the presence of some influential variable other than those recorded in our study. When net station CPUE data were pooled, however, there were few significant differences between sampling areas over a sampling season (Table 6.2). As with other resident species, the offshore physical conditions may affect inshore movement and distribution. High variability between net stations within a sampling area underscores the need for increased localized sampling effort to monitor areas potentially affected by development.

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Appendix A: Seasonal Catch Per Unit Effort 1988-91

Table A.1.— Seasonal CPUE (fish/d) by net station in Arctic Refuge coastal waters, July - September 1988. Number of days fished at each net station: SC01 - 53.46 d; KL05 - 61.86 d; KL10 - 56.99 d; JL12 - 52.83 d; JL14 - 56.93 d; PB01 - 53.19 d; PB02 - 33.17 d.

Family - Species	Net Station						
	SC01	KL05	KL12	JL12	JL14	PB01	PB02
Salmonidae-							
Arctic char	10.16	17.75	5.55	5.38	3.41	2.60	1.39
Least cisco	1.91	0.50	0.81	0.51	0.44	0.58	0.99
Broad whitefish	0.17	0.00	0.05	0.11	0.07	0.06	0.12
Round whitefish	0.00	0.00	0.00	0.00	0.00	0.02	0.00
Arctic grayling	0.04	0.02	0.00	0.00	0.00	0.00	0.00
Chum salmon	0.00	0.02	0.00	0.00	0.00	0.00	0.00
Pleuronectidae-							
Arctic flounder	1.12	16.84	1.14	1.10	4.55	4.27	6.75
Osmeridae-							
Rainbow smelt	0.90	0.45	0.23	0.51	2.69	0.53	2.44
Capelin	1.01	0.00	0.00	0.11	0.09	0.06	0.18
Clupeidae-							
Pacific herring	0.00	0.02	0.04	0.00	0.00	0.02	0.15
Gadidae-							
Arctic cod	311.34	15.97	32.25	55.36	29.77	7.39	141.09
Saffron cod	2.34	2.60	1.89	1.48	1.55	2.63	7.36
Cyclopteridae-							
Greenland sea snail	0.07	0.00	0.00	0.00	0.00	0.00	0.00
Stichaeidae-							
Slender eelblenny	0.45	0.06	0.28	0.09	0.04	0.00	0.00
Gasterosteidae-							
Ninespine stickleback	3.59	1.03	6.14	3.96	20.31	1.13	7.08
Cottidae-							
Fourhorn sculpin	39.58	90.18	29.18	49.52	53.52	14.51	29.06
Arctic sculpin	0.24	0.19	0.21	0.08	0.09	0.24	0.18

Table A.2.— Seasonal CPUE (fish/d) by net station in Arctic Refuge coastal waters, July - September 1989. Number of days fished at each net station: SC01 - 63.46 d; SC04 - 60.36 d; KL05 - 59.26 d; KL10 - 62.96 d; JL12 - 61.10 d; JL14 - 63.07 d.

Family - Species	Net Station					
	SC01	SC04	KL05	KL10	JL12	JL14
Salmonidae-						
Arctic char	4.35	3.58	6.51	8.15	10.34	5.07
Arctic cisco ≤ 200 mm FL	9.69	15.36	1.64	4.31	22.24	10.22
Arctic cisco > 200 mm FL	8.38	13.82	1.28	3.52	8.40	2.97
Least cisco	0.17	0.51	0.03	0.11	0.03	0.02
Broad whitefish	0.46	0.38	0.05	0.21	0.15	0.11
Arctic grayling	0.08	0.33	0.03	0.03	0.00	0.00
Pink salmon	0.06	0.30	0.05	0.05	0.02	0.03
Chum salmon	0.02	0.00	0.00	0.02	0.02	0.00
Pleuronectidae-						
Arctic flounder	3.89	20.56	58.97	13.07	5.34	16.52
Osmeridae-						
Rainbow smelt	0.70	2.00	0.03	0.17	0.76	13.62
Capelin	0.24	0.10	0.00	0.00	0.10	0.00
Clupeidae-						
Pacific Herring	0.19	0.45	0.05	0.00	0.02	0.00
Gadidae-						
Arctic cod	2516.88	706.85	1.27	1.48	10.39	8.24
Saffron cod	2.19	2.98	1.40	3.95	0.98	0.98
Cyclopteridae-						
Greenland sea snail	0.00	0.07	0.00	0.00	0.02	0.00
Stichaeidae-						
Slender eelblenny	0.05	0.10	0.15	0.24	2.25	0.18
Gasterosteidae-						
Ninespine stickleback	3.34	24.35	108.01	9.83	111.54	134.19
Threespine stickleback	0.09	0.00	0.03	0.02	0.00	0.02

Table A.2.— Continued.

Family - Species	Net Station					
	SC01	SC04	KL05	KL10	JL12	JL14
Cottidae-						
Fourhorn sculpin	143.37	152.31	97.46	128.70	126.16	104.56
Arctic sculpin	0.50	0.03	0.22	0.22	1.13	0.19
Arctic staghorn sculpin	0.03	0.00	0.00	0.03	0.05	0.00
Ammodytidae-						
Pacific sandlance	0.00	0.00	0.02	0.00	0.02	0.00
Hexagrammidae-						
Whitespotted greenling	0.02	0.00	0.00	0.00	0.00	0.00

Table A.3.— Seasonal CPUE (fish/d) by net station in Arctic Refuge coastal waters, July - September 1990. Number of days fished at each net station: SC01 - 56.43 d; SC04 - 56.35 d; KL05 -56.03 d; KL10 - 65.59 d; JL12 - 46.30 d; JL14 - 54.53 d; BL02 - 62.39 d; BL04 - 49.23 d.

Family - Species	Net Station							
	SC01	SC04	KL05	KL10	JL12	JL14	BL02	BL04
Salmonidae-								
Arctic char	19.33	9.05	9.50	5.37	4.51	9.24	2.05	0.98
*Arctic cisco ≤ 200 mm FL	26.31	51.90	514.10	54.32	509.33	478.96	490.11	45.11
*Arctic cisco > 200 mm FL	9.93	4.42	2.97	1.03	1.33	1.66	0.27	1.67
Least cisco	10.24	4.26	0.43	0.42	0.65	0.59	0.05	0.20
Broad whitefish	0.09	0.02	0.00	0.00	0.00	0.00	0.03	0.00
Round whitefish	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pink salmon	0.04	0.02	0.00	0.08	0.02	0.02	0.00	0.00
Pleuronectidae-								
Arctic flounder	29.26	44.38	60.36	41.54	48.40	88.94	115.14	19.93
Osmeridae-								
Rainbow smelt	2.20	9.37	1.12	0.31	1.19	2.70	0.27	0.08
Capelin	197.16	0.53	0.05	0.05	0.19	0.15	0.00	0.00
Clupeidae-								
Pacific herring	0.05	0.00	0.29	0.11	0.09	0.11	0.02	0.00
Gadidae-								
Arctic cod	1096.24	351.77	28.27	5.73	1.86	4.86	0.42	0.00
Saffron cod	5.14	5.18	5.84	6.05	4.36	4.60	1.12	0.93
Cyclopteridae-								
Greenland sea snail	1.08	1.03	0.02	0.00	0.02	0.00	0.00	0.04
Stichaeidae-								
Slender eelblenny	1.28	0.00	0.68	0.33	0.04	0.02	0.10	0.14
Gasterosteidae-								
Ninespine stickleback	4.02	2.80	56.10	19.66	12.25	28.55	5.18	0.41

Table A.3.— Continued.

Family - Species	Net Station							
	SC01	SC04	KL05	KL10	JL12	JL14	BL02	BL04
Cottidae-								
Fourhorn sculpin	119.04	164.29	100.15	52.73	109.50	92.54	95.70	8.84
Arctic hooker sculpin	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Arctic staghorn sculpin	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00
Arctic sculpin	0.92	0.07	0.29	0.60	3.22	0.46	4.63	0.63
Ammodytidae-								
Pacific sandlance	0.02	0.00	0.07	0.00	0.02	0.00	0.00	0.00
Anarichadidae-								
Bering wolffish	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00

*Number of days fished at each net station: SC01 - 54.46 d; SC04 - 55.41 d; KL05 - 52.84 d; KL10 - 39.93 d; JL12 - 44.39 d; JL14 - 50.60 d; BL02 - 60.34 d; BL04 - 41.95 d.

Table A.4.— Seasonal CPUE (fish/d) by net station in Arctic Refuge coastal waters, July - September 1991. Number of days fished at each net station: SC01 - 60.80 d; SC04 - 38.21 d; KL05 -55.73 d; KL10 - 61.45 d; JL12 - 49.75 d; JL14 - 62.90 d; BL02 - 60.95 d; BL04 - 53.77 d.

Family - Species	Net Station							
	SC01	SC04	KL05	KL10	JL12	JL14	BL02	BL04
Salmonidae-								
Arctic char	83.96	22.61	23.25	14.89	12.12	10.10	20.56	15.58
*Arctic cisco ≤ 200 mm FL	4.38	4.00	0.88	1.08	1.31	3.61	13.76	7.28
*Arctic cisco > 200 mm FL	10.47	1.06	1.78	2.94	2.87	1.13	2.61	5.04
Least cisco	1.10	0.29	0.09	0.08	0.10	0.00	0.08	0.13
Broad whitefish	0.02	0.00	0.00	0.03	0.06	0.00	0.02	0.02
Arctic grayling	0.03	0.03	0.05	0.07	0.00	0.00	0.07	0.06
Pink salmon	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pleuronectidae-								
Arctic flounder	33.55	45.04	38.63	19.48	12.00	28.81	21.92	15.36
Osmeridae-								
Rainbow smelt	9.19	11.33	0.14	0.72	2.13	1.48	0.54	0.13
Capelin	0.05	0.00	0.00	0.00	0.02	0.00	0.00	0.00
Clupeidae-								
Pacific herring	0.02	0.00	0.00	0.03	0.00	0.00	0.00	0.00
Gadidae-								
Arctic cod	125.82	73.67	4.31	7.24	1.37	5.02	0.07	0.11
Saffron cod	4.28	2.36	5.44	8.62	6.09	5.01	9.84	4.82
Cyclopteridae-								
Greenland sea snail	0.15	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Stichaeidae-								
Slender eelblenny	0.15	0.00	0.23	2.05	0.02	0.00	0.10	0.56
Gasterosteidae-								
Ninespine stickleback	2.88	3.95	0.57	0.75	1.67	5.96	3.31	0.80

Table A.4.— Continued.

Family - Species	Net Station							
	SC01	SC04	KL05	KL10	JL12	JL14	BL02	BL04
Cottidae-								
Fourhorn sculpin	85.85	265.94	94.83	58.83	50.75	98.82	52.85	16.01
Arctic staghorn sculpin	0.02	0.00	0.02	0.07	0.02	0.02	0.00	0.02
Arctic sculpin	0.54	0.05	0.11	0.52	0.86	0.11	0.85	0.13
Ammodytidae-								
Pacific sandlance	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00

*Number of days fished at each net station: SC01 - 55.90 d; SC04 - 29.24 d; KL05 - 37.62 d; KL10 - 43.59 d; JL12 - 37.32 d; JL14 - 59.27 d; BL02 - 54.05 d; BL04 - 46.04 d.

Appendix B: Tag Recovery Data

TABLE B.1.— Summary of tagging and recapture data for Arctic char recaptured along the Beaufort Sea coast, summer 1988-91. Dashed line indicates lengths which were not obtained.

Tagging location	Tagging date	Recapture location	Recapture date	Minimum distance traveled (km)	Length at tagging (mm)	Length at recapture (mm)	Tag number
			1989				
[b]Hulahula	09/07/83	JL14	07/13/89	30.0	377	618	FWS 05610
[b]Aichilik	08/15/84	BL02	07/18/89	7.0	467	503	FWS 03437
			1990				
JL14	07/19/90	SC01	08/17/90	62.0	392	411	FWS 09707
SC04	07/29/90	SC04	07/30/90	0.0	317	317	FWS 11394
BL02	08/05/90	BL02	09/03/90	0.0	345	347	FWS 12690
[a]Oruk.	08/14/86	JL12	07/24/90	21.0	510	555	FWS 07468
JL14	08/10/90	JL14	08/13/90	0.0	339	344	FWS 13578
JL14	08/03/90	JL14	08/08/90	0.0	312	318	FWS 13171
KL10	07/12/90	KL05	07/14/90	5.5	386	380	FWS 08863
KL05	07/14/90	KL05	07/16/90	0.0	323	333	FWS 09782

TABLE B.1.— Continued.

Tagging location	Tagging date	Recapture location	Recapture date	Minimum distance traveled (km)	Length at tagging (mm)	Length at recapture (mm)	Tag number
			1990				
KL10	07/15/90	KL05	07/17/90	5.5	308	337	FWS 09754
			07/26/90				FWS 09754
KL05	07/16/90	KL05	07/18/90	0.0	403	405	FWS 09584
JL14	08/03/90	KL10	08/11/90	5.0	278	376	FWS 13164
KL10	08/27/90	KL10	08/28/90	0.0	504	499	FWS 14937
KL10	08/28/90	[b]Hulahula	09/19/90	20.0	499	---	FWS 14039
		JL14	07/10/90		440		LGL 0299
		[c]Griffin PT	08/15/90				LGL 04515
			1991				
BL02	07/14/90	BL02	07/19/91	0.0	490	441	FWS 12141
BL02	08/03/90	BL02	07/21/91	0.0	425	452	FWS 12321
BL02	08/04/90	BL04	07/28/91	2.0	337	394	FWS 12693
		BL02	07/31/91	0.0		396	FWS 12693

TABLE B.1.— Continued.

Tagging location	Tagging date	Recapture location	Recapture date	Minimum distance traveled (km)	Length at tagging (mm)	Length at recapture (mm)	Tag number
			1991				
BL02	07/26/91	BL04	08/03/91	2.0	337	394	FWS 12693
		BL02	08/05/91	0.0	526	521	FWS 12693
BL02	07/26/91	BL02	08/01/91	0.0	526	527	FWS 13817
			08/02/91	0.0	462	461	FWS 13817
KL05	07/16/90	SC01	07/14/91	57.0	337	378	FWS 09574
BL02	08/03/90	BL02	07/20/91	0.0	370	413	FWS 12322
KL10	07/15/90	KL10	07/31/91	0.0	420	380	FWS 09755
KL10	08/11/90	JL12	07/19/91	3.0	270	311	FWS 13694
JL14	08/07/90	JL12	07/28/91	5.0	341	396	FWS 13509
JL14	08/08/90	SC01	08/03/91	68.0	336	388	FWS 13561
SC01	08/19/90	BL04	08/17/91	109.0	345	390	FWS 11778
SC01	07/21/90	JL14	07/22/91	62.0	471	472	FWS 11143
[a]Oruk.	08/05/86	BL02	07/19/91	32.0	320	527	FWS 07162
SC01	08/21/90	[d]BTI	07/13/91	55.0	425	---	FWS 11969
JL14	08/03/90	[d]BTI	07/12/91	3.0	350	---	FWS 13016

TABLE B.1.— Continued.

Tagging location	Tagging date	Recapture location	Recapture date	Minimum distance traveled (km)	Length at tagging (mm)	Length at recapture (mm)	Tag number
			1991				
KL05	07/31/90	[b]Firth	09/19/91	170.0	431	476	FWS 13212
BL02	07/22/91	BL02	07/25/91	0.0	426	424	FWS 13914
BL02	07/24/91	BL02	07/26/91	0.0	387	388	FWS 13897
			08/02/91	0.0		386	FWS 13897
			08/05/91	0.0		389	FWS 13897
BL02	07/22/91	BL02	07/28/91	0.0	447	447	FWS 13920
BL02	07/20/91	BL02	08/02/91	0.0	452	444	FWS 13870
BL02	07/26/91	BL02	08/02/91	0.0	324	328	FWS 13274
BL02	07/21/91	BL04	07/26/91	2.0	330	330	FWS 13950
BL02	07/22/91	BL04	07/26/91	2.0	335	330	FWS 13935
BL02	07/26/91	BL04	07/27/91	2.0	524	528	FWS 13806
BL02	07/26/91	BL04	07/28/91	2.0	380	379	FWS 13810
BL02	07/25/91	BL04	07/30/91	2.0	427	426	FWS 13444

TABLE B.1.— Continued.

Tagging location	Tagging date	Recapture location	Recapture date	Minimum distance traveled (km)	Length at tagging (mm)	Length at recapture (mm)	Tag number
			1991				
BL02	07/21/91	BL04	08/02/91	2.0	396	398	FWS 13860
BL04	07/22/91	BL02	07/23/91	2.0	444	438	FWS 13901
BL04	07/21/91	BL02	07/25/91	2.0	498	501	FWS 13946
BL04	07/24/91	BL02	07/26/91	2.0	364	368	FWS 13320
BL04	07/24/91	BL02	07/26/91	2.0	381	381	FWS 13317
BL04	07/25/91	BL04	07/29/91	0.0	461	453	FWS 13959
		BL02	07/28/91	2.0		457	FWS 13959
BL04	07/27/91	BL02	07/28/91	2.0	451	450	FWS 13971
BL04	07/27/91	BL02	07/28/91	2.0	345	342	FWS 13962
BL04	07/25/91	BL02	07/26/91	2.0	512	510	FWS 13351
BL04	07/27/91	BL02	07/28/91	2.0	535	537	FWS 13955
BL04	07/26/91	BL02	07/30/91	2.0	335	343	FWS 13406
BL04	07/26/91	BL02	07/31/91	2.0	399	397	FWS 13259
BL04	08/07/91	BL02	08/16/91	2.0	377	379	FWS 12160
BL04	07/26/91	BL04	07/29/91	0.0	484	476	FWS 13256

TABLE B.1.— Continued.

Tagging location	Tagging date	Recapture location	Reacapture date	Minimum distance traveled (km)	Length at tagging (mm)	Length at recapture (mm)	Tag number
			1991				
BL04	07/26/91	BL04	07/29/91	0.0	320	318	FWS 13411
BL04	07/28/91	BL04	07/31/91	0.0	435	433	FWS 13290
KL05	07/24/91	BL02	08/24/91	61.0	324	330	FWS 14600
KL10	07/30/91	JL14	08/10/91	6.0	375	368	FWS 14768
KL10	07/17/91	KL05	08/04/91	6.0	384	390	FWS 14654
KL10	07/16/91	KL05	08/09/91	6.0	316	325	FWS 14638
KL10	07/22/91	KL05	08/13/91	6.0	321	325	FWS 14582
JL12	07/21/91	JL14	07/27/91	5.0	383	370	FWS 14614
JL12	07/21/91	JL14	08/12/91	5.0	352	359	FWS 14613
JL12	08/05/91	KL05	08/14/91	6.0	311	320	FWS 11735
JL14	07/18/91	JL12	07/21/91	5.0	389	458	FWS 14491
JL14	07/17/91	JL12	07/28/91	5.0	310	319	FWS 14412
			07/31/91			320	FWS 14412
JL14	07/14/91	JL14	07/19/91	0.0	456	342	FWS 14271
JL14	07/22/91	KL05	08/05/91	10.0	310	321	FWS 14810

TABLE B.1.— Continued.

Tagging location	Tagging date	Recapture location	Reacapture date	Minimum distance traveled (km)	Length at tagging (mm)	Length at recapture (mm)	Tag number
			1991				
JL14	07/21/91	KL05	08/07/91	10.0	303	299	FWS 14355
JL14	08/04/91	KL05	08/07/91	10.0	352	319	FWS 11647
JL14	07/13/91	KL10	07/18/91	6.0	362	364	FWS 14209
SC01	07/21/91	KL05	08/18/91	55.0	331	338	FWS 12248
SC01	07/15/91	SC01	07/17/91	0.0	375	375	FWS 12542
SC01	07/31/91	SC01	08/01/91	0.0	352	351	FWS 12053
SC01	07/27/91	SC01	08/02/91	0.0	425	427	FWS 12873
			1992				
KL05	07/14/90	[e]Kakto.	06/28/92	0.0	340	---	FWS 09033
KL10	07/14/91	[c]Manning Pt.	07/01/92	0.0	468	---	FWS 14341
KL05	07/15/90	[e]Kakto.	07/27/92	0.0	560	---	FWS 09769

[a]Oruktalik Lagoon [c]Arctic Refuge waters [e]Kaktovik Lagoon

[b]Rivers [d]Barter Island

TABLE B.2.— Summary of tagging and recapture data for Arctic cisco recaptured along the Beaufort sea coast, summer 1988-91. Dashed line indicates lengths which were not obtained.

Tagging location	Tagging date	Recapture location	Recapture date	Minimum distance traveled (km)	Length at tagging (mm)	Length at recapture (mm)	Tag number
				1988			
[a]St. 220	08/20/88	KL10	09/02/88	175.0	357	359	LGL 03150
				1989			
SC01	07/12/87	SC01	08/24/89	4.2	366	396	FWS 10024
[b]Oruk.	08/16/86	CB01	07/26/89	75.0	364	389	FWS 07522
				1990			
Camden Bay	07/27/90	Colville R.	11/05/90	240.0	365	---	FWS 11210
Camden Bay	07/29/90	Colville R.	10/22/90	240.0	358	---	FWS 11293
Camden Bay	07/29/90	Colville R.	10/18/90	240.0	308	---	FWS 11295
Camden Bay	07/29/90	Colville R.	11/12/90	240.0	324	---	FWS 11336
Camden Bay	07/31/90	Colville R.	10/25/90	240.0	330	---	FWS 11077

TABLE B.2.– Continued.

Tagging location	Tagging date	Recapture location	Recapture date	Minimum distance traveled (km)	Length at tagging (mm)	Length at recapture (mm)	Tag number
			1990				
Camden Bay	07/31/90	Colville R.	11/03/90	240.0	316	---	FWS 11087
Camden Bay	08/28/90	Colville R.	11/17/90	240.0	348	---	FWS 14067
Camden Bay	08/28/90	Colville R.	10/26/90	240.0	318	---	FWS 13221
[a]West dock	07/22/90	SC01	08/13/90	150.0	261	271	LGL 2821
[a]Heald Pt.	07/16/88	JL14	07/10/90	202.0	364	444	LGL 8800299
			1991				
KL05	08/04/90	Griffin Pt.	08/--/91	25.0	386	---	FWS 13159
KL05	08/04/91	Griffin Pt.	08/--/91	25.0	397	---	FWS 11637
Harrison Bay	09/11/85	BL04	08/08/91	390.0	283	413	LGL 01562
[a]Gwydyr Bay	07/31/85	BL04	08/19/91	253.0	271	368	LGL 35713
[a]Stump Island	07/23/91	KL10	08/11/91	175.0	320	---	LGL 10893
[a]West Beach	07/19/91	KL10	08/13/91	165.0	294	306	LGL 07454

[a]Prudhoe Bay area

[b]Oruktalik Lagoon

TABLE B.3.— Summary of tagging and recapture data for fourhorn sculpin in Arctic Refuge coastal waters, summer 1988-91. Dashed line indicates lengths which were not obtained.

Tagging location	Tagging date	Recapture location	Recapture date	Minimum distance traveled (km)	Length at tagging (mm)	Length at recapture (mm)	Tag number
			1988				
KL10	07/27/88	KL10	08/14/88	0.0	273	270	FWS 09124
JL12	08/02/88	KL05	08/26/88	8.0	245	246	FWS 09156
KL10	08/08/88	KL10	09/14/88	0.0	273	273	FWS 09492
KL05	08/30/88	[a]Pipsuk	09/05/88	7.0	242	---	FWS 09464
PB02	09/02/88	PB02	09/14/88	0.0	234	232	FWS 09342
			1989				
JL14	09/01/88	JL14	07/30/89	0.0	274	284	FWS 09469
JL14	09/01/88	JL14	08/02/89	0.0	282	294	FWS 09475

TABLE B.3.— Continued.

Tagging location	Tagging date	Recapture location	Recapture date	Minimum distance traveled (km)	Length at tagging (mm)	Length at recapture (mm)	Tag number
			1990				
JL14	07/23/90	JL14	08/04/90	0.0	232	230	FWS 09670
JL14	07/26/90	JL14	09/09/90	0.0	269	275	FWS 10985
KL10	08/30/90	KL05	09/06/90	5.5	219	215	FWS 14092
SC01	07/28/90	SC04	08/14/90	5.0	218	224	FWS 11286
SC04	07/31/90	SC04	08/14/90	0.0	220	224	FWS 11088
SC04	07/28/90	SC04	08/14/90	0.0	208	210	FWS 11265
KL10	07/22/90	KL10	08/08/90	0.0	219	220	FWS 09658
KL10	07/27/90	KL10	09/01/90	0.0	239	239	FWS 14929
SC01	07/27/90	KL10	09/09/90	57.0	205	215	FWS 11182
KL05	08/09/90	KL10	09/11/90	5.5	232	240	FWS 13508

TABLE B.3.— Continued.

Tagging location	Tagging date	Recapture location	Recapture date	Minimum distance traveled (km)	Length at tagging (mm)	Length at recapture (mm)	Tag number
			1991				
BL02	08/29/90	BL02	08/26/91	0.0	260	271	FWS 12298
BL04	08/27/90	BL02	07/24/91	3.0	205	236	FWS 12987
KL05	08/28/90	KL10	07/17/91	6.0	201	224	FWS 14055
KL10	08/30/90	KL05	09/01/91	6.0	204	210	FWS 14100
KL10	07/17/91	KL10	07/22/91	0.0	225	254	FWS 14663
KL10	07/14/91	KL10	07/26/91	0.0	231	229	FWS 14348
KL10	07/18/91	KL10	07/30/91	0.0	220	222	FWS 14432
JL14	07/26/91	JL14	07/27/91	0.0	215	225	FWS 09989
JL14	07/23/90	KL05	08/26/91	0.0	229	223	FWS 09894
JL14	07/16/91	JL14	07/18/91	0.0	208	210	FWS 14631
JL14	07/21/91	JL14	07/23/91	0.0	265	263	FWS 14375
SC01	08/14/90	JL14	07/27/91	62.0	204	220	FWS 11552
SC04	07/26/91	SC01	08/01/91	5.0	242	244	FWS 12341
		SC01	08/05/91	0.0			FWS 12341

[a]Arctic Refuge waters

TABLE B.4.— Summary of tagging and recapture data for Arctic flounder in Arctic Refuge coastal waters, summer 1988-91. Dashed line indicates lengths which were not obtained.

Tagging location	Tagging date	Recapture location	Recapture date	Minimum distance traveled (km)	Length at tagging (mm)	Length at recapture (mm)	Tag number
				1988			
PB02	08/28/88	PB02	09/14/88	0	256	256	FWS 09305
PB02	08/20/88	PB02	08/28/88	0	202	202	FWS 09382
				1989			
KL10	08/14/88	JL12	08/01/89	9.0	290	285	FWS 09192
JL14	07/27/88	JL12	09/04/89	0.0	255	255	FWS 09109
JL14	08/06/88	JL14	07/20/89	0.0	230	237	FWS 09203
KL05	09/08/88	JL14	07/21/89	12.5	245	247	FWS 09496
KL05	09/08/88	JL14	07/24/89	12.5	225	225	FWS 09499
JL14	07/20/88	JL14	07/15/89	0.0	260	260	FWS 09070
		JL14	07/26/89				FWS 09070
JL14	09/02/88	JL14	08/03/89	0.0	268	270	FWS 09478

TABLE B.4.— Continued.

Tagging location	Tagging date	Recapture location	Recapture date	Minimum distance traveled (km)	Length at tagging (mm)	Length at recapture (mm)	Tag number
				1989			
KL05	07/30/88	KL05	07/30/89	0.0	201	210	FWS 09136
KL10	07/29/88	KL05	08/05/89	5.5	241	246	FWS 09118
KL05	08/06/88	KL05	08/13/89	0.0	202	207	FWS 09215
KL05	08/18/88	KL05	08/16/89	0.0	284	290	FWS 09186
KL05	08/18/88	KL05	08/19/89	0.0	230	229	FWS 09177
KL05	08/06/88	KL05	08/29/89	0.0	225	232	FWS 09249
KL05	08/15/88	KL10	07/31/89	5.5	261	248	FWS 09188
				1990			
JL12	07/24/90	JL14	07/26/90	4.0	218	220	FWS 10947
KL10	07/16/90	JL14	08/07/90	18.0	234	236	FWS 08909
BL02	07/16/90	BL02	08/03/90	0.0	211	212	FWS 12089
SC01	07/26/90	SC04	07/30/90	5.0	213	218	FWS 11183
SC04	07/27/90	SC04	08/02/90	0.0	223	224	FWS 11250

TABLE B.4.— Continued.

Tagging location	Tagging date	Recapture location	Recapture date	Minimum distance traveled (km)	Length at tagging (mm)	Length at recapture (mm)	Tag number
				1990			
SC04	07/27/90	SC04	08/05/90	0.0	229	227	FWS 11239
SC01	07/30/90	SC01	07/31/90	0.0	217	211	FWS 11370
SC01	07/28/90	SC01	08/03/90	0.0	208	207	FWS 11280
SC01	07/26/90	SC01	08/05/90	0.0	226	232	FWS 11186
SC04	07/31/90	SC01	08/09/90	5.0	218	219	FWS 11084
SC04	07/29/90	SC01	08/15/90	5.0	225	224	FWS 11388
SC04	08/11/90	SC01	09/22/90	5.0	209	205	FWS 11922
SC04	08/12/90	SC01	09/02/90	5.0	214	211	FWS 11935
				1991			
BL02	07/10/90	BL02	07/19/91	0.0	237	248	FWS 12479
BL02	08/08/90	BL02	07/27/91	0.0	242	244	FWS 12682
BL02	07/22/90	BL02	07/27/91	0.0	251	257	FWS 12925
BL02	07/10/90	BL02	07/30/91	0.0	202	220	FWS 12477

TABLE B.4.— Continued.

Tagging location	Tagging date	Recapture location	Recapture date	Minimum distance traveled (km)	Length at tagging (mm)	Length at recapture (mm)	Tag number
			1991				
BL02	07/10/90	BL02	07/30/91	0.0	231	245	FWS 12482
BL02	07/22/90	BL02	08/01/91	0.0	225	225	FWS 12450
KL05	08/29/90	KL05	08/02/91	0.0	203	206	FWS 14080
KL05	08/06/88	KL05	08/28/91	0.0	231	252	FWS 09212
KL05	08/06/88	KL05	08/11/91	0.0	248	257	FWS 09232
KL10	08/01/90	KL10	07/30/91	6.0	221	225	FWS 13010
KL10	07/16/90	KL10	07/26/91	0.0	234	242	FWS 08909
KL10	07/17/91	KL10	07/27/91	0.0	215	215	FWS 14661
JL12	08/11/90	JL14	07/31/91	5.5	268	269	FWS 13678
JL14	07/23/90	SC04	07/21/91	62.0	202	214	FWS 09679
JL14	07/24/90	KL10	08/14/91	5.0	240	250	FWS 09942
JL14	07/12/91	JL14	07/28/91	0.0	263	262	FWS 14243
JL14	07/12/91	JL14	07/15/91	0.0	215	215	FWS 14244

TABLE B.4.— Continued.

Tagging location	Tagging date	Recapture location	Recapture date	Minimum distance traveled (km)	Length at tagging (mm)	Length at recapture (mm)	Tag number
				1991			
JL14	07/28/90	JL14	07/25/91	0.0	201	210	FWS 09949
JL14	08/08/90	JL14	07/26/91	0.0	227	231	FWS 13558
SC01	08/17/90	JL14	08/12/91	62.0	205	208	FWS 11508
SC01	08/13/90	KL05	08/31/91	55.0	209	215	FWS 11571
SC04	07/27/90	KL10	08/08/91	60.0	202	206	FWS 11248
SC04	07/31/90	SC01	08/09/91	5.0	225	---	FWS 11079
SC04	08/12/90	SC04	07/29/91	0.0	214	210	FWS 11935
SC04	07/26/90	SC04	08/04/91	0.0	220	231	FWS 11166
SC04	07/26/91	SC04	08/07/91	0.0	212	222	FWS 11158
SC04	08/08/90	SC04	07/28/91	0.0	205	205	FWS 11441