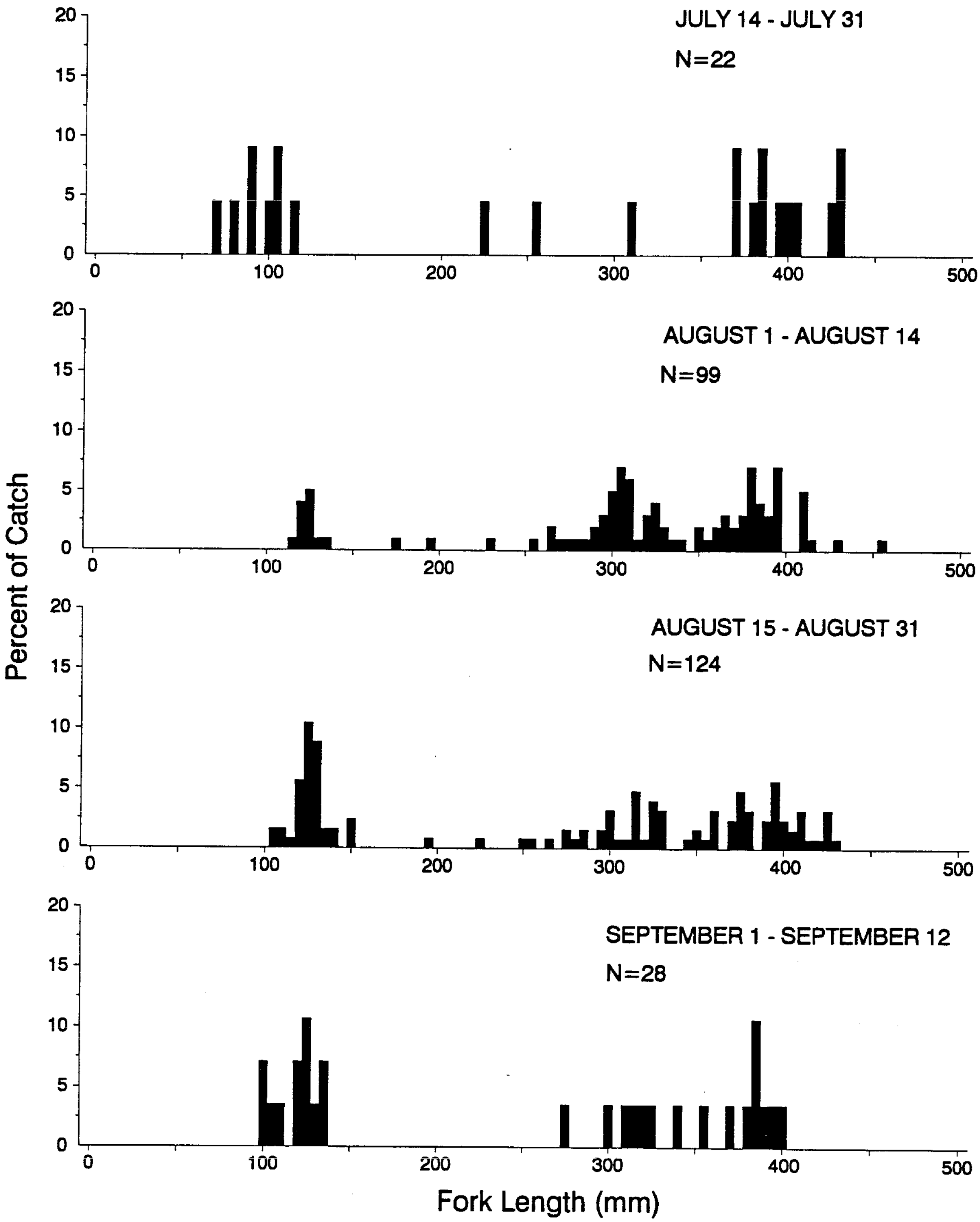

FIGURE 35.– Length frequency of Arctic cisco captured by fyke nets in Kaktovik Lagoon, Arctic Refuge coastal waters, July-September 1991.

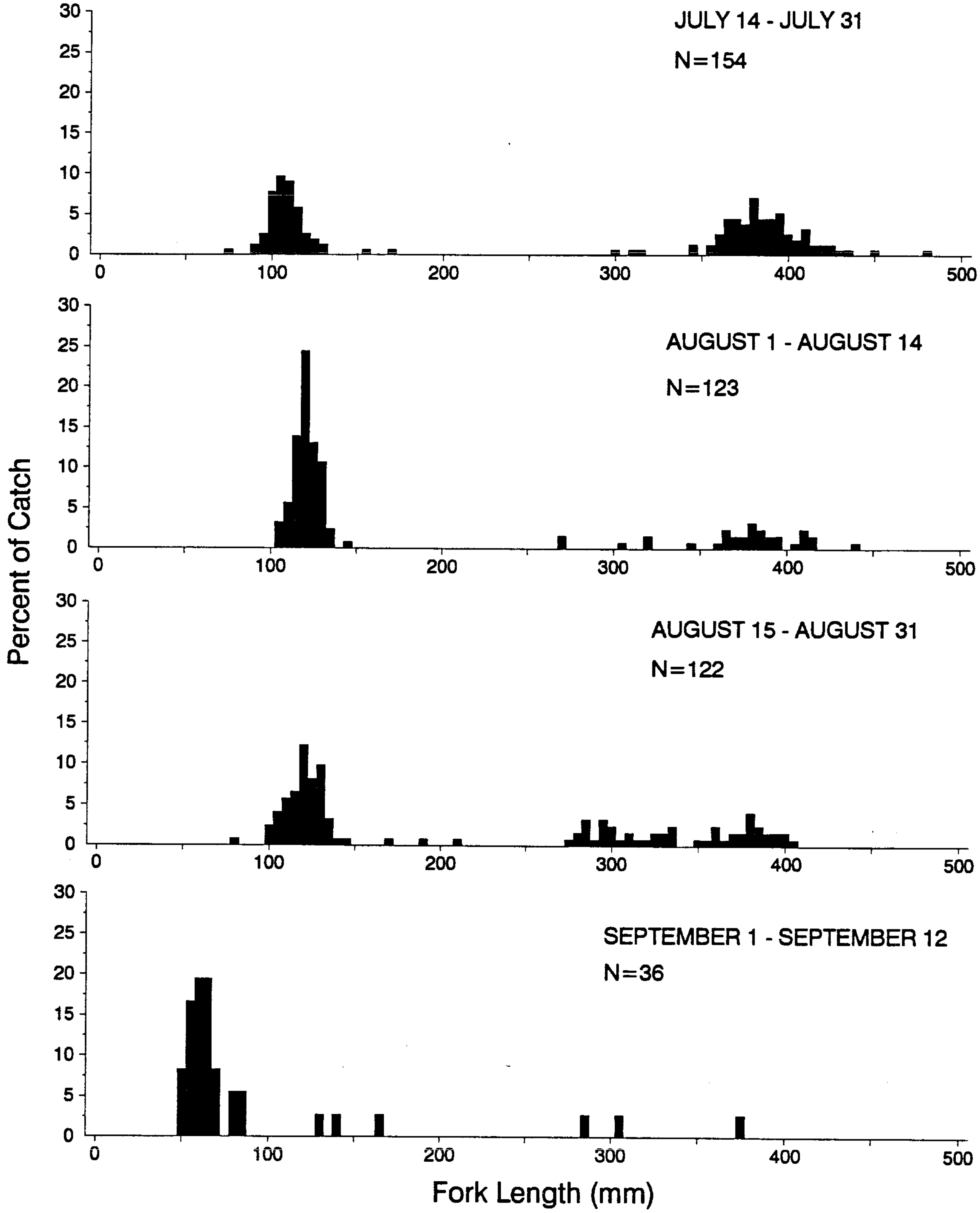

FIGURE 36.– Length frequency of Arctic cisco captured by fyke nets in Jago Lagoon, Arctic Refuge coastal waters, July-September 1991.

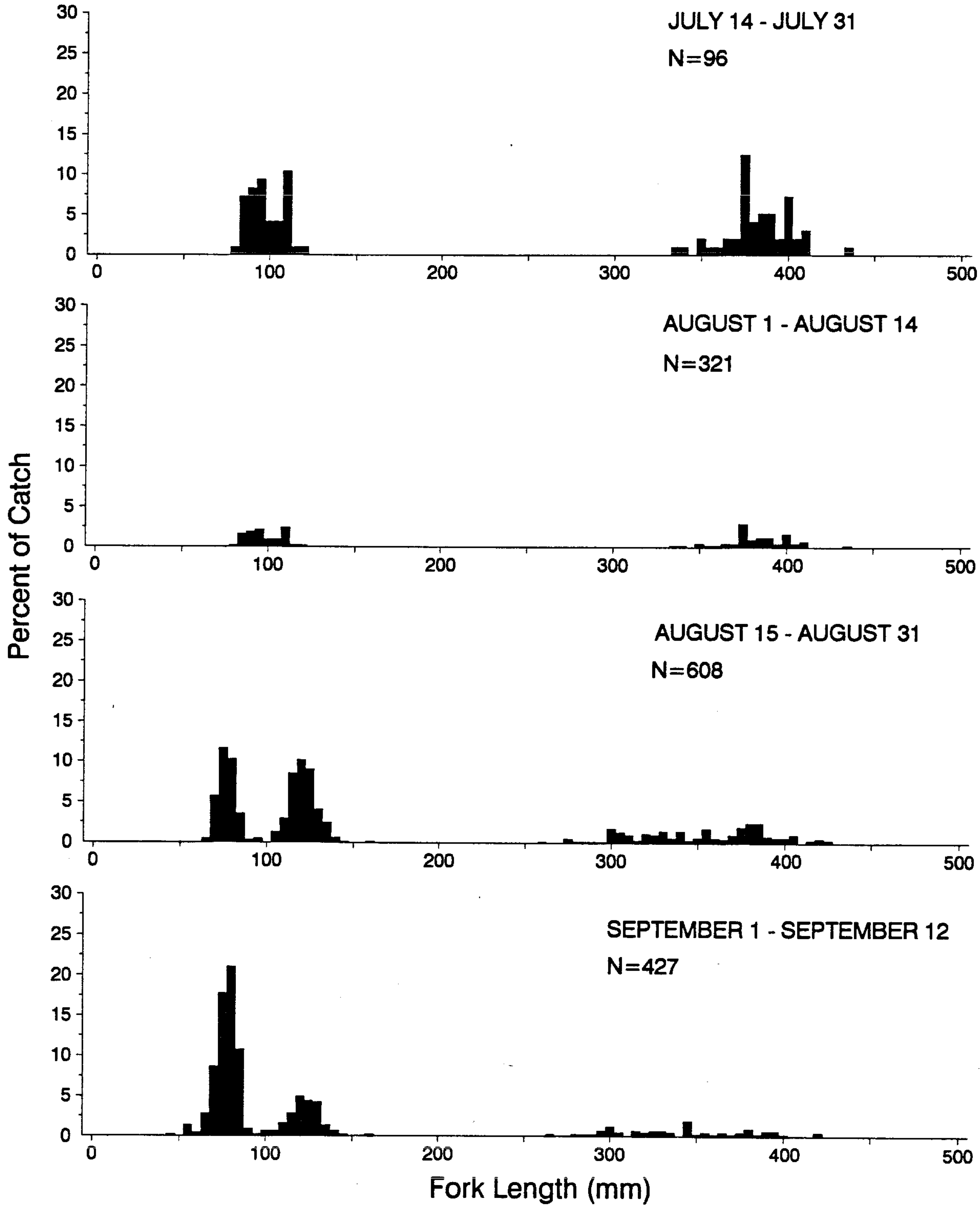

FIGURE 37.- Length frequency of Arctic cisco captured by fyke nets in Beaufort Lagoon, Arctic Refuge coastal waters, July-September 1991.

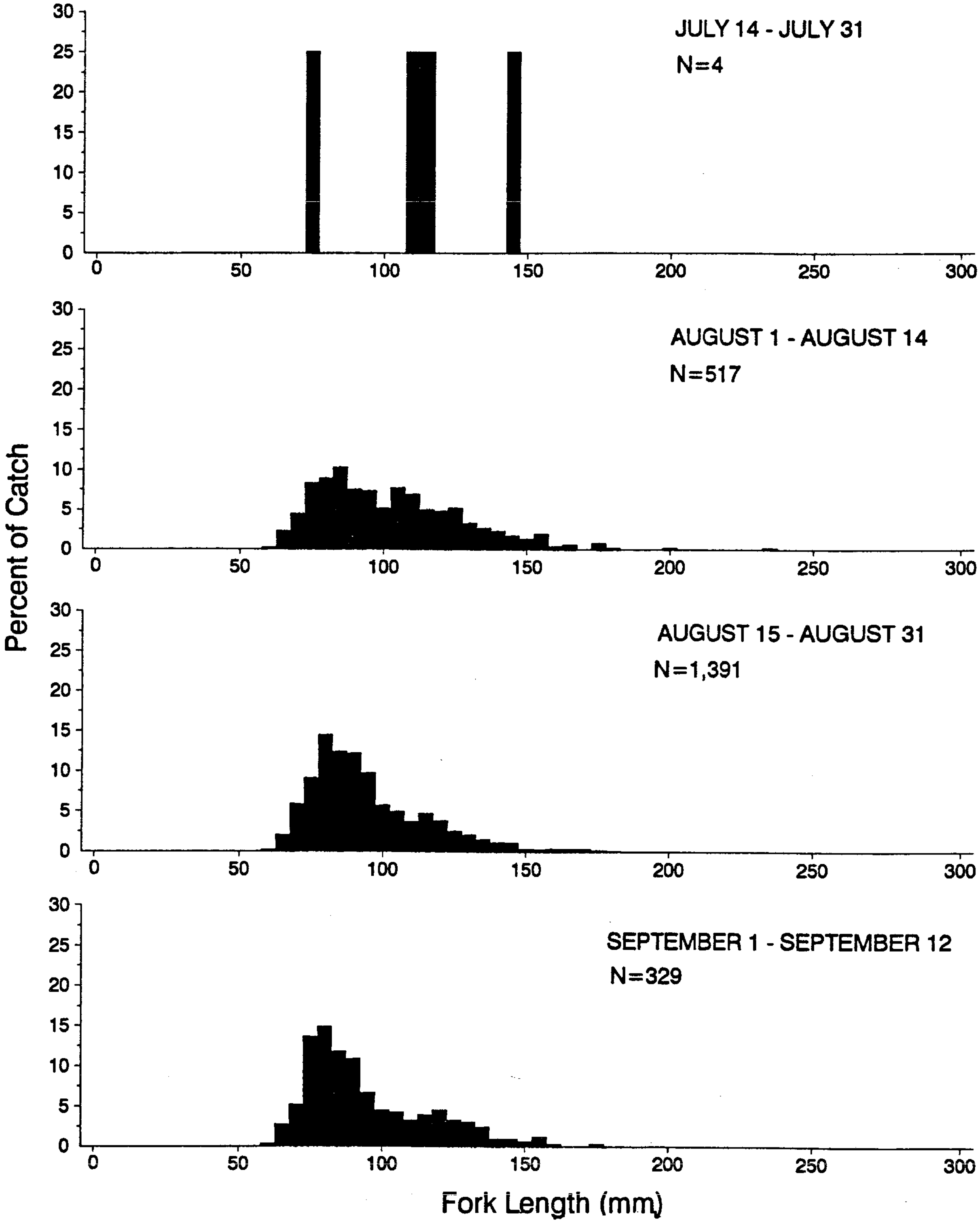

FIGURE 38.– Length frequency of Arctic cod captured by fyke nets in Camden Bay, Arctic Refuge coastal waters, July-September 1991.

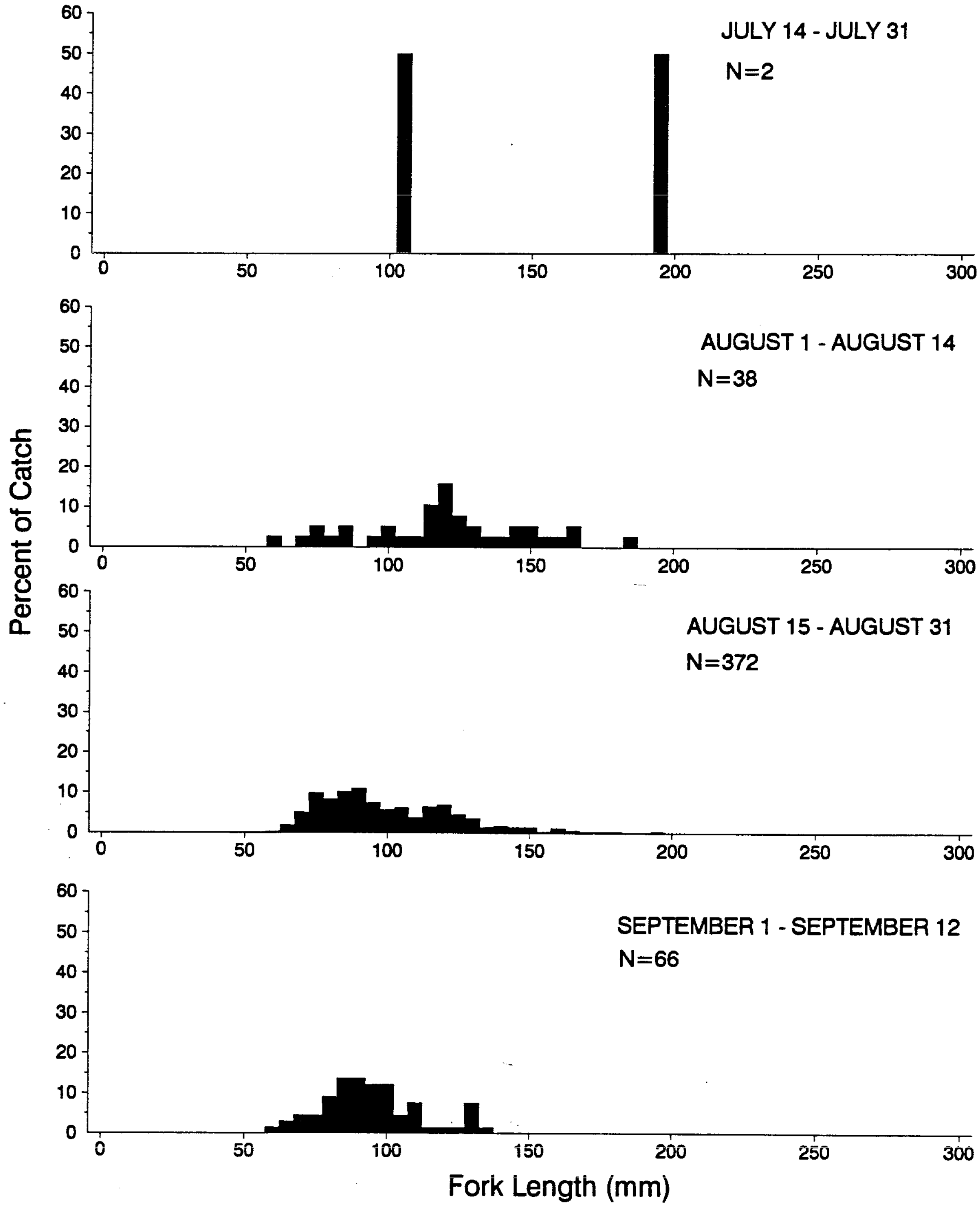

FIGURE 39.— Length frequency of Arctic cod captured by fyke nets in Kaktovik Lagoon, Arctic Refuge coastal waters, July-September 1991.

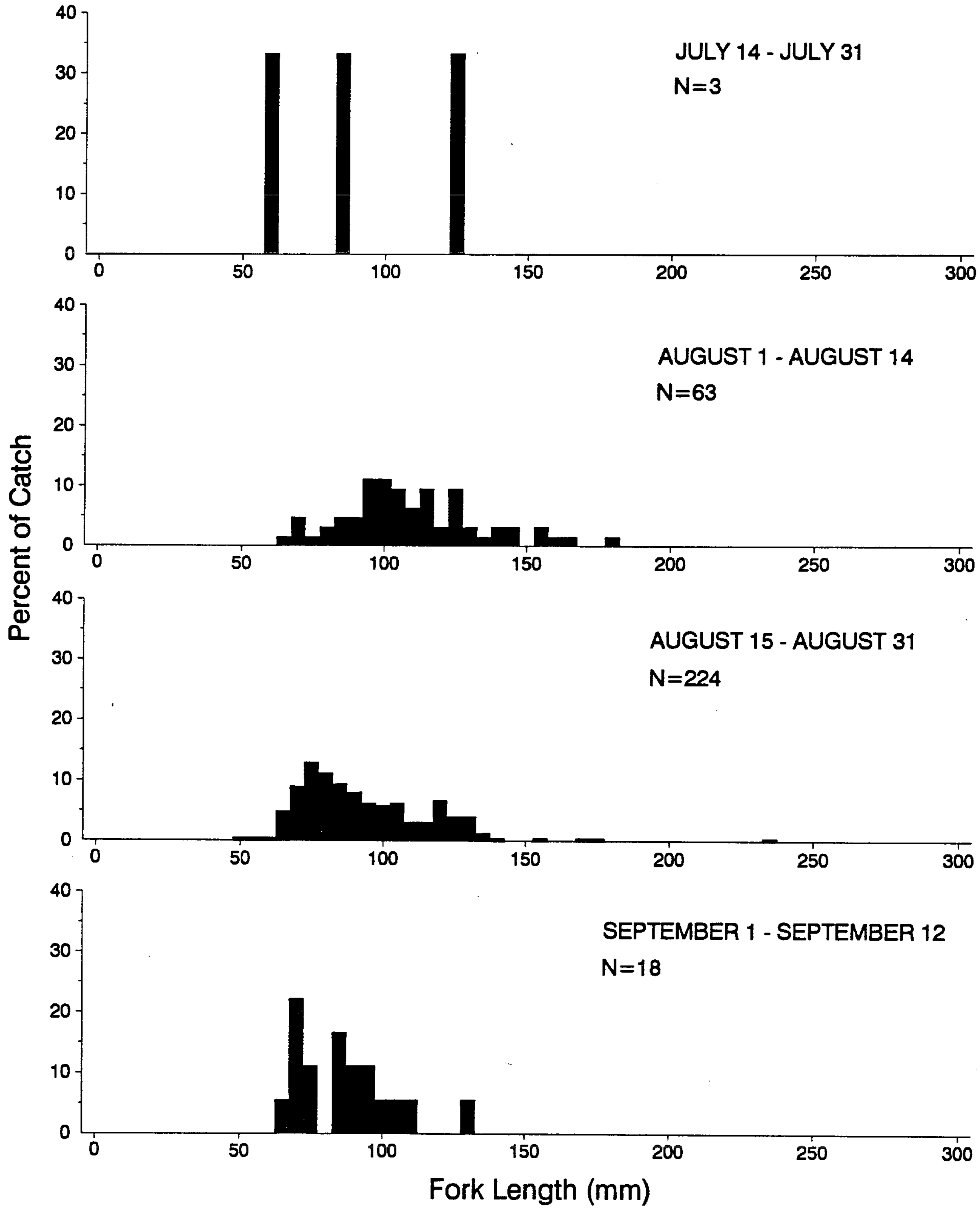

FIGURE 40.- Length frequency of Arctic cod captured by fyke nets in Jago Lagoon, Arctic Refuge coastal waters, July-September 1991.

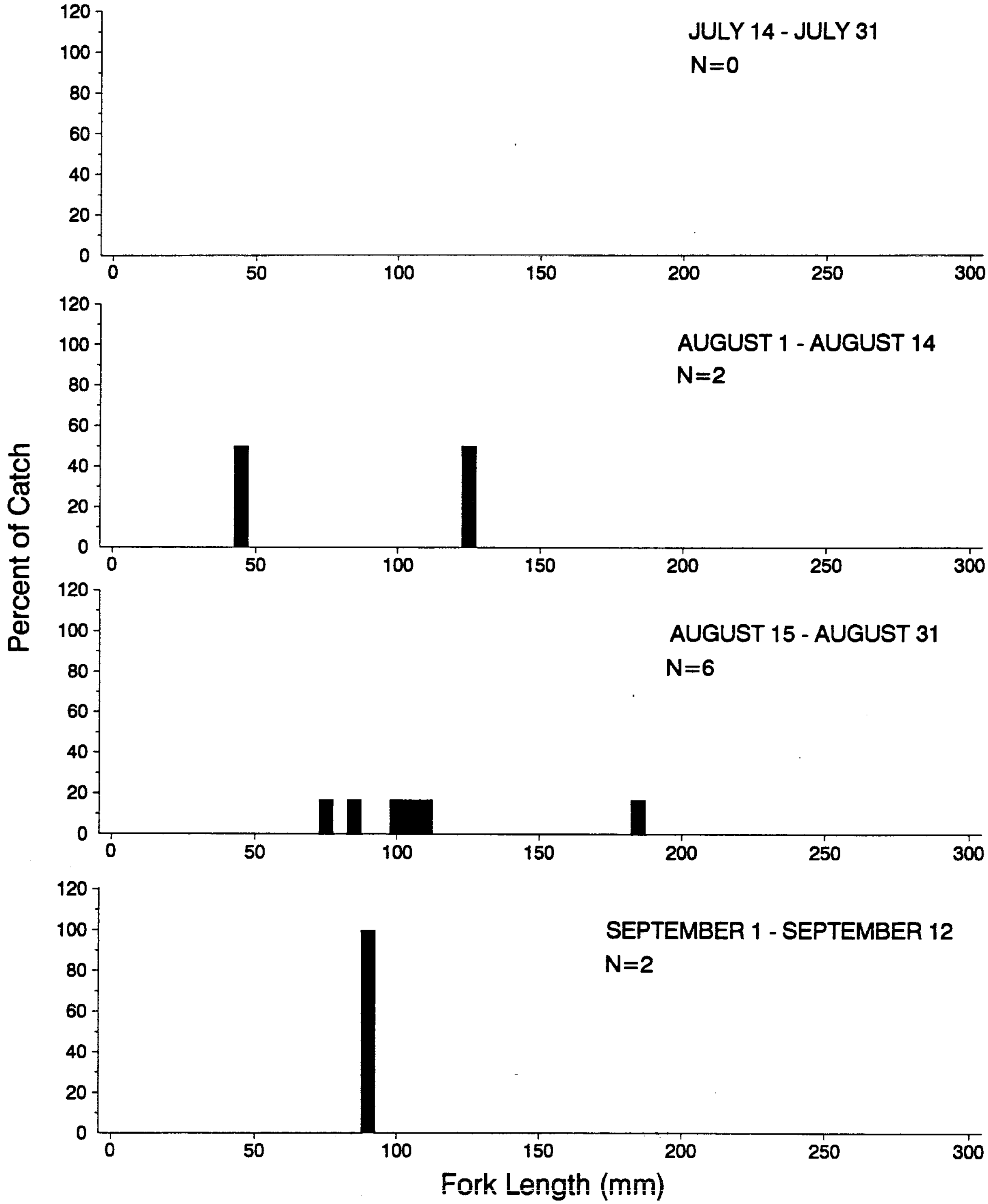

FIGURE 41.– Length frequency of Arctic cod captured by fyke nets in Beaufort Lagoon, Arctic Refuge coastal waters, July-September 1991.

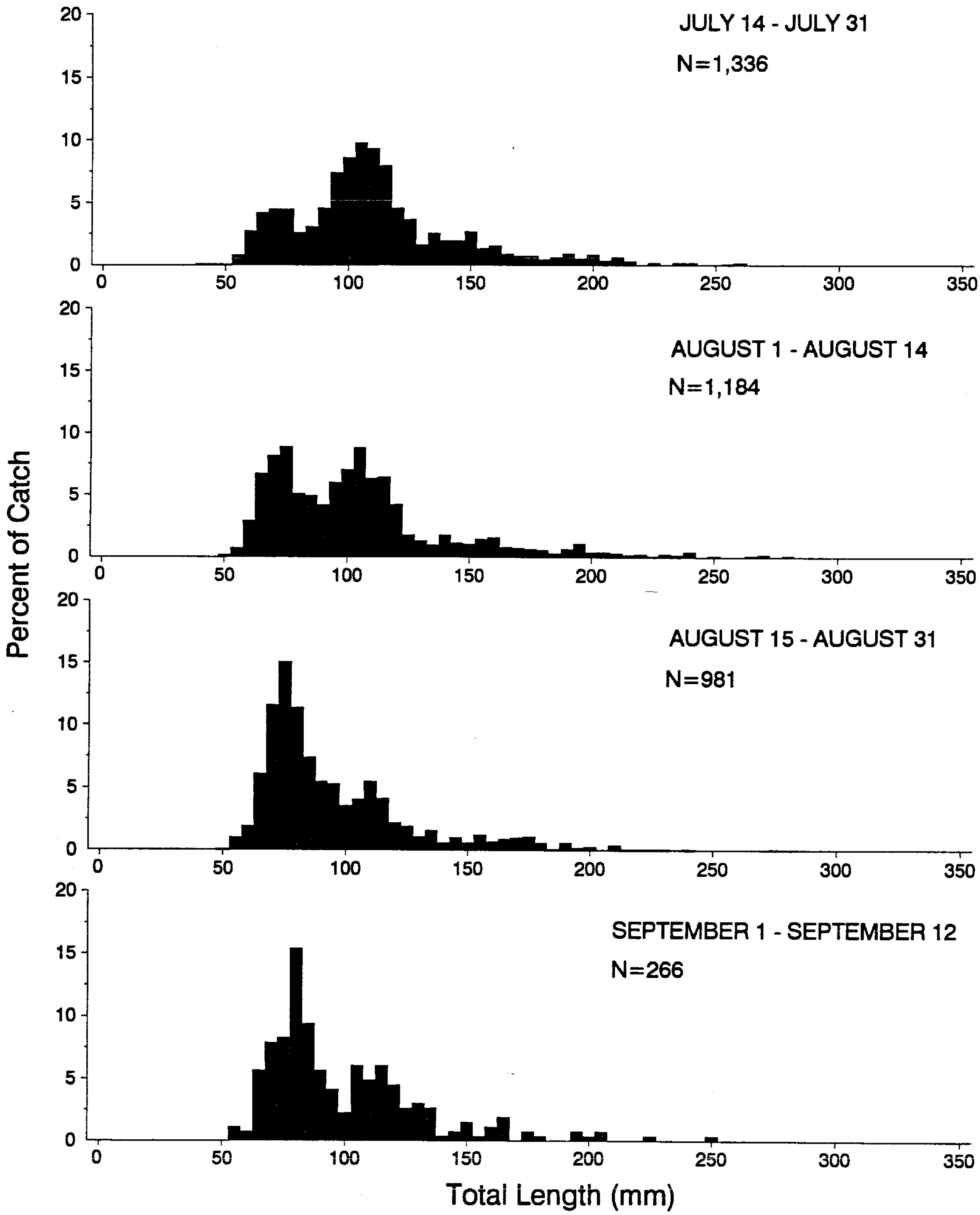

FIGURE 42.- Length frequency of fourhorn sculpin captured by fyke nets in Camden Bay, Arctic Refuge coastal waters, July-September 1991.

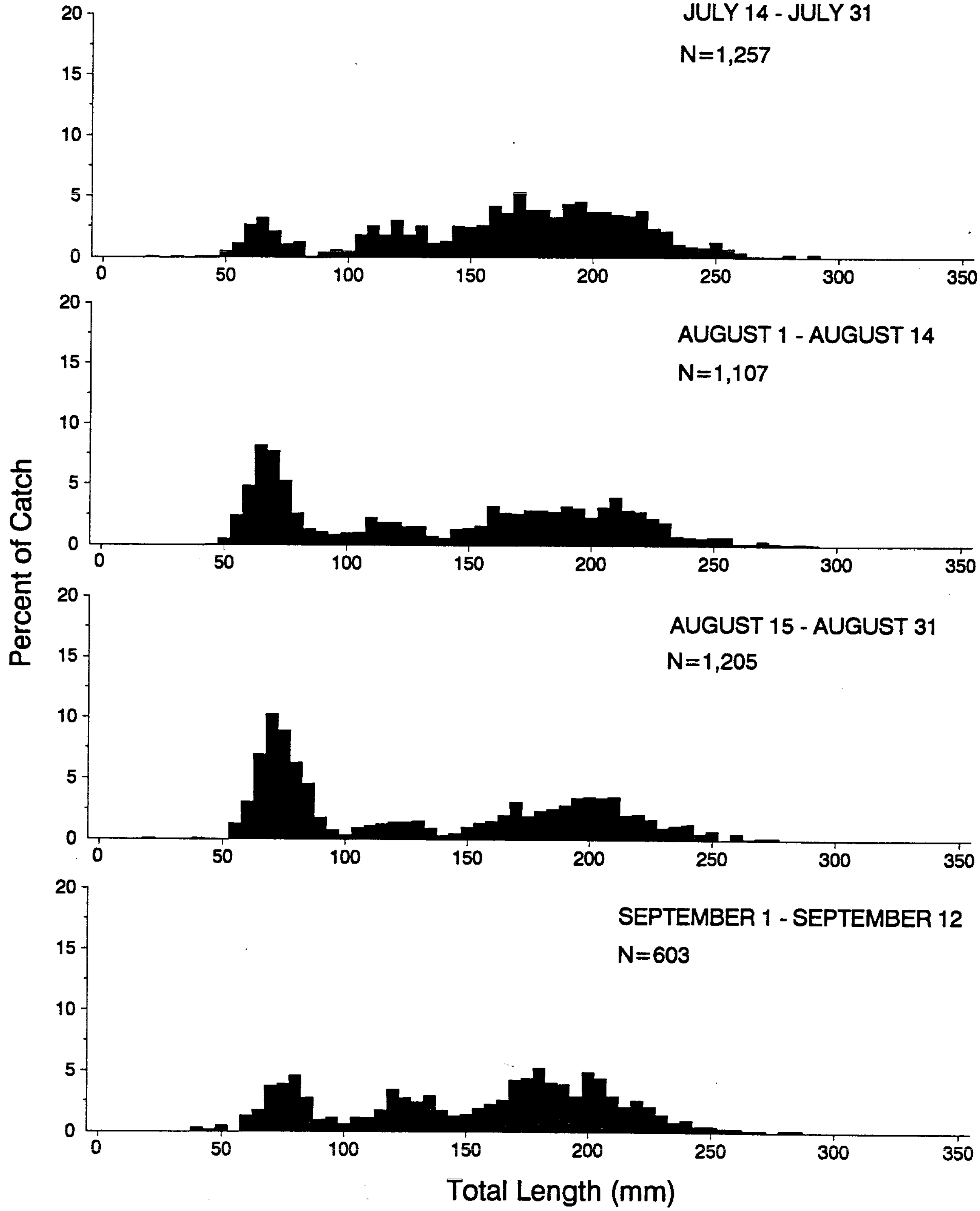

FIGURE 43.– Length frequency of fourhorn sculpin captured by fyke nets in Kaktovik Lagoon, Arctic Refuge coastal waters, July-September 1991.

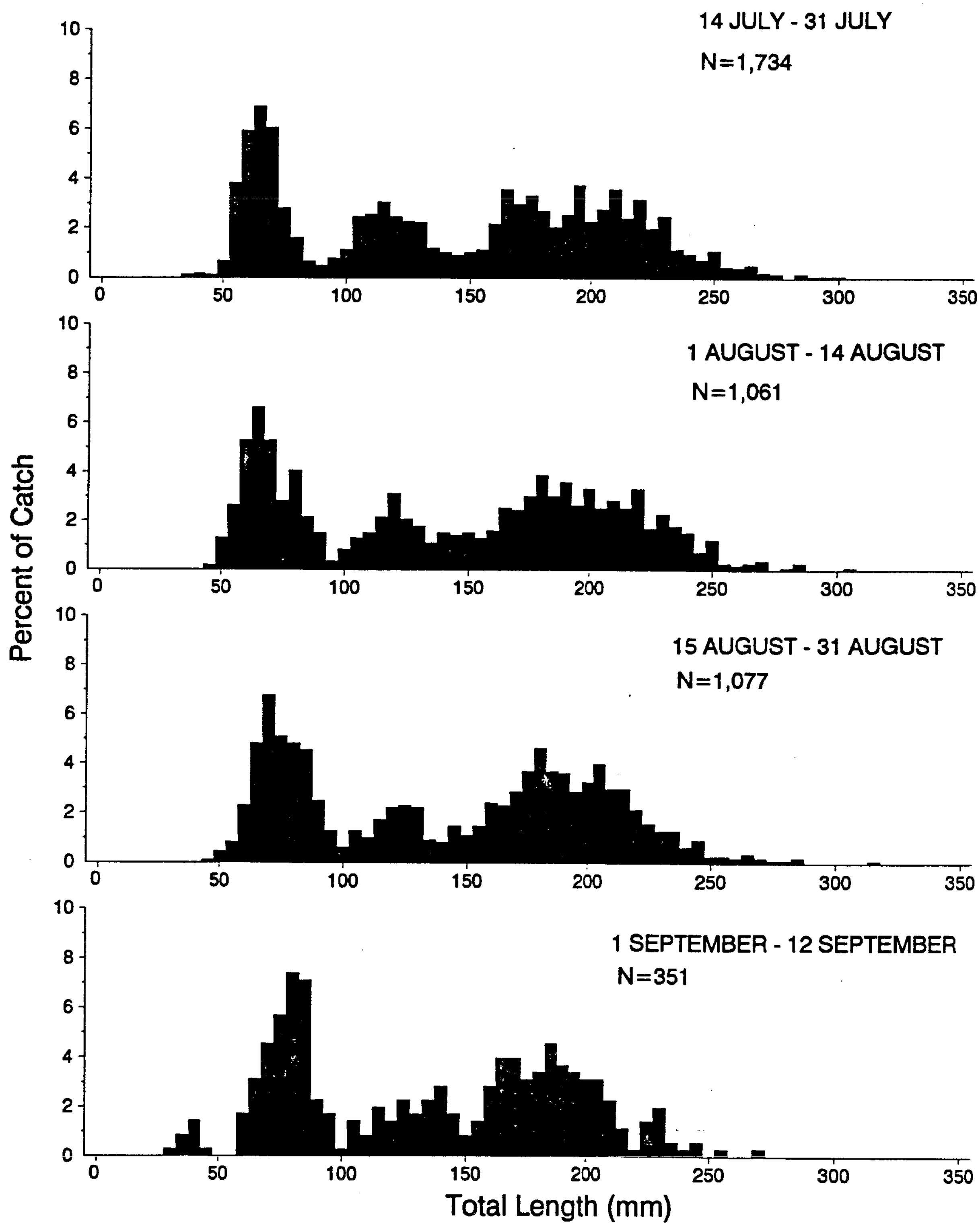

FIGURE 44.- Length frequency of fourhorn sculpin captured by fyke nets in Jago Lagoon, Arctic Refuge coastal waters, July-September 1991.

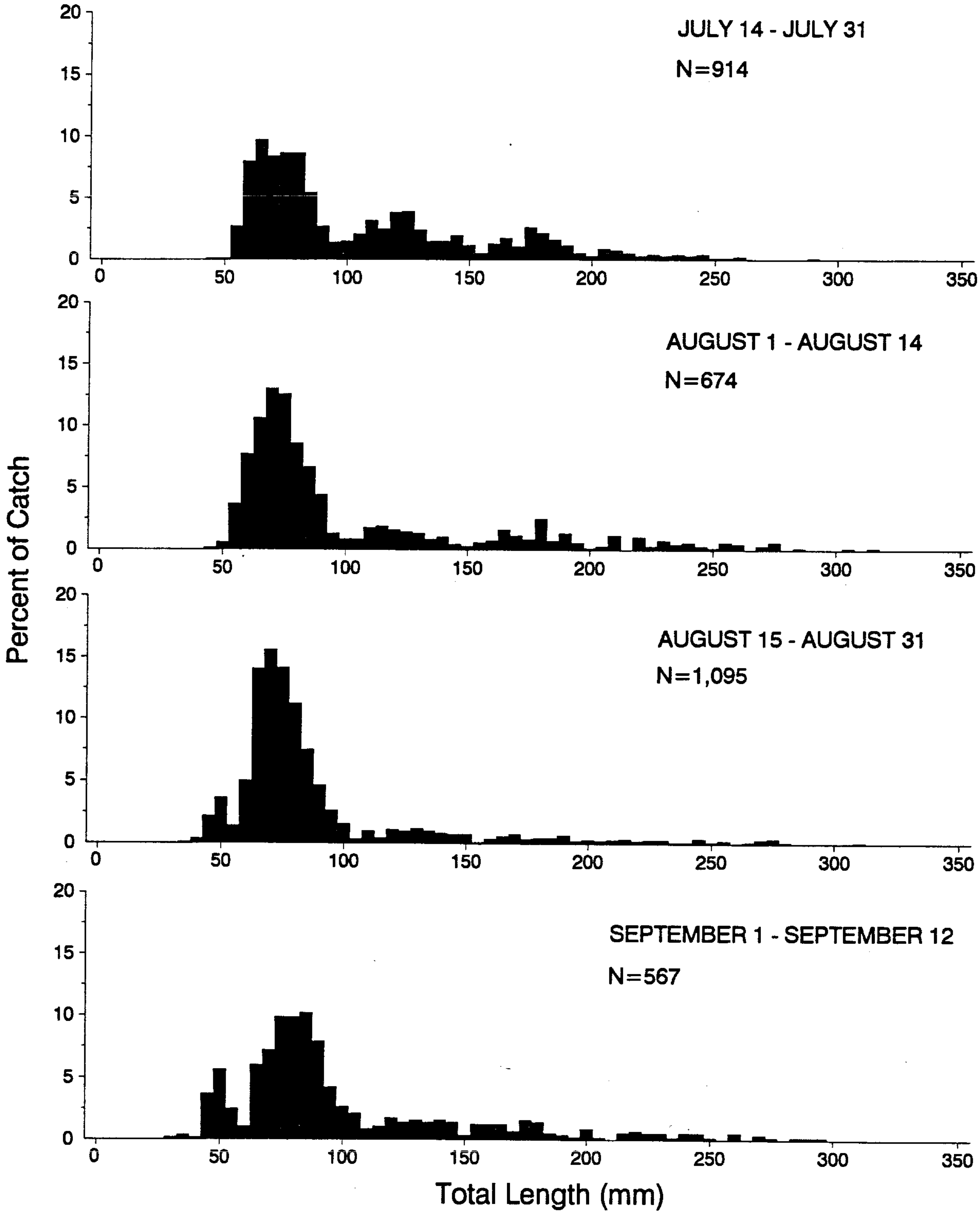

FIGURE 45.— Length frequency of fourhorn sculpin captured by fyke nets in Beaufort Lagoon, Arctic Refuge coastal waters, July-September 1991.

(Figure 44). Size composition at Beaufort Lagoon was fairly stable throughout the field season. Small fourhorn sculpin (<50 mm TL) appeared in Beaufort Lagoon catches in late August, two weeks earlier than at Jago Lagoon.

Arctic flounder captured during 1991 ranged in size from 27 to 305 mm TL (Figures 46-49). Arctic flounder from 50 to 100 mm TL were strongly represented in all areas and in most periods. A secondary modal group was found between 200 and 250 mm TL through August except at Camden Bay. In September, fewer large fish were apparent and higher proportions of smaller fish (40-60 mm TL) were caught in Jago and Beaufort lagoons. These small fish were probably young-of-the-year (Palmer and Dugan 1990).

FISH CONDITION

Weight-length relationships (Figures 50-53) differed significantly ($P < 0.05$) between early and late collection periods for all target species except Arctic cod, which were absent in July and were not tested (Figure 54). Condition, predicted weights at a given length, increased over the course of the summer for Arctic cisco, fourhorn sculpin, and Arctic flounder. Arctic char differed in condition and form (both intercept and slopes estimates differed). Assumptions of normality were met by all species, but homogeneity of variance assumptions were met only by fourhorn sculpin. Removal of outliers (Studentized values greater than the absolute value of 3) made no difference in significance tests of condition except for Arctic cisco, where results changed from not significant to significant. Outliers were often found to be small fish.

Differences in condition between early and late spawning and non-spawning Arctic char and Arctic cisco could not be tested because of the lack of spawning fish. The number of spawners and total number of fish examined for sex and maturity data for each species were as follows: Arctic char, 3 and 181; and Arctic cisco, 2 and 110, respectively.

Significant differences in condition between sexes of target species were found in Arctic cisco (intercept, $P < 0.05$, N = 81) and Arctic flounder (intercept, $P < 0.05$, N = 88). Predicted weights of females were higher than males at a given length. Arctic char (N = 149) and fourhorn sculpin (N = 94) did not exhibit significant differences ($P > 0.05$) in condition for males and females. Normality assumptions were met by all species. With the exception of Arctic char, the assumptions of homogeneity of variance ($P < 0.001$) were met. Removal of outliers did not change the outcome of the statistical tests.

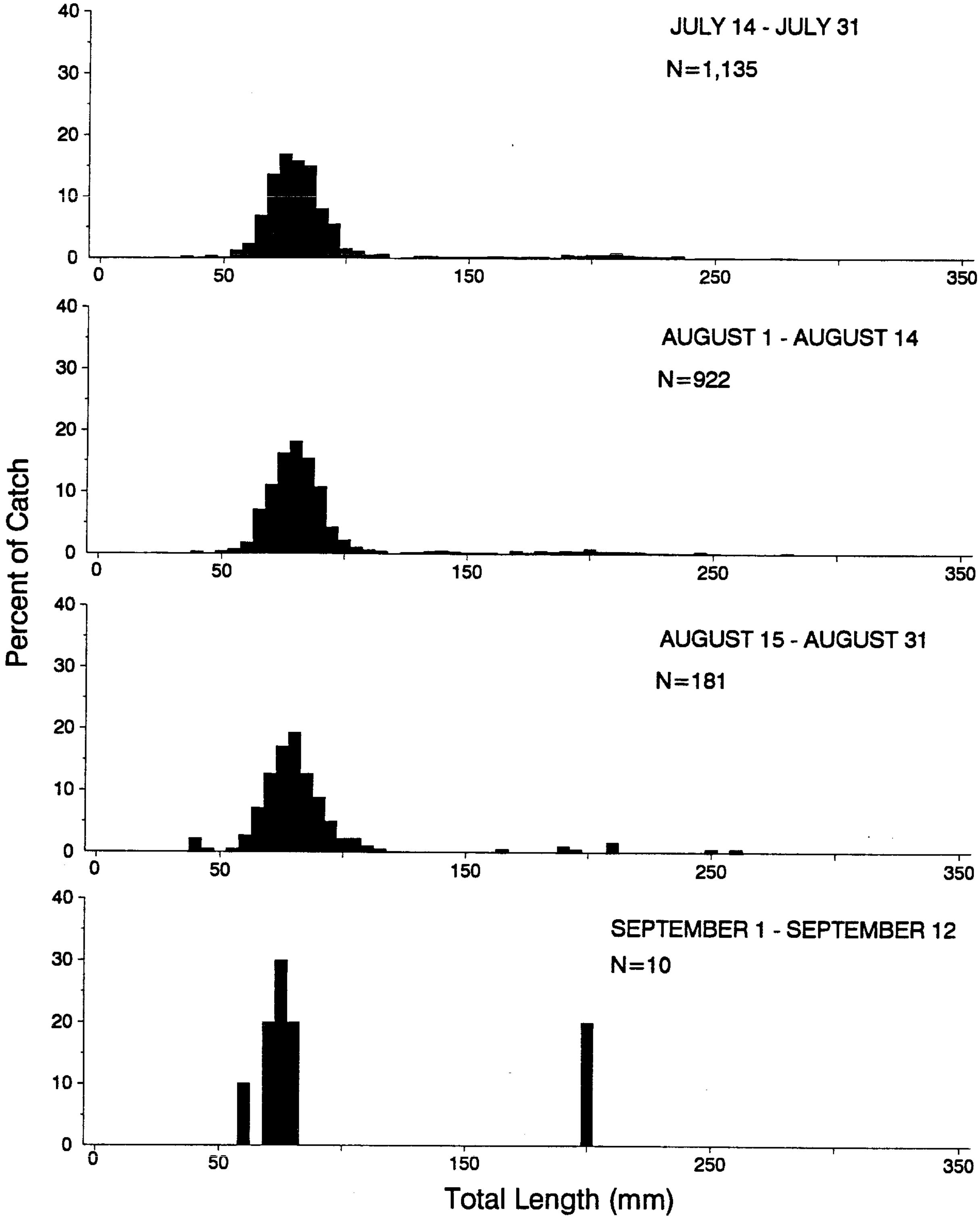

FIGURE 46.- Length frequency of Arctic flounder captured by fyke nets in Camden Bay, Arctic Refuge coastal waters, July-September 1991.

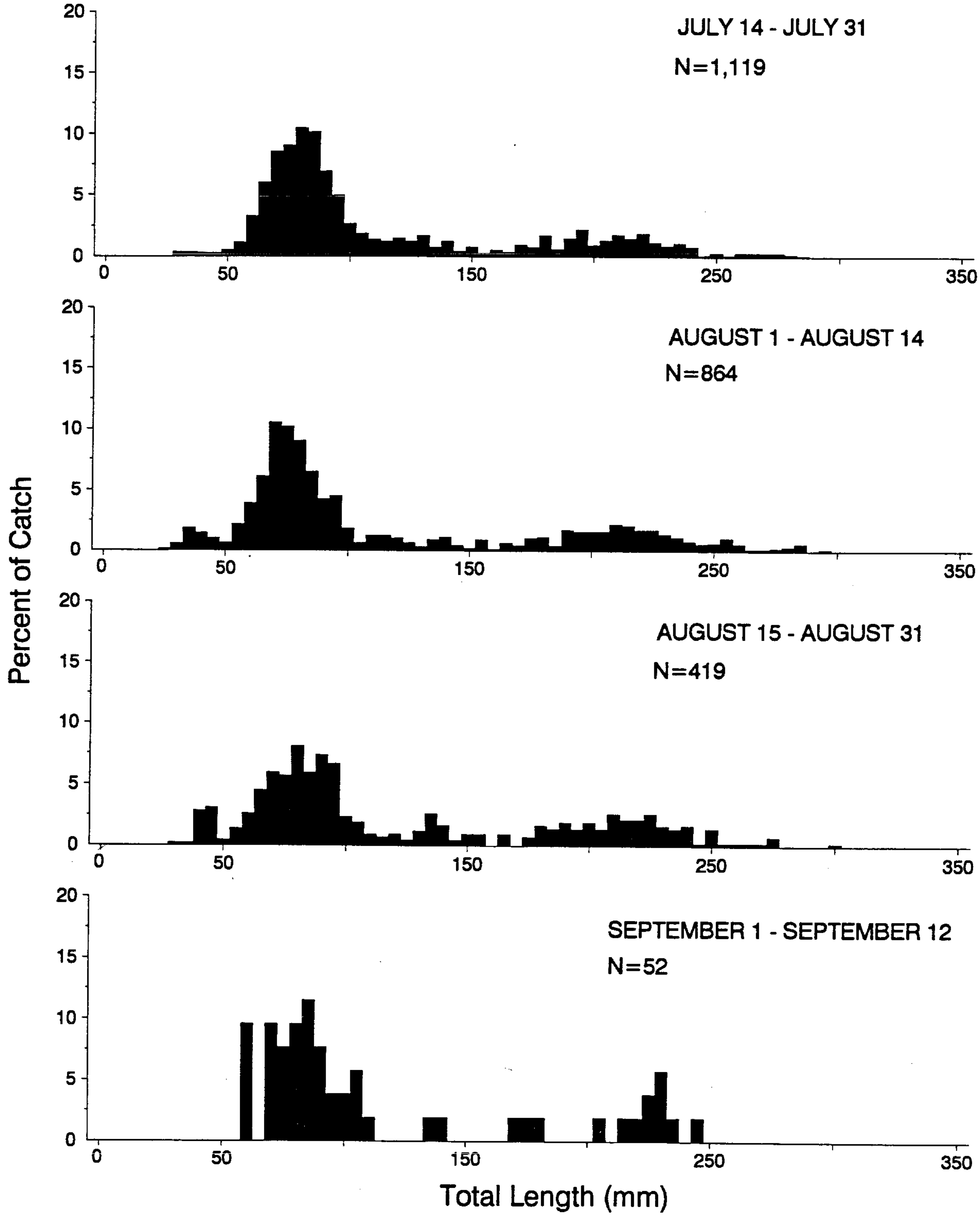

FIGURE 47.– Length frequency of Arctic flounder captured by fyke nets in Kaktovik Lagoon, Arctic Refuge coastal waters, July-September 1991.

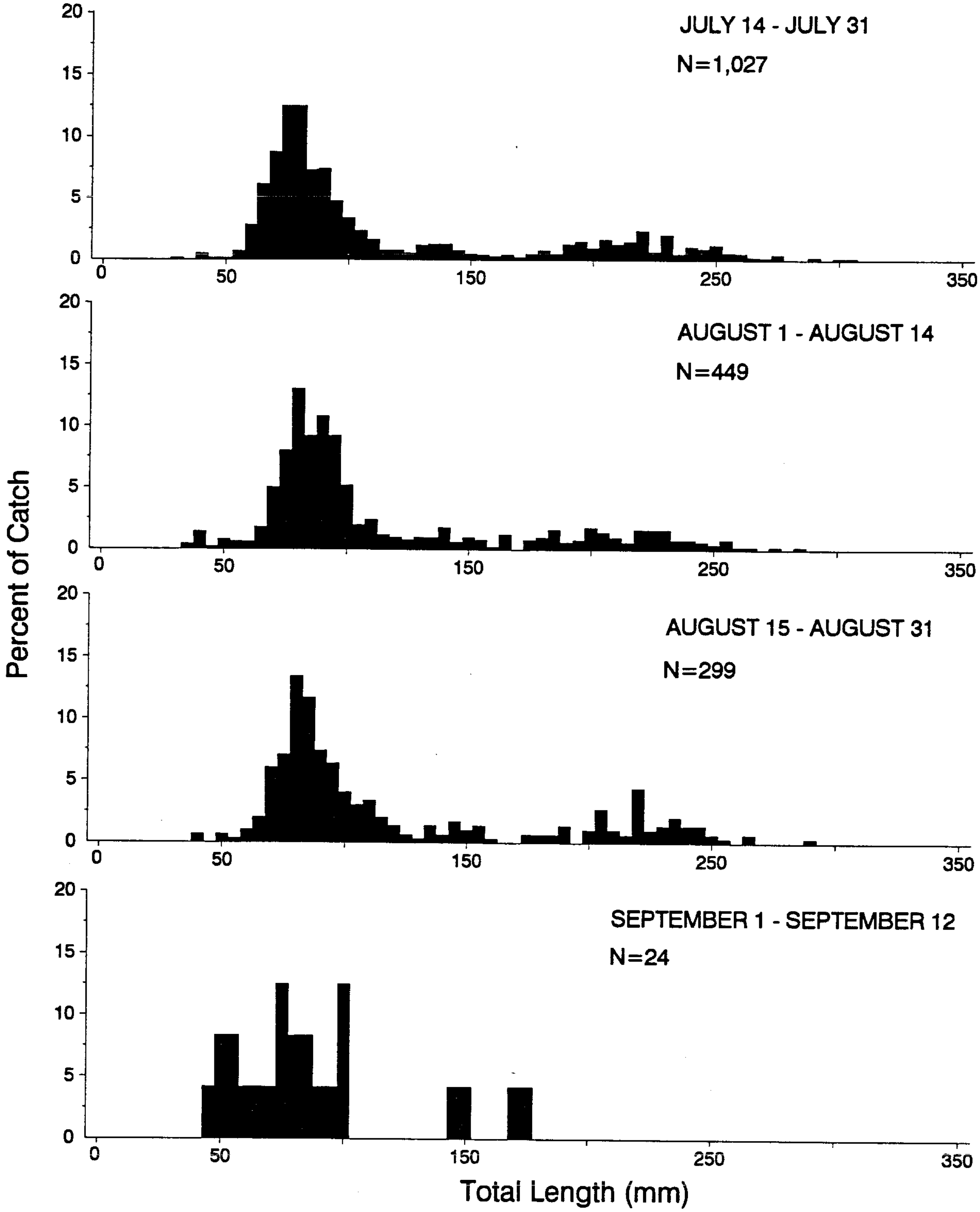

FIGURE 48.— Length frequency of Arctic flounder captured by fyke nets in Jago Lagoon, Arctic Refuge coastal waters, July-September 1991.

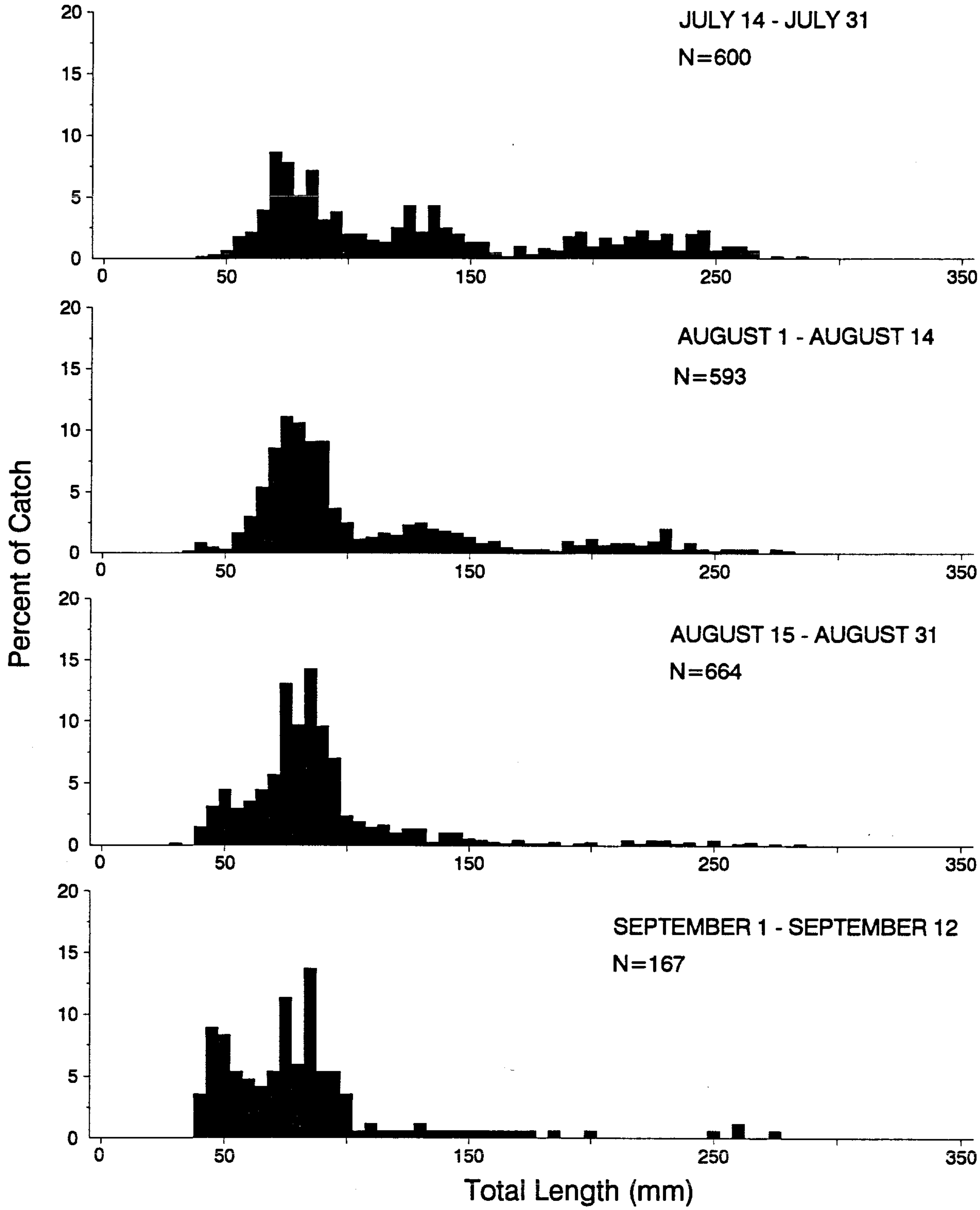

FIGURE 49.- Length frequency of Arctic flounder captured by fyke nets in Beaufort Lagoon, Arctic Refuge coastal waters, July-September 1991.

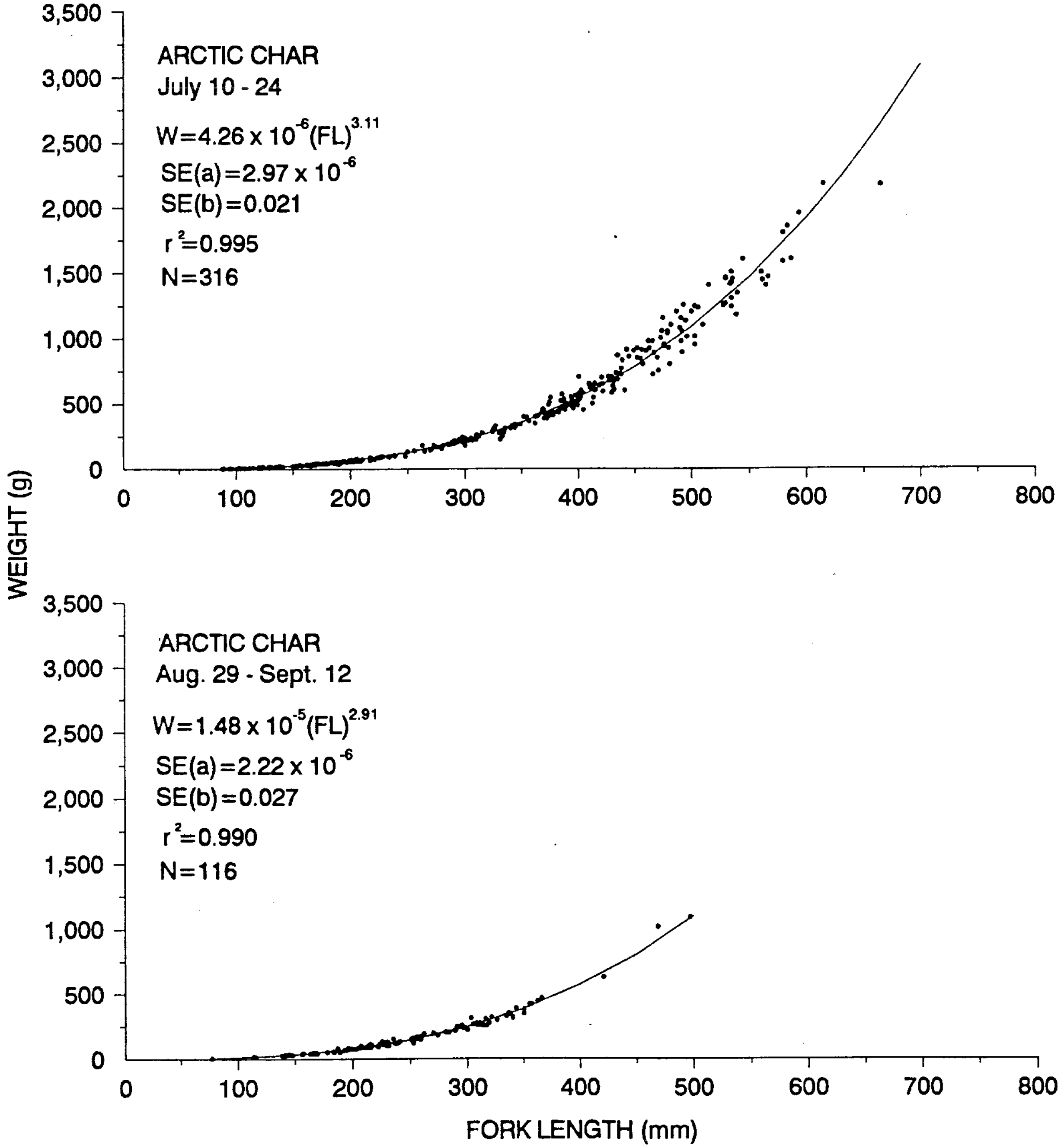

FIGURE 50.– Arctic char condition for early (July 10-24) and late (Aug. 29-Sept. 12) seasons, as modeled by the weight-length relationship, 1991. Arctic char at a given length were heavier in September.

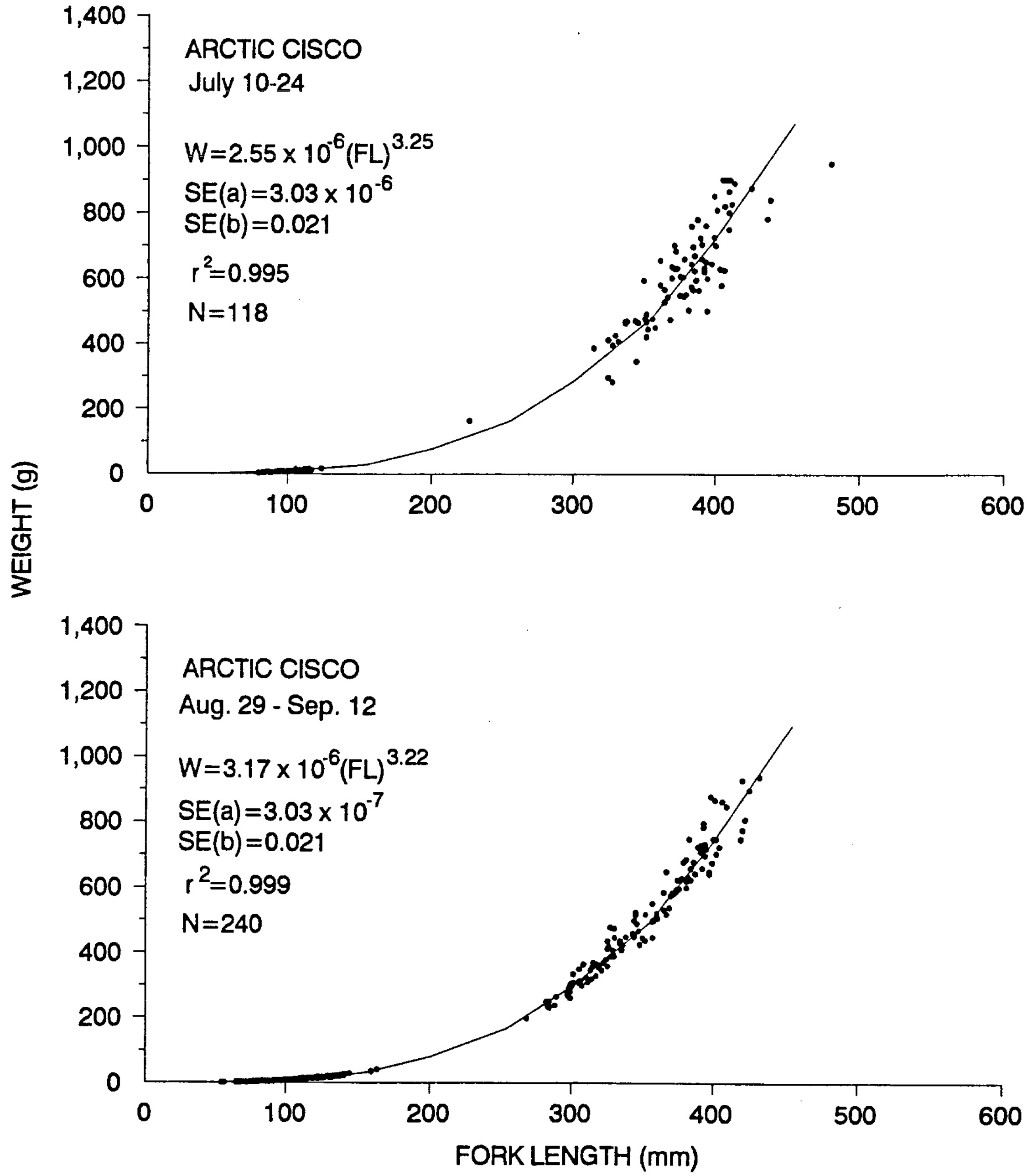

FIGURE 51.- Arctic cisco condition for early (July 10-24) and late (Aug. 29-Sept. 12) seasons, as modeled by the weight-length relationship, 1991. Arctic cisco at a given length were heavier in September.

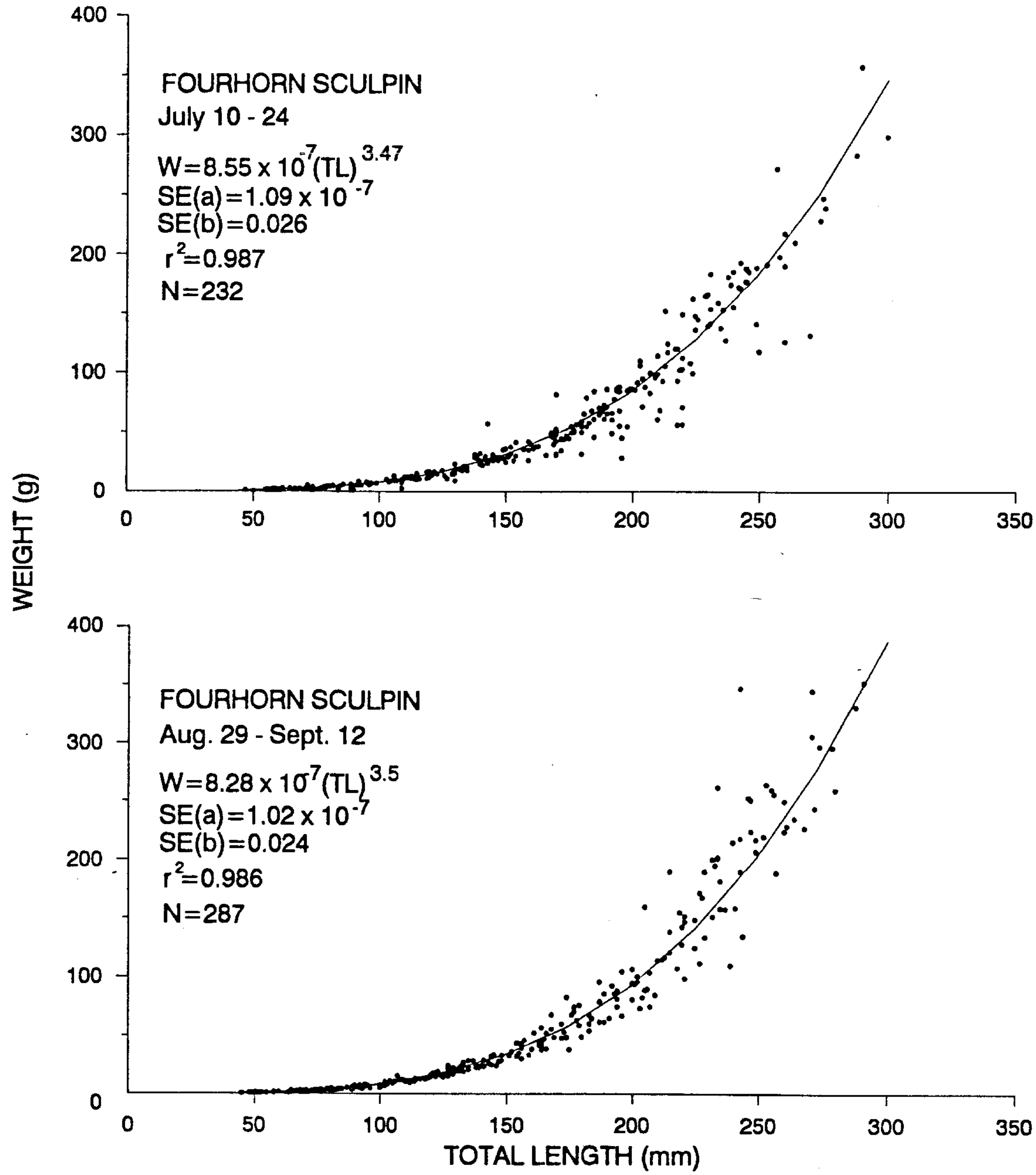

FIGURE 52.- Fourhorn sculpin condition for early (July 10-24) and late (Aug. 29-Sept. 12) seasons, as modeled by the weight-length relationship, 1991. Fourhorn sculpin at a given length were heavier in September.

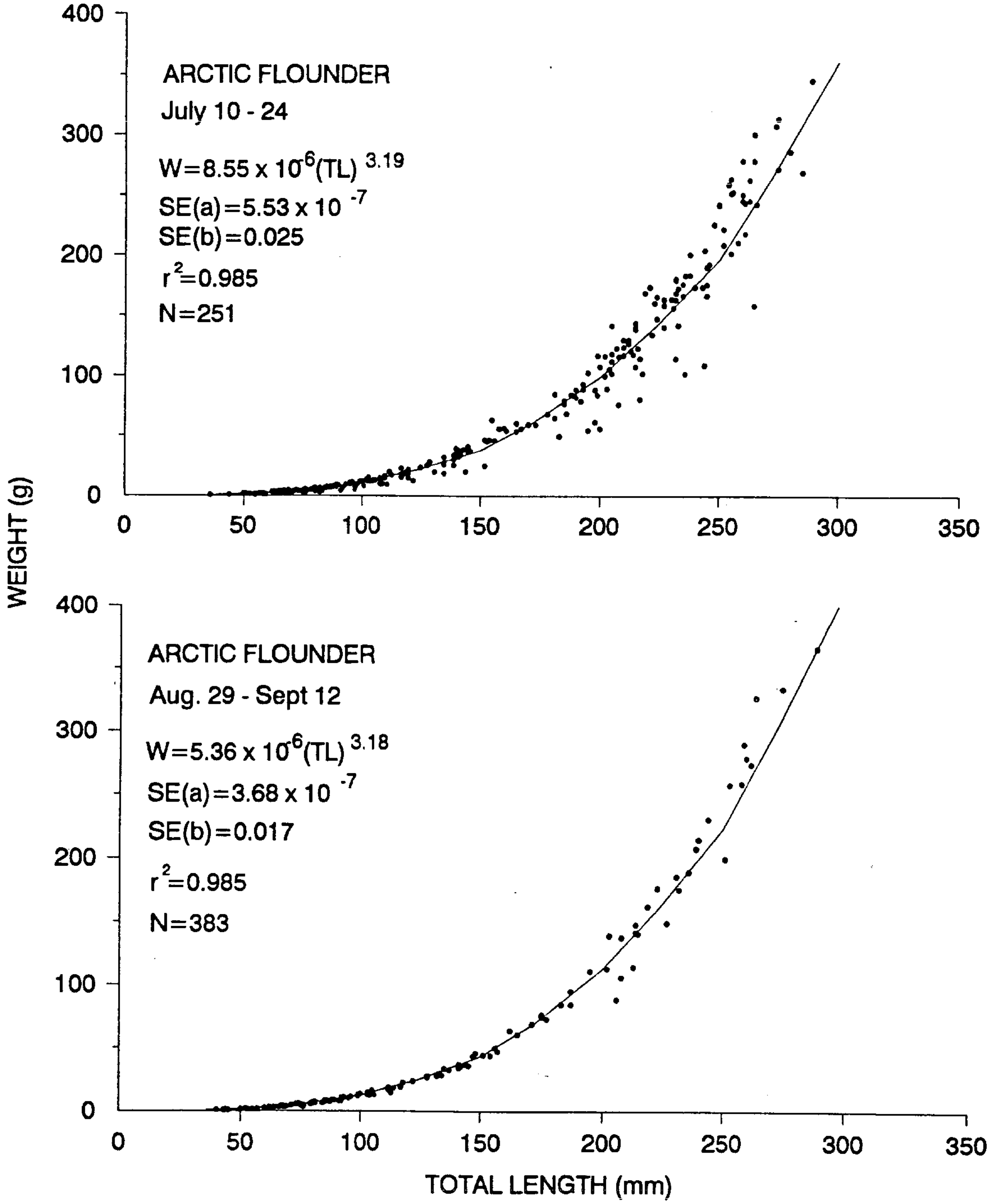

FIGURE 53.– Arctic flounder condition for early (July 10-24) and late (Aug. 29-Sept. 12) seasons, as modeled by the weight-length relationship, 1991. Arctic flounder at a given length were heavier in September.

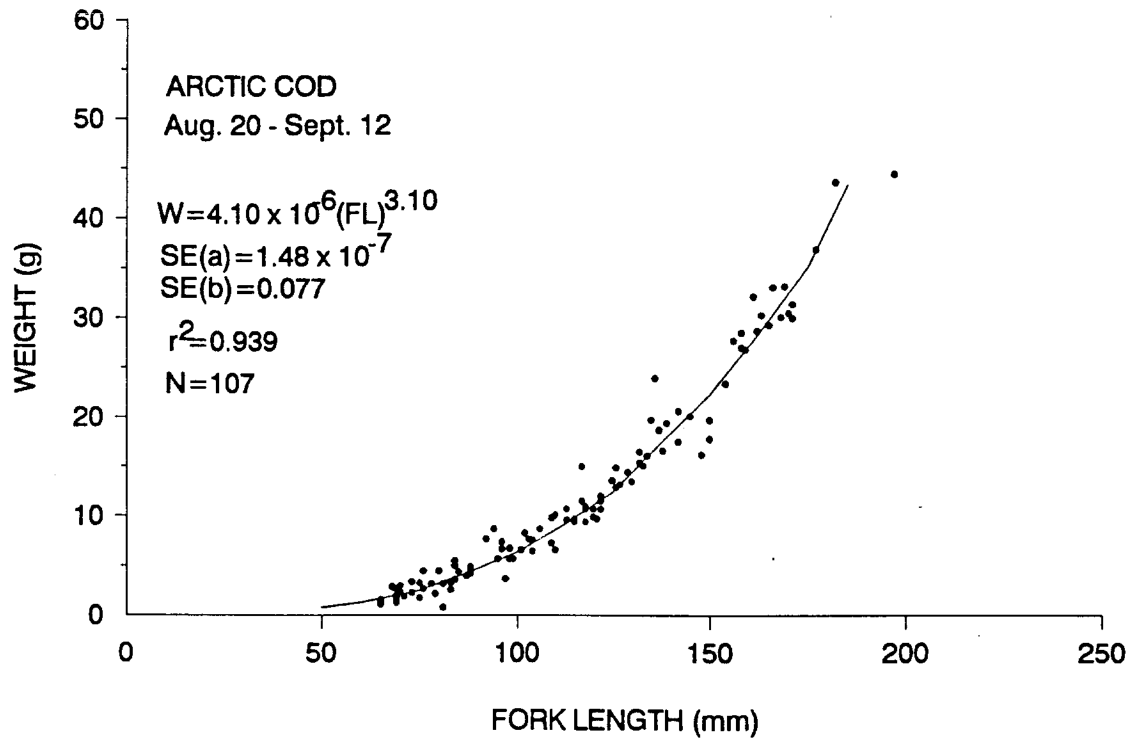

FIGURE 54.– Arctic cod condition for late (Aug. 29-Sept. 12) season, as modeled by the length-weight relationship, 1991. Arctic cod were not available to be sampled early in the season.

AGE AND GROWTH

Age frequencies for July 14-29 corresponded well with length frequencies of the same data set (Figures 55 and 56), execpt for Arctic char. Although validation was not performed on our ageing, this correspondence serves to verify our ageing technique. Length-frequency distributions for Arctic char, however, did not correspond to age-frequencies due to major fluctuations between lengths. Modal age and length groups were as follows: Arctic char - 4 years with no apparent mode in length groups; Arctic cisco - age 1 and ages 7-10 with length modes at 100 mm FL and between 380 and 420 mm FL; fourhorn sculpin - age 3 with a length mode at 120 mm TL; and Arctic flounder - age 2 and age 10 with length modes at 100 mm and 220 mm TL.

von Bertalanffy Growth Model

From the estimated von Bertalanffy growth equations, fourhorn sculpin had the largest estimate of K, indicating high rate of growth. Low sample sizes of older Arctic char, fourhorn sculpin, and Arctic flounder caused the respective fitted curves to extend gradually from the origin (Figures 57 and 58) without showing the classic high rate of increase associated with juvenile fish. Lengths within each age class were highly variable and exceeded 250 mm for Arctic char.

The von Bertalanffy curves for Arctic char and Arctic flounder appear to underestimate the average length at age (Figures 57 and 58), also shown by the low K values (Table 16). This may be explained by slower growth of these two species or by the preponderance of fish ≤ 5 years old. Younger fish may have forced the curve down and, hence, the von Bertalanffy growth model underestimated growth of these two species. The model did not successfully fit to the Arctic cisco age and length data, probably due to the lack of data for ages 0, 3, and 4 (see Table 18). This under-estimation of growth is further indicated by the maximum predicted length (L_∞), was lower than the highest lengths of fish measured (Table 16).

Mean Length-at-Age

Lengths-at-age among ages exhibited wide overlap for each species, especially in older fish (Tables 17-20). Due to low sample sizes of older age groups, mean lengths did not always show an increase in length with increasing age. For example, Arctic cisco showed a decrease in length between ages 8 and 9 and between 10 and 11 (Table 18).

Growth of Tagged Fish

Results from growth analyses for Arctic char tagged in 1990 showed a mean growth increment of 23.67 mm (N = 3, SD = 21.20) for adults and about twice that amount, 50.75 mm (N = 8, SD = 7.30) for juveniles. Adult fournhorn sculpin grew a mean length of 9.38 mm (N = 26, SD = 7.60) between 1990 and 1991.

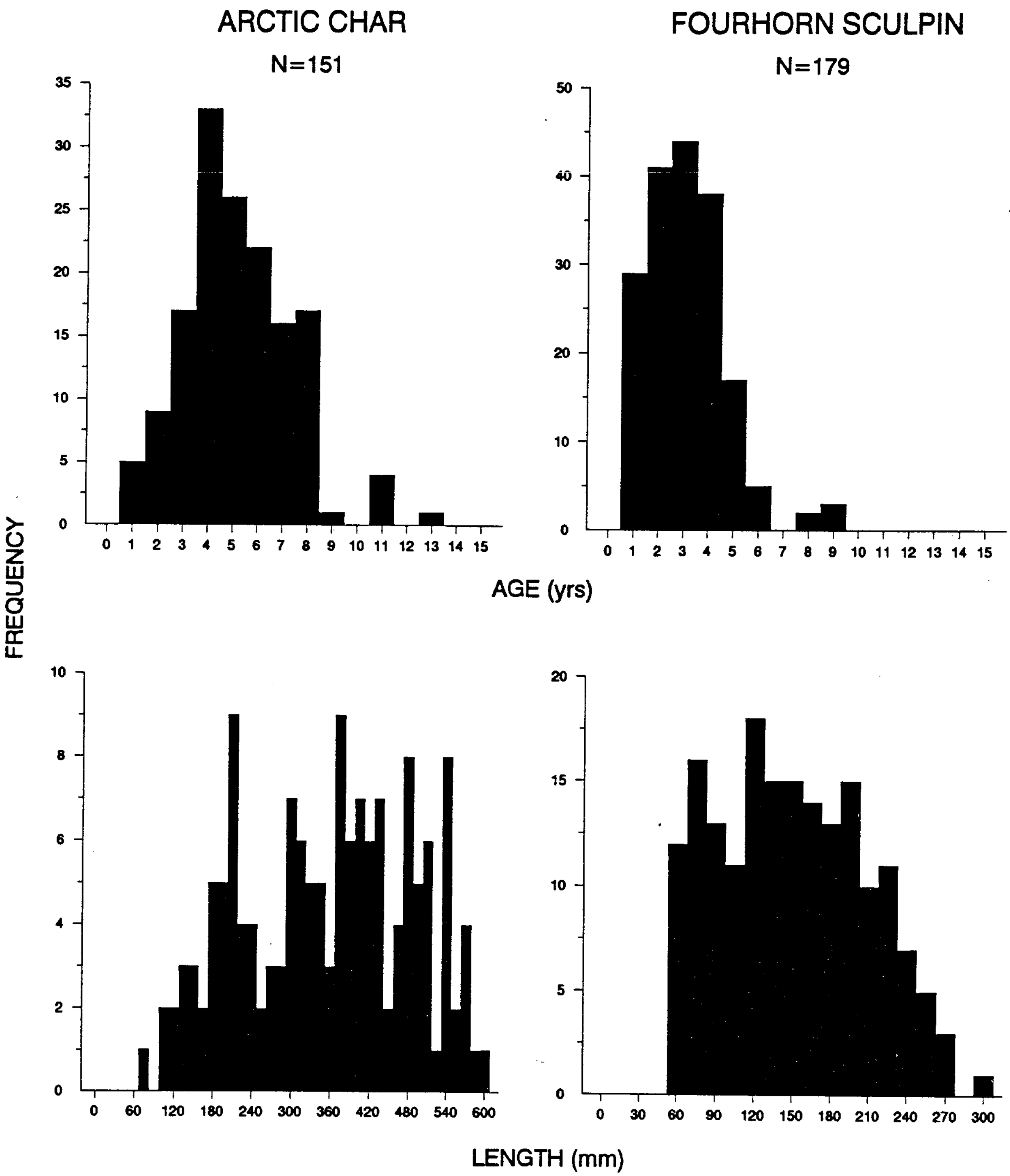

FIGURE 55.— Age and length frequencies of Arctic char and fourhorn sculpin, 1991.

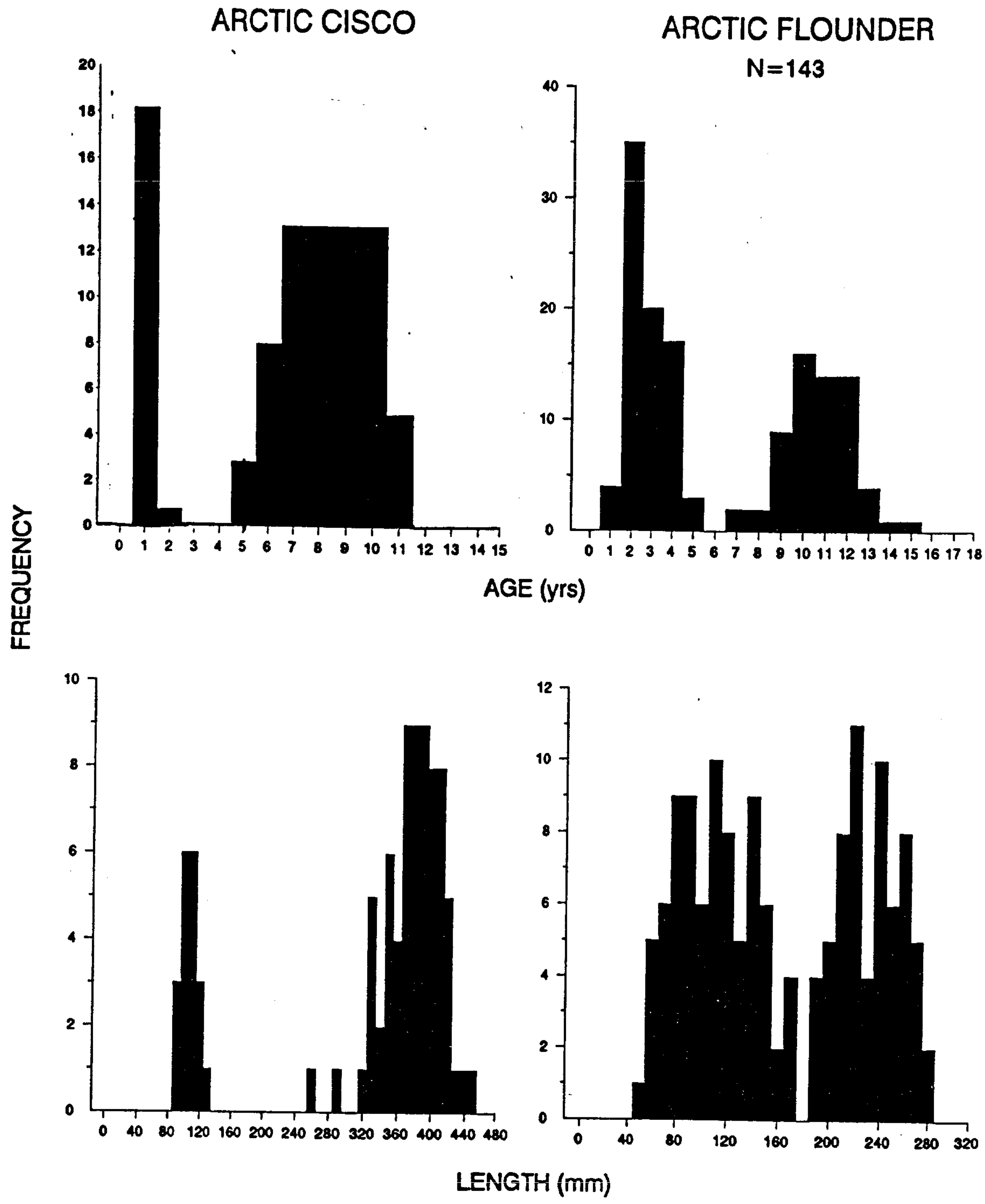

FIGURE 56.— Age and length frequencies of Arctic cisco and Arctic flounder, 1991.

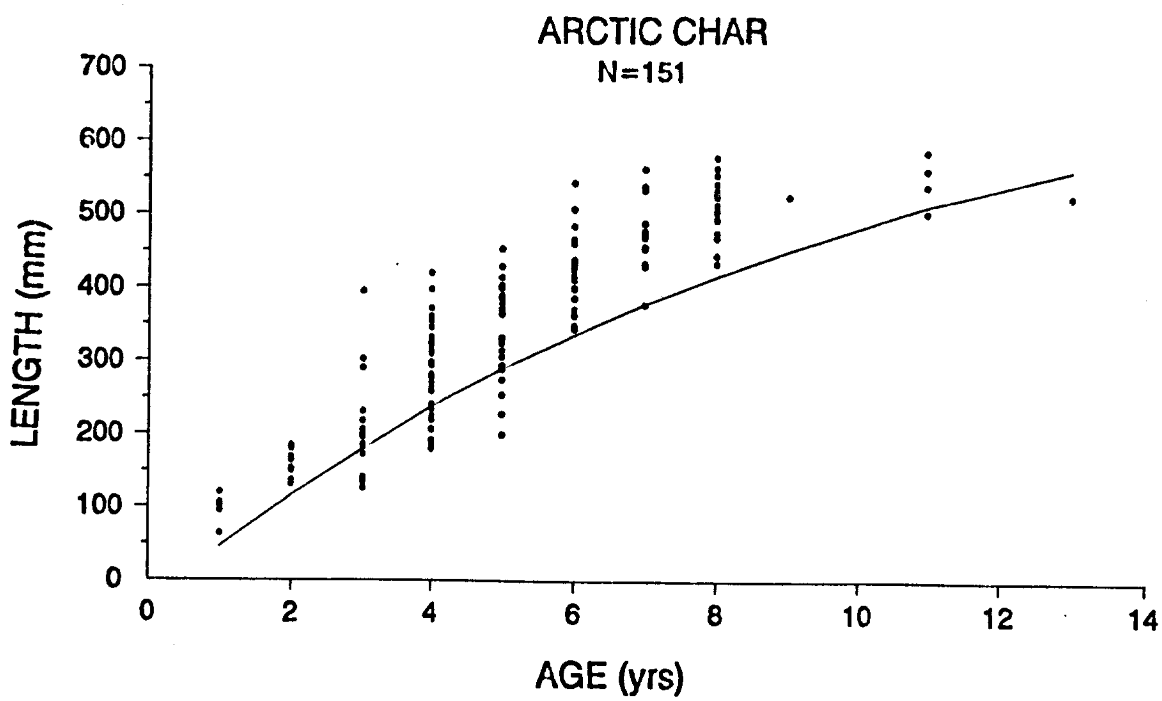

FIGURE 57.— von Bertalanffy growth model fit to age data for Arctic char, 1991.

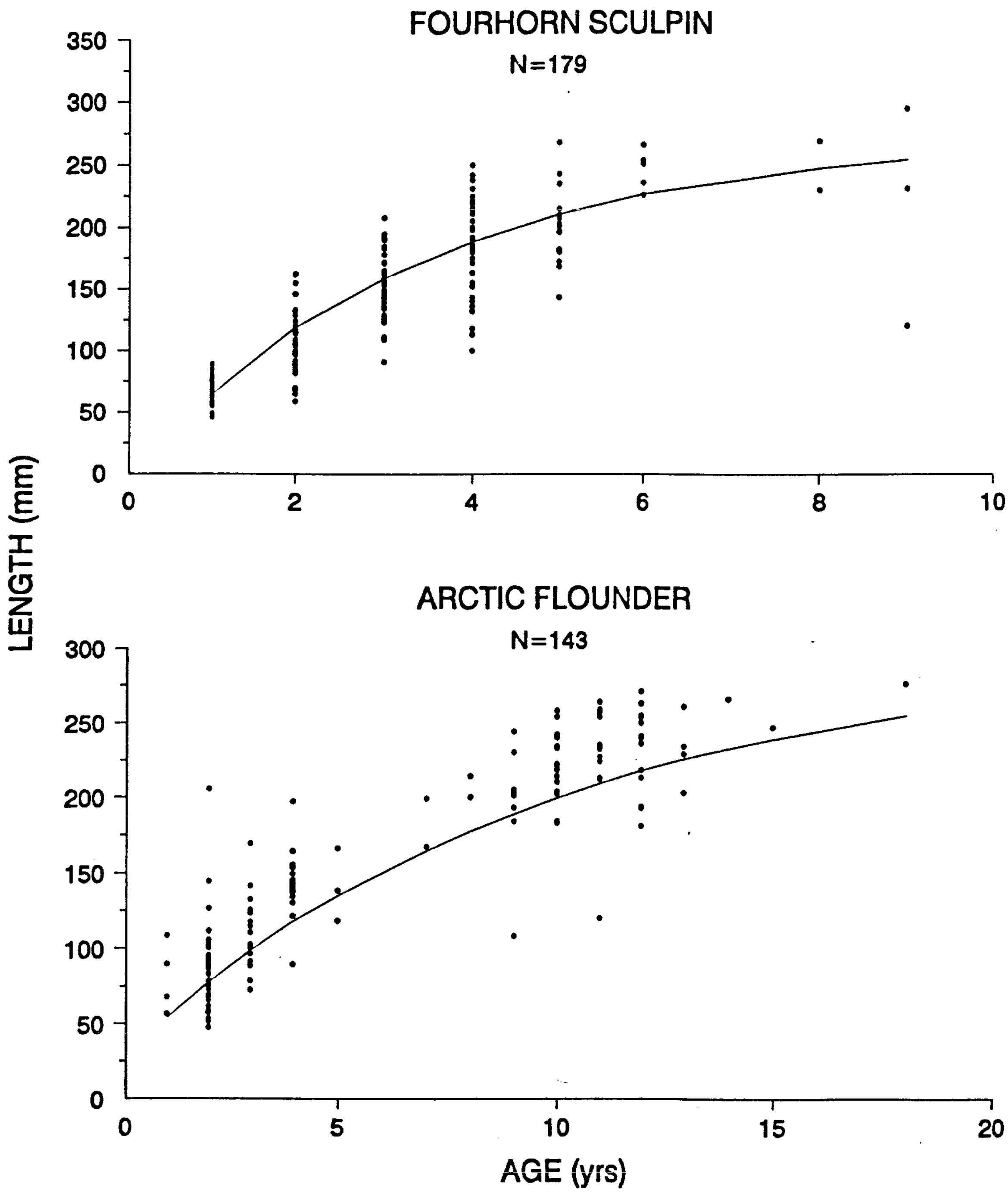

FIGURE 58.— von Bertalanffy growth model fit to age data for fourhorn sculpin and Arctic flounder, 1991.

TABLE 16.— Estimated von Bertalanffy growth parameters, sample size, and standard errors for 1991 age data stratified by species.

Species	N	$L\infty$ (SE)	K (SE)	t_0 (SE)
Arctic Char	151	784.3 (90.03)	0.1 (0.02)	0.4 (0.24)
Fourhorn Sculpin	179	273.0 (21.33)	0.3 (0.05)	0.1 (0.15)
Arctic Flounder	143	300.1 (32.51)	0.1 (0.03)	-1.0 (0.53)

TABLE 17.- Sample size, mean fork length-at-age, standard deviation, and length ranges for Arctic char collected July 14-29, 1991.

Age	N	Mean Fork Length-at-age (mm)	SD	Range
1	5	97.40	20.78	64-120
2	9	159.67	18.28	131-184
3	17	210.82	66.33	126-395
4	33	284.67	62.84	180-420
5	26	346.77	65.46	200-454
6	22	415.27	54.27	345-545
7	16	477.25	44.72	378-564
8	17	511.12	39.81	435-580
9	1	526.00	-	-
10	0	-	-	-
11	4	548.25	35.20	504-587
12	0	-	-	-
13	1	526.00	-	-

TABLE 18.– Sample size, mean fork length-at-age, standard deviation, and length ranges for Arctic cisco collected July 14-29, 1991.

Age	N	Mean Fork Length-at-age (mm)	SD	Range
0	0	-	-	-
1	18	99.22	10.00	83-113
2	1	100.87	13.04	84-127
3	0	-	-	-
4	0	-	-	-
5	3	328.67	13.05	315-341
6	8	339.75	12.00	328-361
7	13	370.85	26.75	325-425
8	13	387.23	23.54	350-435
9	13	385.54	18.15	353-412
10	13	393.31	38.45	283-445
11	5	388.00	11.07	377-403

TABLE 19.– Sample size, mean fork length-at-age, standard deviation, and length ranges for fourhorn sculpin collected July 14-29, 1991.

Age	N	Mean Fork Length-at-age (mm)	SD	Range
1	29	65.79	10.49	46-89
2	41	104.83	22.67	59-162
3	44	151.50	26.18	91-208
4	38	185.97	37.50	100-250
5	17	200.41	30.51	143-268
6	5	246.60	15.71	226-266
7	-	-	-	-
8	2	249.50	27.58	230-269
9	3	248.67	40.51	220-295

TABLE 20.– Sample size, mean fork length-at-age, standard deviation, and length ranges for Arctic flounder collected July 14-29, 1991.

Age	N	Mean Fork Length-at-age (mm)	SD	Range
1	4	81.00	23.17	57-109
2	35	87.80	29.60	48-206
3	20	109.15	23.47	73-170
4	17	142.35	21.63	90-198
5	3	141.67	24.11	119-167
6	0	-	-	-
7	2	184.00	22.63	168-200
8	2	208.00	9.90	201-215
9	9	200.78	39.59	109-245
10	16	221.69	22.01	184-259
11	14	231.57	36.44	121-265
12	14	231.14	28.31	182-272
13	4	232.75	23.77	204-262
14	1	267.00	-	-
15	1	248.00	-	-
16	0	-	-	-
17	0	-	-	-
18	1	277.00	-	-

Instantaneous Growth

Instantaneous growth for age 1 Arctic cisco decreased in calculated weight from early to late periods (*G* = -0.01).

MATURITY

For sex and maturity data, we examined 181 Arctic char, 110 Arctic cisco, 247 fourhorn sculpin and 115 Arctic flounder. Gonadosomatic indices (GSI) were calculated, but showed no vertical grouping by sex or maturity level when plotted against fish length (Figure 59-62). Few fish were identified as current year spawners (Table 21). Where comparisons could be made within a species, GSI ranges overlapped.

FISH MOVEMENTS

A total of 2,690 Arctic char and 530 Arctic cisco (<300 mm FL) were dye-marked during the 1991 field season. Ninety Arctic char (3%) and four Arctic cisco (1%) were recaptured (Table 22). Eight dye-marked Arctic char were recaptured in different sampling areas (Table 22). Two Arctic char marked in Camden Bay and two marked in the Kaktovik/Jago lagoon sampling area moved east; three were recaptured in Beaufort Lagoon and one was recaptured in the Kaktovik/Jago lagoon sampling area. The remaining four Arctic char moved west from Beaufort Lagoon and were recaptured in Camden Bay. One Arctic cisco dye marked in Beaufort Lagoon, was recaptured in the Kaktovik/Jago lagoon sampling area. All other recaptured fish were caught in the same sampling area where dye marking occurred.

A total of 996 Arctic char, 290 Arctic cisco, 189 fourhorn sculpin, and 143 Arctic flounder were tagged in 1991 with anchor (Floy) tags (Table 23). Of these, 88 Arctic char (9%), 18 fourhorn sculpin (10%), and 28 Arctic flounder (20%) were recaptured (Table 23, Appendix B). No recaptures of Arctic cisco from the 1991 tagging effort occurred.

Of the 88 Arctic char tagged and recaptured in 1991, 41 were recaptured at their original tagging station, 21 the day after their release. Another 26 Arctic char were recaptured at a different station within the original sampling area; all within a month of release. The additional eight Arctic char were recaptured in different sampling areas (Appendix B). Three of these eight fish moved east, and were recaptured within a month of release. Two of these eastward moving fish were tagged in Kaktovik Lagoon. One was recaptured 11 days later in Jago Lagoon, a distance of 6 km (travel rate = 0.05 km/d). The other Arctic char was recaptured in Beaufort Lagoon after traveling 61 km (travel rate = 2 km/d). The third fish to move east was tagged in Camden Bay and recaptured in Kaktovik Lagoon a distance of 55 km (travel rate = 2 km/d). Five Arctic char tagged in Jago Lagoon were recaptured west in Kaktovik Lagoon having spent between 3-17 days at large (average travel rate = 9 km/d).

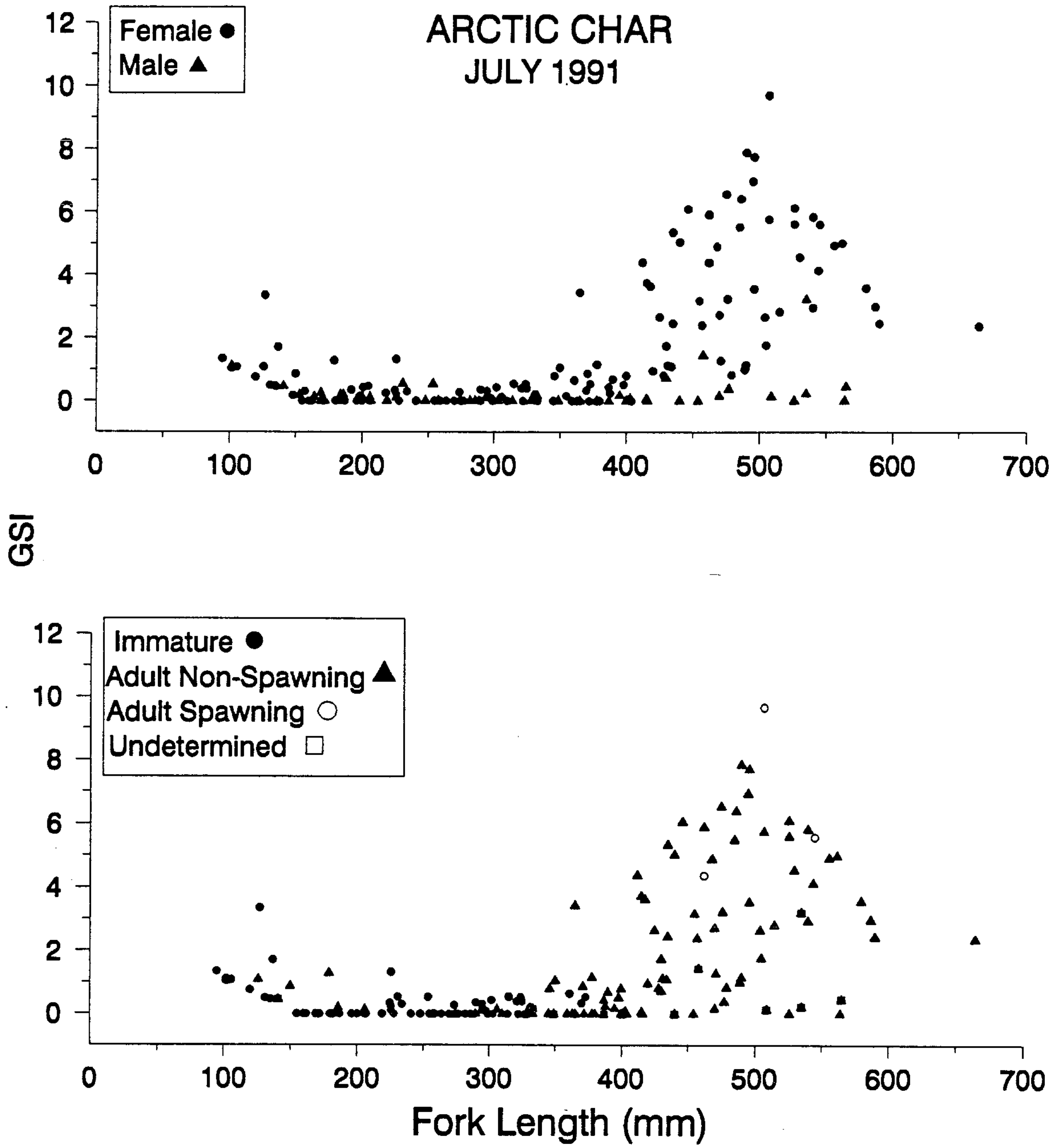

FIGURE 59.- Scatter plots Arctic char Gonadosomatic Index (GSI) on fish length by sex and maturity level. Sex and maturity levels were assigned in the field by dissection and gross examination during July, 1991.

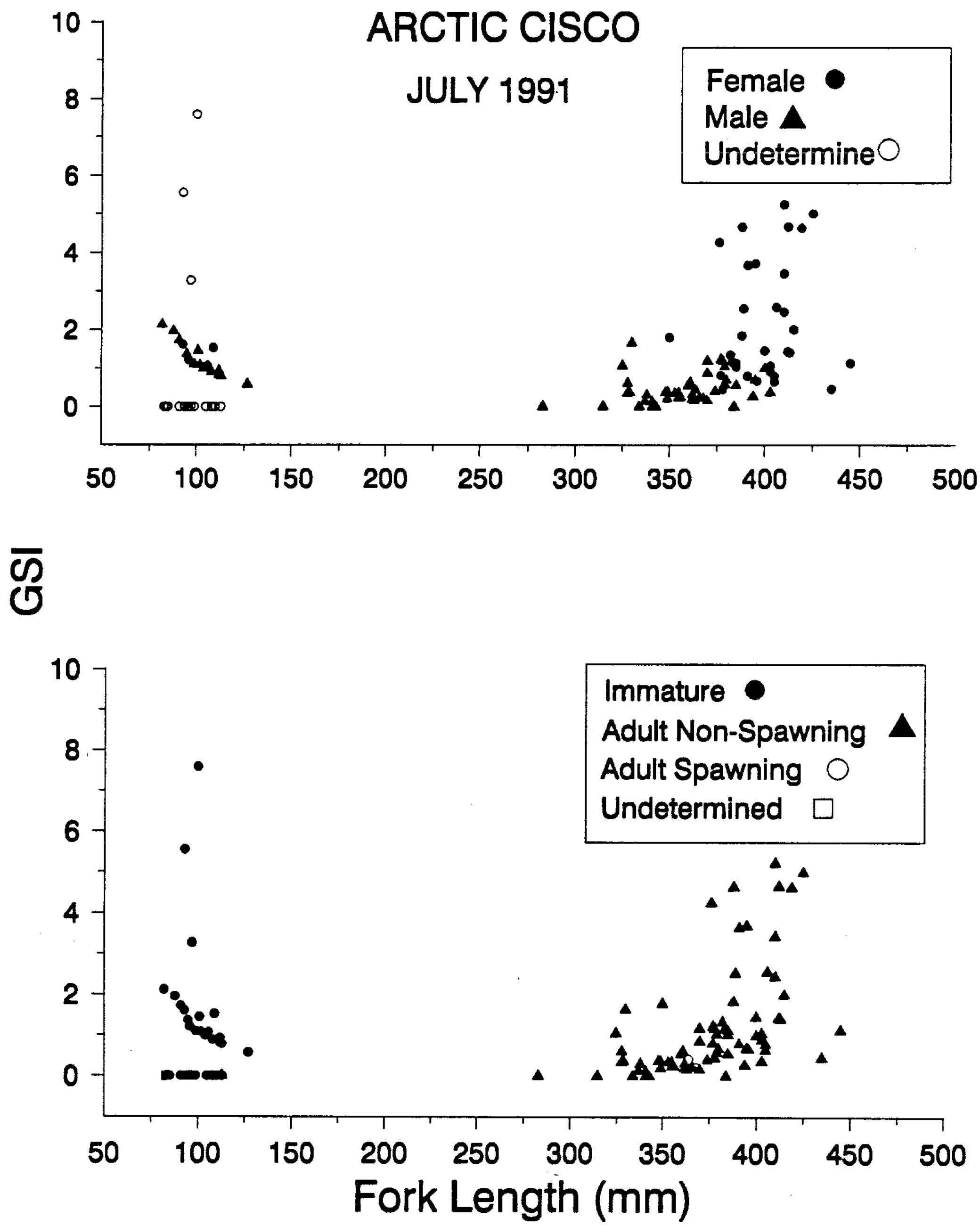

FIGURE 60.- Scatter plots Arctic cisco Gonadosomatic Index (GSI) on fish length by sex and maturity level. Sex and maturity levels were assigned in the field by dissection and gross examination during July, 1991.

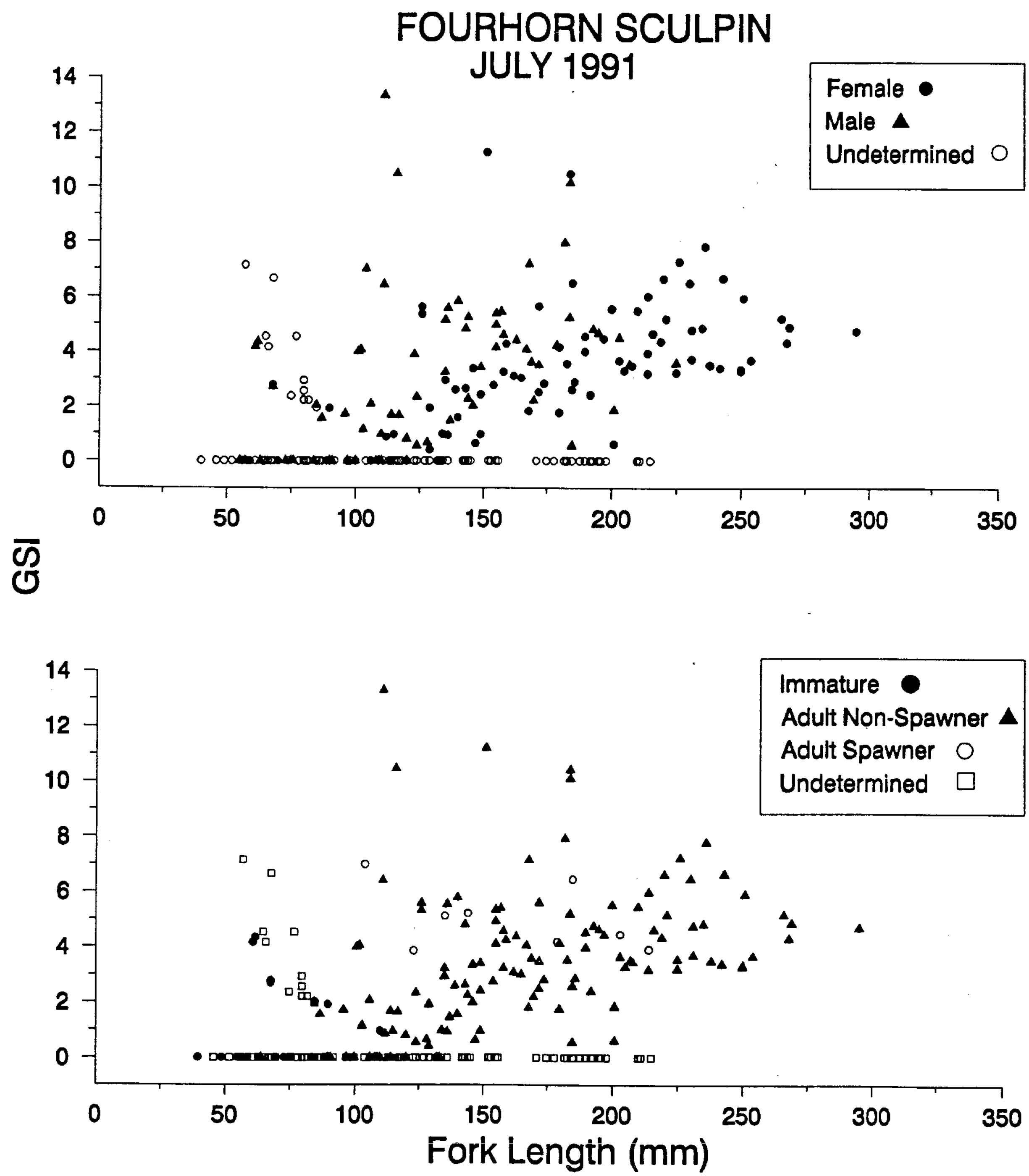

FIGURE 61.– Scatter plots fourhorn sculpin Gonadosomatic Index (GSI) on fish length by sex and maturity level. Sex and maturity levels were assigned in the field by dissection and gross examination during July, 1991.

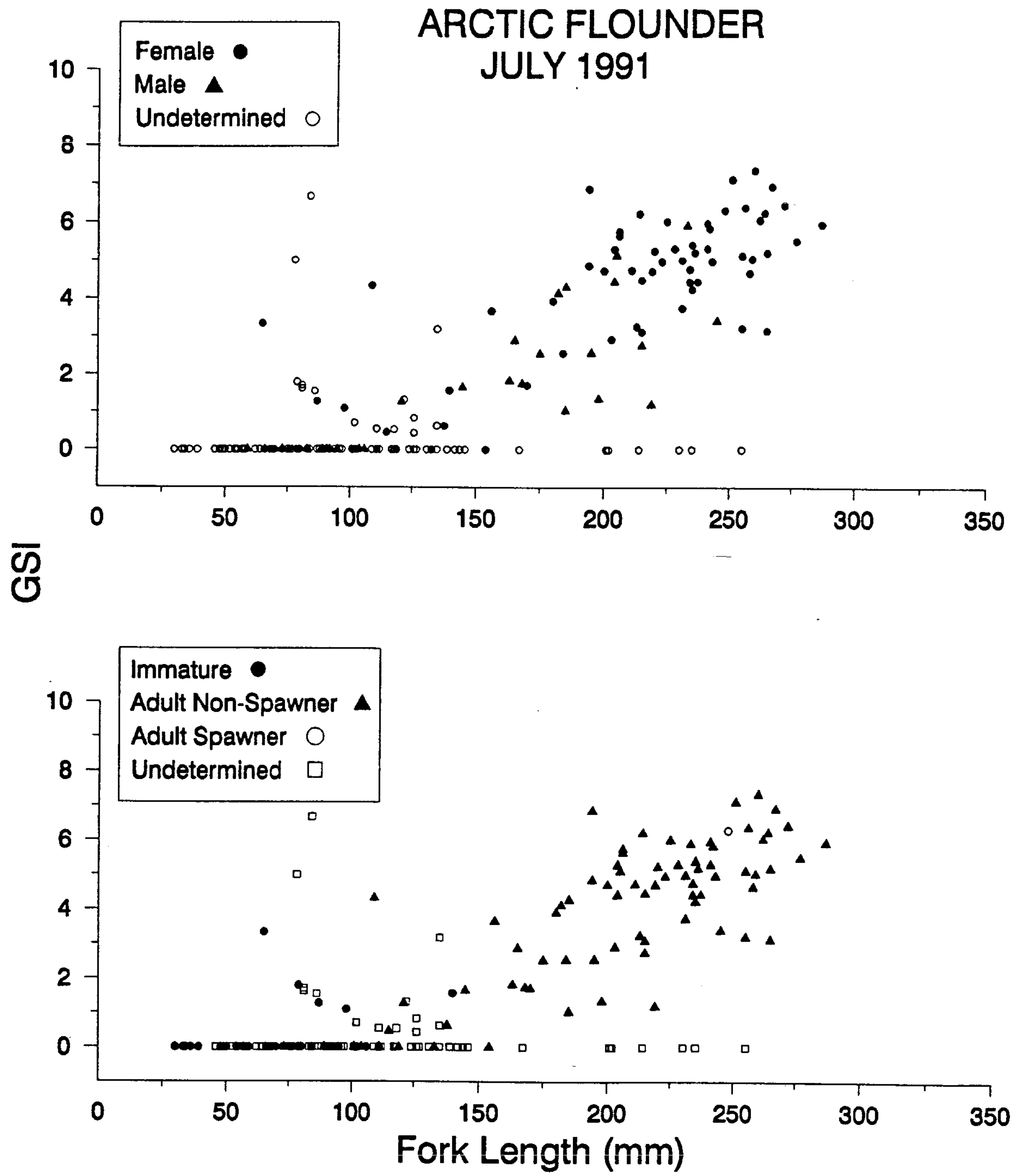

FIGURE 62.— Scatter plots Arctic flounder Gonadosomatic Index (GSI) on fish length by sex and maturity level. Sex and maturity levels were assigned in the field by dissection and gross examination during July, 1991.

TABLE 21.– Mean GSI, fork length, and age for mature non-spawning and spawning target species collected in 1991.

		GSI			Fork length			Age			
Spawning condition	N	$\bar{x}$	SD	Range	$\bar{x}$	SD	Range	N	$\bar{x}$	SD	Range
Arctic char											
Non-spawning females	74	2.5	2.3	0.7-7.9	431	96.1	126-665	61	6.6	1.9	3-13
Spawning females	3	6.6	2.8	4.4-9.7	504	41.6	462-545	3	6.7	1.2	6-8
Non-spawning males	30	0.3	0.6	0.1-3.2	391	114.0	141-565	24	3.8	2.0	3-9
Spawning males	0	---	---	---	---	---	---	0	---	---	---
Arctic cisco											
Non-spawning females	32	2.2	1.5	0.4-5.2	399	18.9	350-445	30	8.6	1.5	4-11
Spawning females	0	---	---	---	---	---	---	0	---	---	---
Non-spawning males	41	0.5	0.4	0.2-1.6	357	25.2	283-403	38	7.7	1.9	4-11
Spawning males	2	0.3	0.1	0.2-0.4	366	2.8	364-368	2	8.5	0.7	8-9
Fourhorn sculpin											
Non-spawning females	72	3.5	2.3	0.6-11.2	184	47.9	90-295	58	4.1	1.7	2-9
Spawning females	2	5.2	1.8	3.9-6.5	199	20.5	185-214	1	4.0	---	---
Non-spawning males	51	3.4	2.9	1.2-13.3	140	35.1	87-225	24	3.4	1.5	2-9
Spawning males	6	5.0	1.1	3.8-7.0	148	36.7	104-203	1	3.0	---	---
Arctic flounder											
Non-spawning females	56	4.4	2.0	0.4-7.4	215	47.2	101-287	53	9.6	3.3	2-18
Spawning females	1	6.3	---	---	248	---	---	1	15.0	---	---
Non-spawning males	20	2.4	1.7	1.2-5.9	173	46.8	73-245	18	8.3	3.5	2-13
Spawning males	0	---	---	---	---	---	---	0	---	---	---

TABLE 22.— Number of fish dye-marked (N) and recaptured by location during the summer of 1991, Arctic Refuge coastal waters.

		Recapture area		
Marking area	N	Camden Bay	Kaktovik and Jago lagoons	Beaufort Lagoon
Arctic char				
Camden Bay	1003	10	1	1
Kaktovik / Jago	806	0	27	2
Beaufort Lagoon	881	4	0	45
Arctic cisco				
Camden Bay	73	0	0	0
Kaktovik / Jago	55	0	1	0
Beaufort Lagoon	402	0	1	2

TABLE 23.— Number of fish tagged (N) and recaptured by location during the summer of 1991, Arctic Refuge coastal waters.

		Recapture area			
Tagging area	N	Camden Bay	Kaktovik Lagoon	Jago Lagoon	Beaufort Lagoon
Arctic char					
Camden Bay	345	4	1	1	1
Kaktovik Lagoon	155	1	7	2	1
Jago Lagoon	193	1	5	7	0
Beaufort Lagoon	303	0	0	0	57
Arctic cisco					
Camden Bay	180	0	0	0	0
Kaktovik Lagoon	6	0	0	0	0
Jago Lagoon	35	0	0	0	0
Beaufort Lagoon	69	0	0	0	0
Fourhorn sculpin					
Camden Bay	15	1	0	1	0
Kaktovik Lagoon	34	0	5	0	0
Jago Lagoon	124	0	1	8	0
Beaufort Lagoon	16	0	0	0	2
Arctic flounder					
Camden Bay	14	5	2	1	0
Kaktovik Lagoon	12	0	6	0	0
Jago Lagoon	64	1	1	6	0
Beaufort Lagoon	53	0	0	0	6

Thirteen Arctic char, marked in previous years, were recaptured in 1991 (Table 24). Seven of the 13 were recaptured in their original tagging area. Six Arctic char were recaptured in different sampling areas. Four of the six were captured to the east. An Arctic char originally tagged in 1986 at Oruktalik Lagooon was recaptured in 1991 at Beaufort Lagoon, increasing over 200 mm in length.

Of the 290 Arctic cisco tagged during 1991, no recaptures were made. However, four Arctic cisco tagged in the Prudhoe Bay area by LGL, Alaska Research Associates, Inc. (LGL), were recaptured (Table 24, Appendix B). Two Arctic cisco tagged in July 1991 were recaptured in Kaktovik Lagoon (average travel rate = 8 km/d). The other two Arctic cisco were tagged in 1985 and recaptured in Beaufort Lagoon (minimum travel distance 253, and 390 km respectively).

During the 1991 season, a total of 189 fourhorn sculpin were tagged and 18 recaptured. Of the fourhorn sculpin tagged in 1991, ten were recaptured at their original tagging station, and one at a different station within the original sampling area (Appendix B). Seven fourhorn sculpin, marked in previous years, were recaptured in 1991 (Table 24). Two of the seven were recaptured at their original tagging station. Three additional fourhorn sculpin were recaptured within their respective sampling areas. Two fourhorn sculpin were recaptured in a different sampling area (Appendix B). One, tagged in Jago Lagoon, was recaptured in Kaktovik Lagoon, approximately 10 km away. The second fourhorn sculpin moved from Camden Bay and was recaptured in Jago Lagoon, approximately 62 km east of its release site.

Twenty-eight Arctic flounder were recaptured and 143 tagged during the 1991 field season. Of the Arctic flounder tagged in 1991, all were recaptured at their original tagging stations (Table 23, Appendix B). Twenty-three Arctic flounder, marked in previous years, were recaptured in 1991 (Table 24). Sixteen of the 23 were recaptured at their original tagging stations, two tagged in 1988 and 14 tagged in 1990. Recaptures of two Arctic flounder occurred within their respective sampling areas. Five Arctic flounder were recaptured in a different sampling area. Three of the five moved east from Camden Bay to Kaktovik and Jago lagoons (minimum distance traveled was approximately 59 km) and two tagged in Jago Lagoon moved west. One was recaptured 6 km away in Kaktovik Lagoon, the other in Camden Bay, 62 km from its release site.

TABLE 24.– Summary of tagging and recapture data for fish species recaptured from previous years in Arctic Refuge coastal waters, summer 1991. 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
Arctic char							
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	BL02	07/31/91	0.0	337	396	FWS 12693
BL02	08/03/90	BL02	07/20/91	0.0	370	413	FWS 12322
BL02	08/04/90	BL04	07/28/91	2.0	337	394	FWS 12693
KL05	07/16/90	SC01	07/14/91	57.0	337	378	FWS 09574
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
Arctic cisco							
Harrison Bay	09/11/85	BL04	08/08/91	390.0	265	413	LGL 01562
Gwydyr Bay	07/31/85	BL04	08/19/91	253.0	271	368	LGL 35713
Fourhorn Sculpin							
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	09/01/90	6.0	204	210	FWS 14100
JL14	07/26/90	JL14	07/27/91	0.0	215	225	FWS 09989

TABLE 24.—Continued.

Tagging location	Tagging date	Recapture location	Recapture date	Minimum distance traveled (km)	Length at tagging (mm)	Length at recapture (mm)	Tag number
			Fourhorn sculpin				
JL14	07/23/90	KL05	08/26/91	0.0	229	223	FWS 09894
SC01	08/14/90	JL14	07/27/91	62.0	204	220	FWS 11552
			Arctic Flounder				
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
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
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	6.0	240	250	FWS 09942
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	08/08/90	SC04	07/28/91	0.0	205	205	FWS 11441

[a]Oruktalik Lagoon

DISCUSSION

RELATIVE ABUNDANCE AND DISTRIBUTION

During the 1991 field season the most prevalent target species was fourhorn sculpin. Although analyses are yet to be done, this appears to be a change from previous years of the study when Arctic cod in 1988 and 1989 and Arctic cisco ≤ 200 mm FL in 1990 were the most abundant target species (Frugé et al. 1989; Palmer and Dugan 1990; Underwood et al. 1992). The highest catch rate of Arctic cod occurred at Camden Bay station SC01, but was not significantly different from the fourhorn sculpin catch rate. The highest fourhorn sculpin catch rates occurred in Camden Bay and Jago Lagoon, while the lowest were in Kaktovik and Beaufort lagoons. These differences suggest that fourhorn sculpin abundance varies across the study area, as opposed to variation along an east to west gradient as found in previous years (Frugé et al. 1989; Palmer and Dugan 1990; Underwood et al. 1992). Analysis and comparison of oceanographic and catch data may provide better insight into this relationship.

Relative abundance of Arctic char during the 1991 field season fluctuated spatially and temporally. As in 1988, and 1990, Arctic char abundance appeared to decline during September. Even with differences in effort, this decrease seems to agree with McCart's (1980) observation that Arctic char leave the sea, and start their upstream migration in August. Data from 1991 included the highest daily observation of fish/d of the four years of study: 84 fish/d in 1988, ≈53 fish/d in 1989, ≈150 fish/d in 1990, and 843 fish/d in 1991 (Frugé et al. 1989; Palmer and Dugan 1990; Underwood et al. 1992). Of the four years, three of the four maximum Arctic char observations came from station SC01 in Camden Bay (the exception being station KL05 in 1989). This difference suggests spatial variation in abundance between station SC01 and all other stations.

Abundance of Arctic cisco ≤ 200 mm FL during the 1991 field season was noticeably different from previous years. Catch rates of over 100 fish/d never occurred, the highest being 95 fish/d at station BL02 on September 7, 1991. In previous years, catch rates exceeding 100 fish/d occurred before August 11 at Beaufort Lagoon and Pokok Bay. Therefore, maximum catch rates of Arctic cisco ≤ 200 mm FL in 1991 were lower and occurred at a later date than in previous years. Differences in catch rates between Beaufort Lagoon and all other sampling areas appear to be due to the prevalence of young-of-the-year Arctic cisco, 50-90 mm FL. This difference suggests spatial variation between Beaufort Lagoon and the other sampling areas. One possible reason for this difference is that Beaufort Lagoon is the first location in the study area in which Mackenzie River Arctic cisco 50-90 mm FL would be caught on their westward migration (Gallaway et al. 1983). If future analysis of oceanographic and meteorological data indicate that 1991 was a year of mixed wind vectors, this data would support Fechhelm and Griffiths (1990) hypothesis that mixed wind vectors delay the appearance of Arctic cisco ≤ 200 mm FL in coastal waters off Alaska.

Abundance of Arctic cisco > 200 mm FL, as in previous years, did not provide evidence of distinct trends. The maximum catch rate of 49 fish/d was neither the lowest nor highest maximum catch rate for the four years of study. There were no apparent temporal trends between stations or sampling areas. Spatial variability is suggested by the fact that Camden Bay station SC01 had a significantly higher catch rate than the other net stations. This difference suggests spatial variation between station SC01 and all other stations for Arctic cisco > 200 mm FL.

Arctic cod abundance fluctuated, as in past field seasons, starting with low daily catch rates, and increasing in August. The highest daily catch rates occurred at the Camden Bay stations as in other years of the study. The most notable change was that the highest daily catch rate was 1,838 fish/d at station SC01. This catch rate was considerably lower than 3,137 fish/d in 1988 (Pokok Bay), 63,752 fish/d in 1989 (Camden Bay), and 67,875 fish/d in 1990 (Camden Bay) (Frugé et al. 1989; Palmer and Dugan 1990; Underwood et al. 1992). Of the four years, three of the maximum Arctic cod catch rates came from station SC01 (the exception being station PB02, Pokok Bay, in 1988). These differences between Camden Bay and the other sampling areas suggest a spatial difference between locations.

Arctic flounder daily catch rates varied as in previous years of the study. Of the eight net stations, seven showed evidence of a decreasing catch rate through the season. The exception was station BL04 which showed an increasing trend until September 3, 1991. Spatial differences were indicated in that stations SC04 and KL05 had significantly higher catch rates than station JL12. Analysis of oceanographic data may result in identification of similarities between these stations favorable to Arctic flounder.

LENGTH FREQUENCY DISTRIBUTIONS

Length frequency distributions of Arctic char for 1991 had some similarities to those of previous years (Frugé et al. 1989; Palmer and Dugan 1990; Underwood et al. 1992). The mode from 170 to 220 mm FL, which shifted to the right over the course of the summer, was comparable to modes found previously in 1988-90. Often, modal groups between 125 mm and 225 mm FL were present and shifted to the right over the course of the season. This similarity between years could be interpreted as consistent recruitment from year to year of successive year classes followed by seasonal growth. Also, common to all years and most sampling areas, was the reduction of Arctic char larger than 300 mm FL as a proportion of the catch later in the season. This could be explained by migration during August of larger Arctic char into freshwater rivers prior to spawning and overwintering. One difference in length frequency distributions between years includes the relatively poor representation of any size classes of Arctic char in September 1990 (Frugé et al. 1989; Palmer and Dugan 1990; Underwood et al. 1992).

Length frequency distributions of Arctic cisco in 1991 showed some differences compared to those of 1990 (Underwood et al. 1992). The 1991 distributions showed few fish below 100 mm FL except in September at Beaufort Lagoon. In 1990, young-of-the-year appeared earlier in the season and were more widely distributed. Recruitment of young-of-the-year Arctic cisco would be considered poor in 1991 compared to 1990. Recruitment to the area in 1988 and 1989 was intermediate (Frugé et al. 1989; Palmer and Dugan 1990). Common to all years is the presence of juvenile Arctic cisco during July. Juvenile fish, especially those between 100 and 150 mm FL, present in July during a heavy ice year suggests overwintering of small Arctic cisco may occur in refuge waters. It seems unlikely that juvenile fish would distribute so widely along the Alaskan coast so early in the season. Poor representation by Arctic cisco from 150 to 250 mm FL has been a general trend with few exceptions over the four years. Larger Arctic cisco appear to be an important component of the catch early in the season each year, but less important later in the summer. Current hypotheses of Arctic cisco life history and movements would suggest that mature fish occurring in Arctic Refuge waters would be traveling east from the area of the Colville River, Alaska, to spawn in the Mackenzie River, Canada. Greater proportions of large fish early in the season would suggest that peak movement occurs in July, then slows later in the season.

Length frequency distributions of Arctic cod were much the same in 1991 as in previous years with two exceptions. Distributions showed low representation in July at all stations, a substantial change from past years. Second, Arctic cod were present earlier in the year at Beaufort Lagoon than previous years (Frugé et al. 1989; Palmer and Dugan 1990; Underwood et al. 1992).

Fourhorn sculpin length frequency distributions were similar to those of previous years (Frugé et al. 1989; Palmer and Dugan 1990; Underwood et al. 1992). Two to three modal groups gradually shifted to the right during the course of the open water season. An additional mode consisting of fourhorn sculpin from 30 to 60 mm TL appeared in September each year. These small fish appear to be young-of-the-year. The overall consistency of the pattern between years indicates regular recruitment and growth.

Length frequency distributions of Arctic flounder in 1991 were similar to those in 1990 (Underwood et al. 1992), but much different than those of previous years (Frugé et al. 1989; Palmer and Dugan 1990). The strong modal group of fish 50 to 100 mm TL during 1990 continued to be the predominant size group in 1991. The mode shifted to the right during the course of the 1991 season indicating growth. A small mode of fish 40 to 60 mm TL appeared in Beaufort and Jago lagoons in 1991, indicating another year-class. A similar mode of small fish was present in 1989, but not in 1990. This pattern may indicate uneven recruitment between years.

FISH CONDITION

Detected differences in condition of early and late fish collections reflected an increase in weight for a given length for three species. Arctic cisco, Arctic flounder and fourhorn sculpin became more robust over the course of the open water season. One would expect fish to increase fat reserves and gonadal tissue during the warmer summer season. Differences in Arctic char form (slope estimates) make generalizations about condition tenuous. Scatter plots of Arctic char lenghts indicate that large fish were not captured in September. Mostly immature Arctic char from September were thus compared to all size groups which were present in the July sample. Detection of a difference in body form (slope estimates) would be expected in such a situation.

Departures from statistical assumptions of homoscedasticity were not great and would not affect analyses which are considered robust regarding unequal variances. The fact that outliers were often small fish (probably young-of-the-year) might indicate that the length-weight relationship of the small fish differs from those of the large fish. This suggests that for long term monitoring a separate weight-length relationship should be developed for small fish.

The 1991 results depart from those of 1990 in two ways. First, in 1990 Arctic cisco declined in condition over the course of the open water season. Hypotheses were presented for this (Underwood et al. 1992), but the phenomena remains unexplained. Second, in 1990 significant differences in intercepts ($P = 0.09$) and slope ($P = 0.07$) were not found between early and late Arctic char. Small differences in the data set could be expected to alter the results. Differences between early and late season condition emphasize the importance of the time of sampling when monitoring changes in weight-length relationships.

Differences in condition by sex could be expected (Bagenal and Tesch 1978). The 1991 results would indicate that researchers should consider developing separate weight-length relationships by sex for Arctic cisco and Arctic flounder. Additional analysis of other data sets would aid in such a discussion. If condition is to be used as a tool to monitor change in the future, the not significant results between sexes in Arctic char and fourhorn sculpin also need further research for confirmation.

Condition differences between spawners and non-spawners do not appear to have an effect on the weight-length relationship of Arctic char or Arctic cisco. The small number of spawners identified in our samples makes their influence minimal. Palmer and Dugan (1990) also found extremely low numbers of current year spawners in 1989. This statement is tempered, however, by the field crew's inability to identify spawners of the current year. This problem was discussed at length by Craig and Haldorson (1981) who pointed out the difficulty of determining, by dissection and gross examination, which fish would spawn in a given year. In addition, gonadosomatic indices offered no clear distinction between mature non-spawning and spawning Arctic char and Arctic cisco.

AGE AND GROWTH

Species sampled in our study of the coastal waters of the Arctic Refuge exhibit growth patterns that are characteristic of Arctic organisms. Craig (1989) considered Arctic anadromous fishes to be limited by, but well adapted to, low temperatures, lack of over-wintering habitat, and short feeding seasons. He refers to these species as K-strategists, characteristics of which, relative to temperate and tropical systems, include slow growth, delayed maturation, low fecundity, and multi-cohort spawning stocks. These characteristics are exhibited in the life-histories of both anadromous and marine species in our study. Because of the extremely slow turn-over of generations, organisms in this type of system are highly vulnerable to exploitation and/or disturbance.

Wide overlap in length ranges between older age groups have been reported for other Beaufort Sea coastal areas (Craig and Mann 1974; Griffiths et al. 1975, 1977; Craig 1977; Lawrence et al. 1984; Wiswar and West 1987; Bond and Erickson 1987; Whitmus et al. 1987; Palmer and Dugan 1990) and is characteristic of non-exploited populations (Parker and Johnson 1991). Low sample sizes may account for some length overlap and apparent lack of growth with age of older fish (Johnson 1972). Immature fish, however, exhibit relatively fast growth as shown by the increments between mean length at age values of Arctic char and Arctic cisco, which are twice that of adults (Tables 17 and 18). Although fast growth of age 1 Arctic cisco was not evident between the early and late periods of the season, our sample sizes were perhaps too low to detect seasonal growth or growth was low during 1991.

Arctic flounder and fourhorn sculpin are long-lived and relatively sedentary species and can be highly negatively impacted by habitat disturbance because of low generation turnover and the inability to make extensive movements to other areas.

Arctic char are thought to exhibit a bi- or tri-modal length frequency distributions throughout their geographic range, indicating separation between juveniles and adults (Parker and Johnson 1991). During our early sampling period in 1991, length and age frequencies of anadromous Arctic char corresponded poorly (Figure 55). However, length frequencies were bi- and tri- modal (Figures 30-33), which agrees, with length frequency distributions from past studies (Wiswar and West 1987; Frugé et al. 1989; Palmer and Dugan 1990; Underwood et al. 1992). Small sample sizes and the limited time of sampling for the Arctic char we aged may account for this discrepancy with the overall length frequencies.

We caught few age 0 Arctic cisco in 1991. Several factors could have contributed to the absence of this age-group, including: 1) heavy ice conditions inhibited their dispersal from the east; 2) offshore migration routes (Schmidt et al. 1991); 3) recruitment of young-of-the-year was low due to biotic (i.e. food) or abiotic (i.e. winds, temperature, salinity) factors; and 4) unfavorable wind conditions. Successful recruitment of young-of-the-year Arctic cisco into the Sagavanirktok and Colville river deltas is thought to be controlled by prevailing winds. During summers of strong easterly winds from mid-July to late-August, recruitment of young-of-the-year into Alaskan waters is facilitated and increased. In years which weak easterly winds or westerly winds prevail, young-of-the-year Arctic cisco recruitment into Alaskan waters is delayed or possibly prevented (Schmidt et al. 1991, Fechhelm and Griffiths 1990).

MATURITY

Craig and Haldorson's (1981) discussion of the problem of identifying current year spawners focused mainly on Arctic cisco. Scatter plots of GSI versus length (Figures 58-61) show a similar problem of distinguishing spawners in the other three species examined in this year's study. The plots also emphasize the arbitrary nature of using GSI levels to identify current year spawners. Clear groupings of current year spawning adults could not be distinguished.

GSI scatter plots do reveal the minimum length of fish at first maturity. Although one Arctic char shows an elevated GSI at just over 350 mm FL, most Arctic char exhibiting elevated GSI were larger than 400 mm Fl. Palmer and Dugan (1990) reported fish greater than 400 mm FL were above age 5, which agrees with otolith readings from 1991. Arctic cisco exhibited elevated GSI levels at lengths of approximately 325 mm FL, which corresponds to age 5 and older fish (Palmer and Dugan 1990). Additional data are needed for Arctic cisco because few fish from 250 to 350 mm FL were caught. Fourhorn sculpin can mature at a small size of 70 mm TL. Elevated GSI levels of fourhorn sculpin occurred at a relatively short length corresponding to ages of 1 to 3 years (Palmer and Dugan 1990). Arctic flounder also exhibit elevated GSI levels at short lengths (< 100 mm TL).

Each GSI scatter plot also showed a group of larger fish with low GSI levels. Although GSI for fourhorn sculpin and Arctic flounder at a given length varied widely in larger fish, a group of fish with low GSI values was also present. Low GSI levels may indicate that individuals do not spawn every year and all the four target species exhibit this characteristic.

FISH MOVEMENTS

Although 157 marked Arctic char were recaptured in 1991 (recovery rate ≈4%), most recaptures (83%) occurred in the original sampling area where the fish were marked. A possible explanation for this high recapture occurrence is the abundant food supply found within the sampling areas. Arctic char use nearshore habitats as feeding locations (Craig and McCart 1976). Recaptured fish from original sampling areas support the theory of nearshore feeding behavior (Craig and McCart 1976; Griffiths and Dillinger 1981; Craig 1984). To acquire necessary food during the brief summer season, it is advantageous for Arctic char to occur where food is abundant, namely in nearshore areas (Craig 1989). Given the local abundance of prey in the lagoons, Arctic char need not move extensively to feed, hence the high occurrence of recaptures.

Tagged Arctic char recaptured in different sampling areas appear to agree with current migration theories (Craig 1984). Our tagging data indicated both eastward and westward movement along the coast. This agrees with Craig's (1984) observation that Arctic char entering coastal waters from overwintering rivers disperse east and west along the coast. Many anadromous populations of Arctic char of the Arctic Refuge migrate from rivers into the lagoons during spring (Craig and McCart 1976), remaining in the shallow nearshore area throughout the summer to feed. This dispersal can be of considerable distance (Craig and McCart 1976). Furniss (1975) reported two Arctic char from the Sagavanirktok River drainage migrating 300 km west to the Elson Lagoon near Barrow, Alaska. McCart (1980) reported that an Arctic char tagged in the Firth River, Canada was recaptured in the Canning River, a minimum travel distance of 250 km. Tagging results from 1991 indicated one Arctic char traveling a minimum distance of 109 km, and six traveling 56 km. Arctic char return to the freshwater systems for overwintering as early as August and continue the pattern into October (Craig 1984). Our tagging data also suggested late summer movement of Arctic char into freshwater by a sharp drop in recaptures after mid-August.

Westward movement of small Arctic cisco (< 200 mm FL) in refuge waters was documented during the 1991 field season by the presence of a dye-marked fish from Beaufort Lagoon in the Kaktovik and Jago lagoon sampling area. Little is known about the movement of these older immature fish. During the winter, they take up residence in coastal zones close to river deltas (Gallaway et al. 1983). Migrating young Arctic cisco (Ages 0-1) from the Mackenzie River are believed to be moving westward through refuge waters to overwintering areas in the Colville and Sagavanirktok River deltas (Frugé et al. 1989).

None of the 290 large Arctic cisco (> 200 mm FL) tagged during 1991 field season was recaptured which was similar to past studies (West and Wiswar 1985; Wiswar and West 1987; Wiswar et al. *in preparation*). These authors suggested that large Arctic cisco use the lagoons for brief time periods, before continuing their coastal movements, hence the lack of within-year recaptured Arctic cisco. Movement of four large Arctic cisco tagged in Prudhoe Bay and recaptured during the 1991 field season is consistent with current migration theories for this species (Gallaway et al.1983; Fechhelm et al. 1989). Gallaway et al. (1983) suggested that sexually mature large Arctic cisco (Ages 7-9, > 350 mm FL) migrate toward the Mackenzie River drainage during the open-water season.

Movement patterns of fourhorn sculpin and Arctic flounder during the 1991 field season generally occurred within the boundaries of the Arctic Refuge. Our findings were consistent with previous studies (Craig 1984; Palmer and Dugan 1990) in that many fourhorn sculpin (N = 5) and Arctic flounder (N = 19) from previous years were recaptured in the same area where tagged. These authors reported localized movement patterns for both species in Beaufort Sea coastal waters. But, the eastward movement of one fourhorn sculpin and four Arctic flounder from Camden Bay to Kaktovik and Jago lagoons and the westward movement of one Arctic flounder from Jago Lagoon to Camden Bay indicate these species can move considerable distances along the coast.

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APPENDIX A: Area and station catch per unit effort.

TABLE A.1.– Mean daily catch per unit effort (fish/d) ± 1 DS, by fyke net sampling areas in Arctic Refuge coastal waters, July - September 1991.

Species	Camden Bay N = 87	Kaktovik Lagoon N = 95	Jago Lagoon N = 90	Beaufort Lagoon N = 105
Arctic cod	121.31 ± 265.44	6.56 ± 20.02	4.25 ± 12.97	0.08 ± 0.30
Fourhorn sculpin	149.66 ± 235.02	78.55 ± 82.46	89.10 ± 197.30	36.60 ± 37.37
Ninespine stickleback	3.17 ± 4.72	0.73 ± 1.23	4.17 ± 6.09	2.08 ± 4.93
Arctic flounder	40.30 ± 51.62	31.58 ± 31.52	24.37 ± 31.29	19.99 ± 17.28
Arctic cisco (≤200 mm)	4.37 ± 7.79	1.03 ± 2.26	2.69 ± 4.11	11.12 ± 16.14
Arctic cisco (>200 mm)	6.74 ± 8.91	1.94 ± 3.14	1.67 ± 2.22	3.12 ± 4.95
Arctic char	65.54 ± 109.45	21.70 ± 22.00	12.46 ± 10.23	19.12 ± 19.47
Saffron cod	3.77 ± 5.22	7.57 ± 9.80	6.56 ± 8.27	7.80 ± 10.65
Rainbow smelt	10.70 ± 19.14	0.50 ± 1.25	2.09 ± 4.05	0.36 ± 0.78
Slender eelblenny	0.90 ± 0.29	0.19 ± 4.26	0.01 ± 0.12	0.06 ± 0.22
Arctic sculpin	0.31 ± 1.60	0.35 ± 0.97	0.52 ± 1.37	0.50 ± 0.90
Broad whitefish	0.01 ± 0.10	0.02 ± 0.19	0.04 ± 0.20	0.02 ± 0.15
Least cisco	0.90 ± 1.87	0.12 ± 0.45	0.05 ± 0.27	0.11 ± 0.45
Pacific herring	0.01 ± 0.10	0.02 ± 0.14	0.00 ± 0.00	0.00 ± 0.00
Pink salmon	0.01 ± 0.11	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Capelin	0.03 ± 0.16	0.00 ± 0.00	0.01 ± 0.11	0.00 ± 0.00
Arctic grayling	0.03 ± 0.18	0.07 ± 0.29	0.00 ± 0.00	0.07 ± 0.26
Arctic staghorn sculpin	0.01 ± 0.10	0.04 ± 0.21	0.01 ± 0.06	0.01 ± 0.11
Greenland seasnail	0.09 ± 0.32	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Pacific sand lance	0.00 ± 0.00	0.00 ± 0.02	0.00 ± 0.00	0.00 ± 0.00
Unidentified sculpin	0.07 ± 0.46	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00

TABLE A.2.– Mean daily catch per unit effort (fish/d) ± standard deviation by fyke net sampling stations in Arctic Refuge coastal waters, July - September 1991.

	Camden Bay		Kaktovik Lagoon		Jago Lagoon		Beaufort Lagoon	
Species	SC01 (N=55)	SC04 (N=32)	KL05 (N=44)	KL10 (N=51)	JL12 (N=41)	JL14 (N=49)	BL02 (N=56)	BL04 (N=49)
Arctic cod	142.58 (±307.79)	84.74 (±168.14)	4.54 (±11.57)	8.30 (±25.13)	1.68 (±4.94)	6.40 (±16.77)	0.08 (±0.35)	0.07 (±0.25)
Fourhorn sculpin	75.27 (±120.86)	277.52 (±317.95)	101.76 (±113.02)	58.53 (±30.27)	54.24 (±48.39)	116.60 (±261.79)	54.20 (±41.67)	16.48 (±16.19)
Ninespine stickleback	2.60 (±3.85)	4.15 (±5.87)	0.57 (±0.96)	0.86 (±1.42)	1.77 (±1.67)	6.18 (±7.58)	3.16 (±6.45)	0.84 (±1.43)
Arctic flounder	34.23 (±47.89)	50.73 (±56.74)	42.41 (±38.19)	22.23 (±20.51)	12.66 (±10.39)	34.17 (±38.86)	22.81 (±16.84)	16.76 (±17.38)
Arctic cisco (≤200mm)	4.77 (±9.25)	3.69 (±4.27)	0.77 (±1.20)	1.25 (±2.88)	1.31 (±1.99)	3.36 (±5.01)	14.41 (±20.02)	7.36 (±8.83)
Arctic cisco (>200mm)	10.15 (±9.59)	0.88 (±1.96)	1.51 (±1.72)	2.32 (±3.95)	2.27 (±2.70)	1.17 (±1.57)	2.19 (±2.78)	4.19 (±6.49)
Arctic char	90.46 (±126.53)	22.72 (±48.51)	28.11 (±27.29)	16.17 (±14.23)	13.54 (±10.71)	11.55 (±9.83)	21.12 (±21.36)	16.84 (±16.98)
Saffron cod	4.46 (±5.87)	2.59 (±3.65)	5.63 (±7.34)	9.25 (±11.32)	7.22 (±8.36)	6.02 (±8.24)	10.24 (±12.48)	5.01 (±7.26)
Rainbow smelt	9.44 (±18.91)	12.87 (±19.64)	0.14 (±0.37)	0.80 (±1.62)	2.59 (±5.44)	1.67 (±2.32)	0.55 (±0.96)	0.14 (±0.40)
Slender eelblenny	0.14 (±0.35)	0.00 (±0.00)	0.24 (±0.68)	2.01 (±5.68)	0.03 (±0.17)	0.00 (±0.00)	0.07 (±0.23)	0.05 (±0.21)
Arctic sculpin	0.48 (±2.00)	0.02 (±0.12)	0.05 (±0.23)	0.61 (±1.26)	0.99 (±1.89)	0.13 (±0.39)	0.85 (±1.08)	0.10 (±0.31)
Broad whitefish	0.02 (±0.13)	0.00 (±0.00)	0.00 (±0.00)	0.04 (±0.26)	0.08 (±0.29)	0.00 (±0.00)	0.02 (±0.14)	0.02 (±0.16)

TABLE A-2.—Continued.

Species	Camden Bay		Kaktovik Lagoon		Jago Lagoon		Beaufort Lagoon	
	SC01 (N=55)	SC04 (N=32)	KL05 (N=44)	KL10 (N=51)	JL12 (N=41)	JL14 (N=49)	BL02 (N=56)	BL04 (N=49)
Least cisco	1.24 (±2.22)	0.32 (0.73)	0.12 (±0.45)	0.11 (±0.45)	0.12 (±0.39)	0.00 (±0.00)	0.09 (±0.39)	0.13 (±0.51)
Pacific herring	0.02 (±0.13)	0.00 (±0.00)	0.00 (±0.00)	0.04 (±0.19)	0.00 (±0.00)	0.00 (±0.00)	0.00 (±0.00)	0.00 (±0.00)
Pink Salmon	0.02 (±0.13)	0.00 (±0.00)	0.00 (±0.00)	0.00 (±0.00)	0.00 (±0.00)	0.00 (±0.00)	0.00 (±0.00)	0.00 (±0.00)
Capelin	0.05 (±0.21)	0.00 (±0.00)	0.00 (±0.00)	0.00 (±0.00)	0.02 (±0.16)	0.00 (±0.00)	0.00 (±0.00)	0.00 (±0.00)
Arctic grayling	0.04 (±0.19)	0.03 (±0.17)	0.05 (±0.21)	0.08 (±0.35)	0.00 (±0.00)	0.00 (±0.00)	0.07 (±0.27)	0.06 (±0.25)
Arctic staghorn sculpin	0.02 (±0.13)	0.00 (±0.00)	0.00 (±0.03)	0.08 (±0.28)	0.01 (±0.08)	0.00 (±0.02)	0.00 (±0.00)	0.02 (±0.15)
Greenland seasnail	0.14 (±0.40)	0.00 (±0.00)	0.00 (±0.00)	0.00 (±0.00)	0.00 (±0.00)	0.00 (±0.00)	0.00 (±0.00)	0.00 (±0.00)
Pacific sand lance	0.00 (±0.00)	0.00 (±0.00)	0.00 (±0.03)	0.00 (±0.00)	0.00 (±0.00)	0.00 (±0.00)	0.00 (±0.00)	0.00 (±0.00)
Unidentified sculpin	0.11 (±0.57)	0.00 (±0.00)	0.00 (±0.00)	0.00 (±0.00)	0.00 (±0.00)	0.00 (±0.00)	0.00 (±0.00)	0.00 (±0.00)

APPENDIX B: Tag and recapture data for Arctic coastal waters.

TABLE B.1.– Summary of all tagging and recapture data for fish species recaptured in Arctic Refuge coastal waters, Summer 1991. Dashed line indicates lengths which were not obtained. Next day recaptures are not included.

Tagging location	Tagging date	Recapture location	Recapture date	Minimum distance traveled (km)	Length at tagging (mm)	Length at recapture (mm)	Tag number
			Arctic char				
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	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
BL02	07/22/91	BL02	07/28/91	0.0	447	447	FWS 13920
BL02	08/04/90	BL02	07/31/91	0.0	337	396	FWS 12693
BL02	07/26/91	BL02	08/01/91	0.0	526	527	FWS 13817
BL02	07/24/91	BL02	08/02/91	0.0	387	386	FWS 13897
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	07/19/91	BL02	08/02/91	0.0	462	461	FWS 13817
BL02	07/26/91	BL02	08/03/91	0.0	526	521	FWS 12693
BL02	07/22/91	BL02	08/05/91	0.0	389	388	FWS 13917
BL02	07/24/91	BL02	08/05/91	0.0	387	389	FWS 13897
BL02	08/03/90	BL02	07/20/91	0.0	370	413	FWS 12322
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	08/04/90	BL04	07/28/91	2.0	337	394	FWS 12693
BL02	07/25/91	BL04	07/30/91	2.0	427	426	FWS 13444
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	BL02	07/28/91	2.0	461	457	FWS 13959

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
			Arctic char				
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
BL04	07/26/91	BL04	07/29/91	0.0	320	318	FWS 13411
BL04	07/27/91	BL04	07/29/91	0.0	461	453	FWS 13959
BL04	07/26/91	BL04	07/30/91	0.0	375	377	FWS 13401
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
KL05	07/16/90	SC01	07/14/91	57.0	337	378	FWS 09574
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
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
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
JL14	07/17/91	JL12	07/31/91	5.0	310	320	FWS 14412
JL14	08/07/90	JL12	07/28/91	5.0	341	396	FWS 13509
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
JL14	07/21/91	KL05	08/07/91	10.0	303	299	FWS 14355

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
			Arctic char				
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
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
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
[a]Oruk.	08/05/86	BL02	07/19/91	32.0	320	527	FWS 07162
			Arctic cisco				
Harrison Bay	09/11/85	BL04	08/08/91	390.0	283	413	LGL 01562
Gwydyr Bay	07/31/85	BL04	08/19/91	253.0	271	368	LGL 35713
Stump Island	07/23/91	KL10	08/11/91	175.0	320	---	LGL 10893
[b]West Beach	07/19/91	KL10	08/13/91	165.0	294	306	LGL 07454
			Fourhorn Sculpin				
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	09/01/90	6.0	204	210	FWS 14100
KL10	07/17/91	KL10	07/22/91	0.0	225	254	FWS 14663

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
Fourhorn sculpin							
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	07/26/90	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
SC01	08/05/91	SC01	08/01/91	0.0	242	244	FWS 12341
Arctic Flounder							
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
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

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
			Arctic flounder				
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
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
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

[a]Oruktalik Lagoon

[b]Prudhoe Bay area