FINAL REPORT
31 May 2000

THE 1999 POINT THOMSON UNIT NEARSHORE MARINE FISH STUDY

Prepared by

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and the
Point Thomson Unit Partners

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ABSTRACT

Coastal marine anadromous/amphidromous fish species were sampled at five locations in Lions Bay near Point Thomson during July and August 1999. These studies were designed to describe fish species present in the vicinity of a proposed coastal dock to support oil and gas development in the Point Thomson Unit. Large numbers of Arctic cisco juveniles (age 0) were captured during August, indicating a wind-aided recruitment of this species from the Mackenzie River likely occurred in 1999. Relatively large numbers of adult least cisco, adult humpback whitefish, and adult broad whitefish also were captured; this suggests that the summer foraging range for these species from the Colville River (least cisco, humpback, and broad whitefish) and the Sagavanirktok River (broad whitefish) extends eastward to Lions Bay. Large catches of Dolly Varden also indicate the Lions Bay area is important foraging habitat for Dolly Varden, probably from the Canning River. A few Arctic grayling were captured as these fish moved between coastal freshwater streams during summer feeding migrations.

INTRODUCTION

Study Objective

During July-August 1999, LGL Alaska Research Associates, Inc. (LGL) collected data on fish resources in coastal waters near Point Thomson, Alaska. The objective of this study was to describe the distribution and abundance of marine and diadromous fishes in the barrier island lagoon system known as Lions Bay. This information will be used to evaluate environmental issues associated with the proposed construction of a coastal docking facility at Point Thomson that would support future oil and gas development in the region. LGL coordinated this study with a companion oceanographic program conducted simultaneously by URS Greiner Woodward-Clyde (URS). Results of the oceanographic study are reported separately in URS (2000). The following report describes the results of the fish monitoring study.

Citations in this Report

Much of the current understanding of arctic diadromous fishes and associated ecological processes are based on data collected during a series of summer fish monitoring studies in the Prudhoe Bay/Sagavanirktok Delta region from 1981 to 1998. These studies were specifically designed to monitor the effects of oil development on regional fish resources. The 18-year data set has served as the basis for numerous peer-reviewed publications, and these published documents are cited in this report as the primary sources of information. Nevertheless, there are some trends in the population dynamics of diadromous, freshwater, and marine fishes that, although factual, have never been published and which can not be referenced by any single technical report. In such cases, and for economy of space, the collective Prudhoe Bay Studies (PBS) will be cited as PBS (1982-1999). They include Griffiths and Gallaway (1982), Critchlow (1983), Griffiths et al. (1983), Woodward-Clyde Consultants (1983), Moulton et al. (1986), Cannon et al. (1987), Glass et al. (1990), LGL (1990, 1991, 1992, 1993, 1994a, 1994b, 1999a, 1999b), Reub et al. (1991), and Griffiths et al. (1995, 1996, 1997).

STUDY AREA

Lions Bay is a barrier island lagoon system located on the Beaufort Sea coast of Alaska approximately 85 km east of Prudhoe Bay. In the Point Thomson vicinity, a string of barrier islands protects the mainland shore creating an embayment that can reach 4-5 km in width and 3-4 m in depth (Fig. 1). The principal inlet connecting Lions Bay to the Beaufort

Sea is Mary Sachs Entrance. West of Mary Sachs Entrance the barrier island system tails seaward away from the mainland shore for another 40-45 km with the barrier islands becoming more scattered and smaller. The eastern end of Lions Bay is formed by the convergence of Flaxman Island and the mainland coast near Brownlow Point. The main source of freshwater discharge into Lions Bay comes from the Staines River located near the eastern end of the bay (see Fig. 1). Tundra streams located along the mainland shore provide additional discharge.

METHODS

Fyke Net Sampling

Fyke nets were used to collect fish during the Point Thomson study (see Fig. 1). Nets consisted of paired stainless steel frames measuring 1.7 m (5.6 ft.) by 1.8 m (6.0 ft), each supporting a cod end trap made of 1.27 cm stretched-mesh netting (Fig. 2). The two separate traps shared a single 60-m (200 ft) lead constructed of 2.5-cm knotless nylon mesh net. A single 15-m (50 ft) wing emanated from each of the traps. The entire device was set perpendicular to the shoreline as depicted in Figure 2. Once set, the nets fished continuously weather and ice conditions permitting.

Four sampling sites were established along the mainland shore, two west (stations 601 and 602) and two east (stations 603 and 604) of the Point Thomson pad (see Fig. 1). A fifth net (Station 605) was located inside a barrier island just east of Mary Sachs Entrance. Sampling sites were determined largely by bathymetry. In most areas along the mainland, depths increase to >2 m within several meters from shore. Such conditions precluded sampling by fyke nets which require shallow areas (<2 m in depth) out to 70-80 m from shore. Sites that were sampled were characterized by isolated shoals that accommodated the fishing gear.

Station 602 was originally sited near the tip of Point Thomson itself (see Fig. 1); however, strong currents in this area constantly washed out the fyke net lead. The net was subsequently relocated to the permanent 602 site. Station 600 was temporarily fished early in the summer. The site was within a shallow lagoon system immediately east of the Point Thomson pad and was protected from drift ice that was prevalent throughout the main lagoon during the early part of the summer. Ice within Lions Bay prevented deployment of the primary fyke nets until 10 July. Station 600 was sampled to obtain data as early in the summer as possible but was never intended as a permanent site. It was abandoned on 10 July when the primary sites were established.

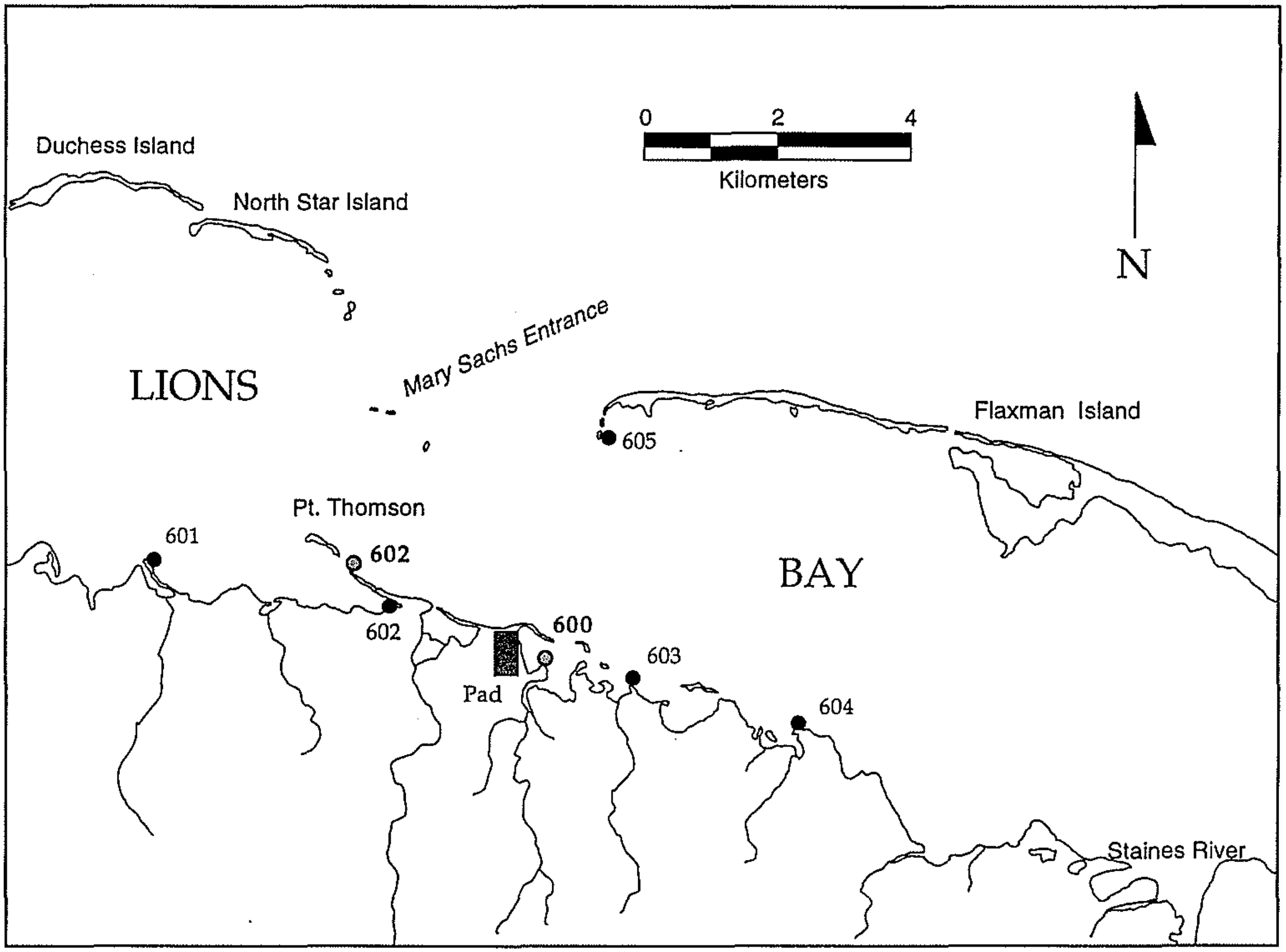

Figure 1. Map of the Point Thomson study area. Numbered fyke nets are denoted by solid symbols. Temporary Net 600 and the original site for Net 602 are denoted by shaded symbols.

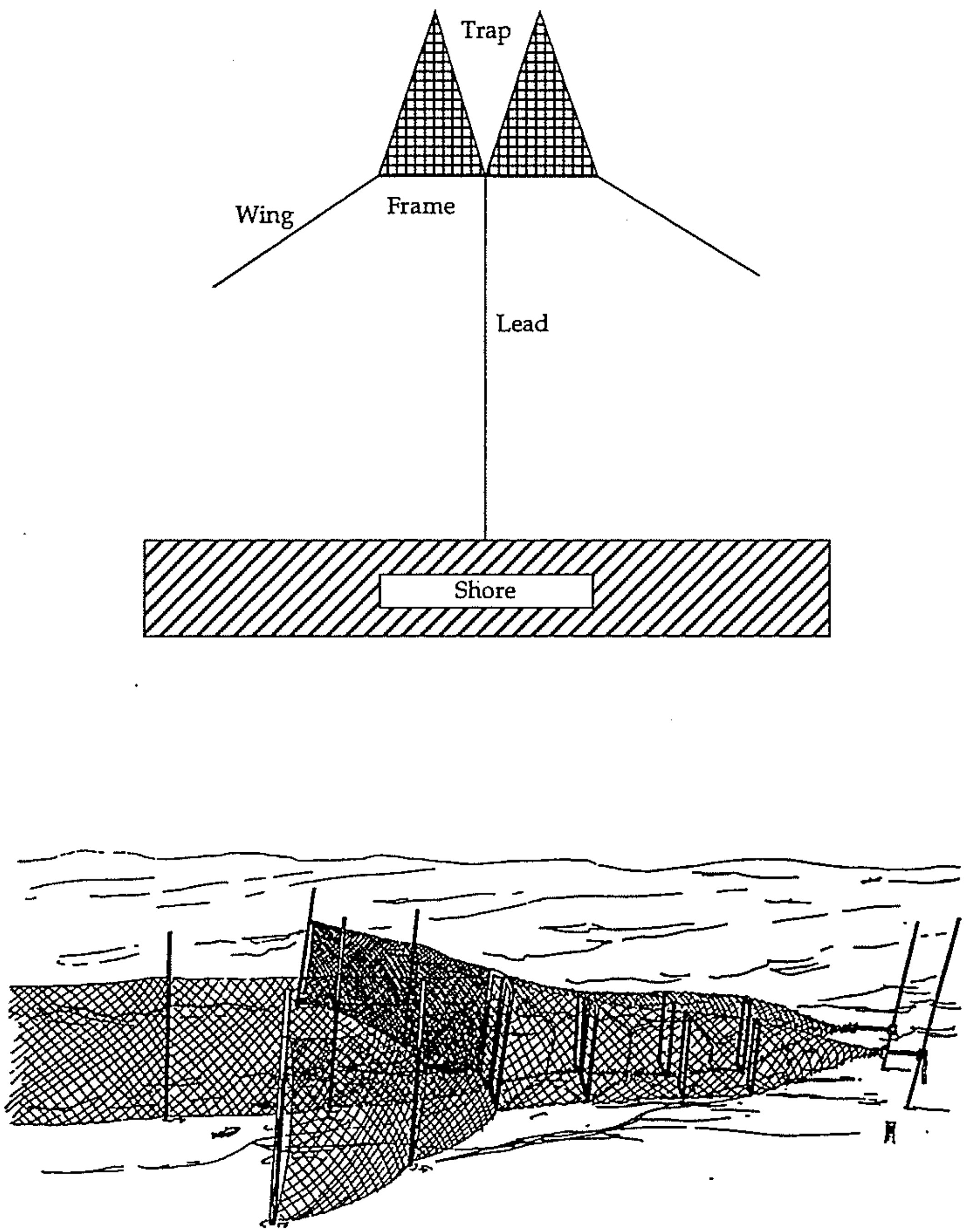

Figure 2. Diagrammatic representation of a double cod-end fyke net and its orientation along the shore.

Fish were removed daily from each cod end trap and placed in floating holding pens where they were held while being processed. All specimens were enumerated and identified to species when possible. Young fish to be measured were first anesthetized in a dilute solution of MS-222 (tricaine methane sulfonate) to minimize scale loss and stress during handling. Anesthetized fish were placed in a holding pen and allowed to recover before being released.

Arctic cisco (*Coregonus autumnalis*), broad whitefish (*C. nasus*), least cisco (*C. sardinella*), Dolly Varden (*Salvelinus malma*) and humpback whitefish (*C. pidschian*) caught at all locations were measured to the nearest mm fork length (FL). In cases where large numbers of these species were captured, a subsample of 50 fish were measured. Each of these species have historically been segregated into specific size cohorts for the purposes of subsampling (Cannon et al. 1987; Glass et al. 1990; LGL 1990, 1991, 1992, 1993, 1994a, 1994b, 1999a, 1999b; Reub et al. 1991; and Griffiths et al. 1995, 1996, 1997). We maintained this protocol and the following size groupings were used for subsampling: Arctic cisco and broad whitefish <120 mm, 120-250 mm, >250 mm; Dolly Varden <350 mm and ≥350 mm; and least cisco <180 mm and ≥180 mm.

Counts of dead fish were recorded at each net by species and size group as a measure of net mortality. When large numbers of a specific size group/species were encountered, the percent mortality of the entire group was estimated by visual inspection. These percentages were later extrapolated to unmeasured fish as a total estimate of mortality.

Hydrography

Salinity/temperature/depth (STD) profiles were recorded daily at the cod end of each fyke net. Temperature and salinity measurements were taken at 0.5 m (1.6 ft) depth increments with a Hydrolab Surveyor III Conductivity-Temperature-Depth profiler.

Data Management

Physical and biological data were recorded on waterproof coding forms in the field. Data sheets were checked for accuracy and consistency at the end of each day and corrections made if necessary. Data were entered into EXCEL computer files at the Point Thomson field camp and verified after entry by two crew members. Data files were later screened for errors using several computer programs designed to detect spurious data. Questionable data that could not be reasonably resolved were flagged and not included in any of the subsequent analyses.

Data Analysis

Catch-per-unit-effort (CPUE) for individual fish species or size cohorts within species is expressed as the number of fish collected per fyke net per 24 h of fishing effort (fish/net/24 h). The total catch from each cod end was divided by the proportion of the day that the cod end fished, thereby yielding the number of fish caught per day by side of net. The total CPUE for each two-sided fyke net was calculated by summing the CPUE of the two cod ends. Unmeasured fish were prorated into respective size cohorts (discussed separately for each species below) before the standardization by effort occurred.

Explanation of Graphics

A graphic format is used in this report which requres some explanation. Figure 3 shows the length at date data for Arctic cisco collected in the Prudhoe Bay region during the summers 1985 to 1996. Each panel within the figure consists of a matrix (i.e., a grid of columns and rows). Each column represents a sampling date, generally running from late June through the end of August. Rows represent fish length in 1 mm increments. There are major demarcations at 100, 200, 300, and 400 mm. Within each grid cell are entered the number of fish collected on a particular day at that particular size (length). For example, 11 fish measuring 71 mm in length were collected on 19 August 1985 (not distinguishable in figure). When these data are pieced together, they provide both short- and long- term length profiles of the Arctic cisco population in the Prudhoe Bay region. The black diagonal swaths or "clouds" in the top half of each panel (i.e., fish <200 mm) represent the presence of distinct age cohorts. The graphic clearly shows how an age cohort grows in size during each year and from one year to the next and shows its contribution to the overall population. Note the sudden appearance of fish 50-90 mm in length during August in many years. These are newly recruited age-0 fish arriving at Prudhoe Bay from Canada. Despite some overlap, these age cohorts can be identified and subsequently tracked in following years. This graphic format is presented for several species in the following report.

Data Correction

From 29 July to 1 August, 211 juvenile (<210 mm) least cisco were collected at Point Thomson. In retrospect, we believe these fish to be Arctic cisco which were misidentified as least cisco. This conclusion is based upon the following considerations.

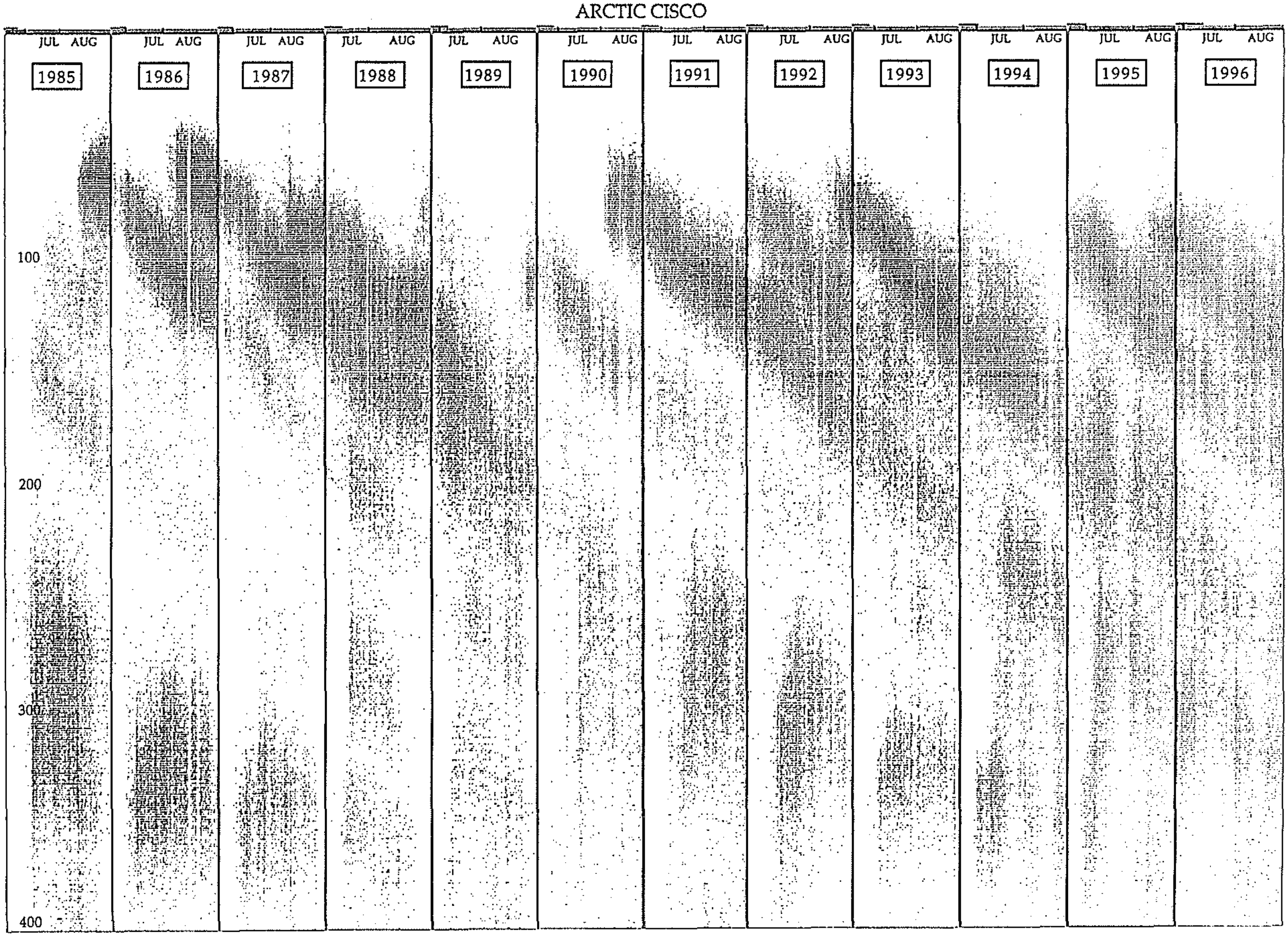

Figure 3. Catch by length data for Arctic cisco collected at Prudhoe Bay during the summers 1985-1996.

First, the known distribution of least cisco in the Beaufort Sea makes the presence of juvenile fish in the Point Thomson area highly unlikely. Diadromous least cisco in the Beaufort Sea are associated with two main population centers. Alaskan populations occur in "tundra" rivers that lie west of and include the Colville River, while Canadian populations are associated with the Mackenzie River drainage (Craig and McCart 1975; Craig 1984; Craig 1989). There are no known spawning populations associated with the Sagavanirktok River nor with the "mountain" rivers that lie along the 600 km of coastline between the Mackenzie and Colville rivers. Because of proximity to the two least cisco population centers, it is assumed that most adult, and therefore any juvenile, least cisco found in coastal waters between Prudhoe Bay and the U.S. Canadian border are from Colville River stocks.

While the presence of adult least cisco is common in North Slope coastal waters, juvenile fish are limited in their summer dispersal from the Colville River. The variable abundance of small fish (≤180 mm) is linked to wind-governed transport processes (Fechhelm et al. 1994). West winds in early summer (primarily July) create easterly flowing coastal currents which enhance the eastward dispersal of small least cisco from the Colville River. On average, small least cisco do not reach Prudhoe Bay in one of every two years (Fechhelm et al. 1994). Because Point Thomson is approximately twice the distance from the Colville River as is Prudhoe Bay, the presence of juvenile fish at the more remote location is unlikely.

Second, nearly all of the juvenile least cisco were collected during a four day period from 29 July to 1 August. This coincides with a four day period of field crew change when the senior LGL field biologist was not present. Distinguishing between juvenile least and Arctic cisco can be difficult for even the most experienced fisheries biologist given their morphometric similarities. The likelihood of misidentifications was therefore highest during the four day period.

Third, the size distribution of least cisco reported for 29 July to 1 August coincides with that typically reported for Arctic cisco. Figure 3 shows length at date data for Arctic cisco collected at Prudhoe Bay from 1985 to 1996 (see Explanation of Graphics above). The distinct separation of year classes as indicated by the diagonal swaths <200 mm has historically allowed for the distinction of age-0, age-1, and age-2 fish (PBS 1982-1999). The first panel in Figure 4 shows length at date data for Arctic cisco collected at Point Thomson in 1999. Note the recruitment of age-0 fish (50-70 mm) on 7 August. Also note two faint diagonal swaths, the first running from 110 to 140 mm, the second from 170-200 mm. Given

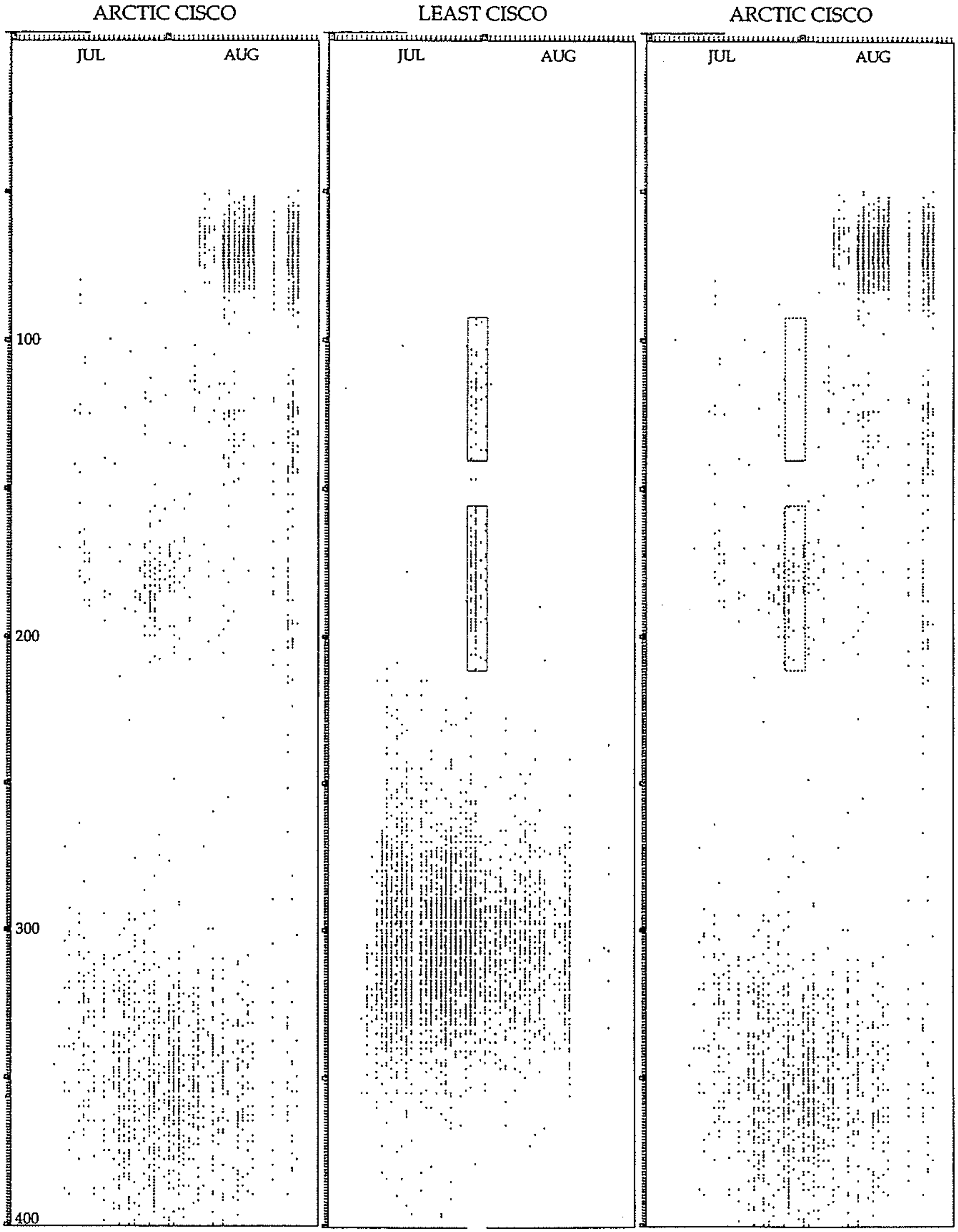

Figure 4. Catch by length data for Arctic and least cisco collected at Point Thomson in 1999. Two groups of small "least cisco" caught from 29 July to 1 August are blocked by dotted lines. These blocks (not the size data) are superimposed on the Arctic cisco catch data in the third panel (duplicate of first panel). Data indicate that small "least cisco" collected at Point Thomson match the size distribution of age-1 and age-2 Arctic cisco.

the historic profile reported for Prudhoe Bay, we believe these two swaths to represent age-1 and age-2 Arctic cisco, respectively.

The middle panel of Figure 4 shows the length at date data for least cisco collected at Point Thomson in 1999. The "juvenile least cisco" collected from 29 July to 1 August are denoted by two dotted rectangles. The locations of the two dotted rectangles are superimposed on the length data for Arctic cisco in the third panel. They coincide reasonably well with the size distributions of age-1 and age-2 Arctic cisco.

Fourth, the seasonal catch patterns of juvenile Arctic cisco versus juvenile least cisco make more intuitive sense when the questionable fish are classified as Arctic cisco. Figure 5 shows the seasonal catch of juvenile fish at Point Thomson for the original species identification. It seems improbable that virtually all juvenile least cisco collected during the entire summer would be taken during this four day period. Further, the period 29 July-1 August was preceded by nearly two weeks of east winds. East winds prevent least cisco from moving eastward along the coast and it is doubtful that they would suddenly appear in the study area under those meteorological conditions. Figure 6 illustrates catch data when the questionable fish are assumed to be Arctic cisco. Under this scenario there were virtually no juvenile least cisco caught throughout the summer. This is the expected case. Transformed data also indicate a large surge in CPUE for age-2 fish during the four-day period. However, this surge was preceded by four days of increasing CPUE, making the surge a more reasonable possibility.

For these reasons we believe the 211 juvenile least cisco identified from 29 July to 1 August are most likely juvenile Arctic cisco. These fish have therefore been added to the Arctic cisco database for subsequent analysis and discussion.

Statistical Analysis

In several cases involving specific species and age/size cohorts, catch rates at Point Thomson were compared with those reported previously near Prudhoe Bay (PBS 1982-1999). Mid-water fyke nets were used during some of the early Prudhoe Bay studies (Moulton et al. 1986; Cannon et al. 1987; Glass et al. 1990; Reub et al. 1991). Compared to conventional fyke nets which are set along the shoreline, mid-water nets were set in open water and typically caught fewer fish than shoreline nets (Moulton et al. 1986; Cannon et al. 1987; Glass et al. 1990; Reub et al. 1991). So as not to bias comparisons of CPUE between Point Thomson (all shoreline fyke nets) and the Prudhoe Bay area, data collected from mid-water nets at Prudhoe Bay were deleted from the analyses.

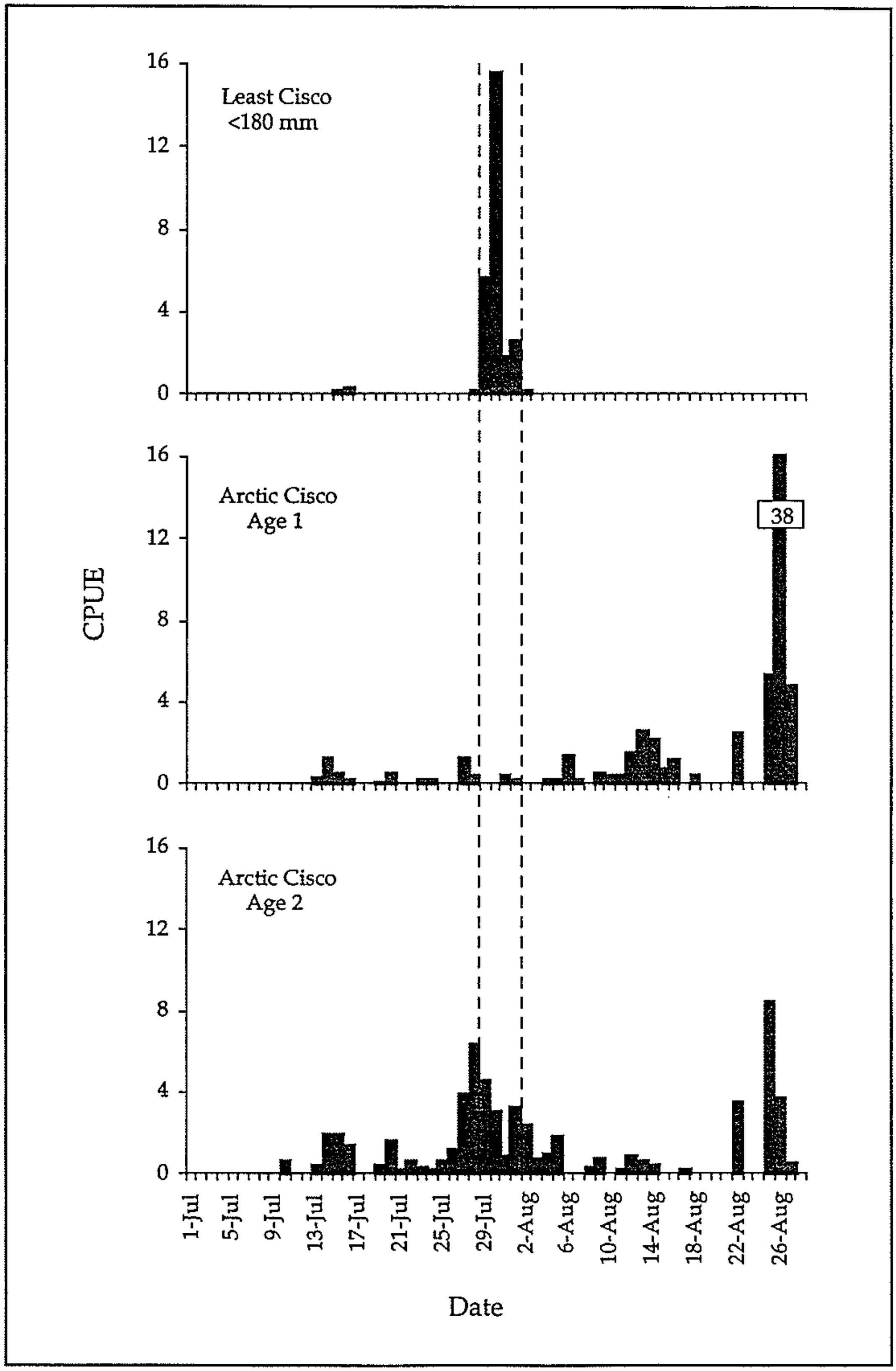

Figure 5. Catch-per-unit-effort (CPUE: fish/net/24 h) for small least cisco (<180 mm), age-1 Arctic cisco (Cohort 2), and age-2 Arctic cisco (Cohort 3) collected at Point Thomson in 1999. Vertical dashed lines denote the four day period when most of the juvenile least cisco were caught.

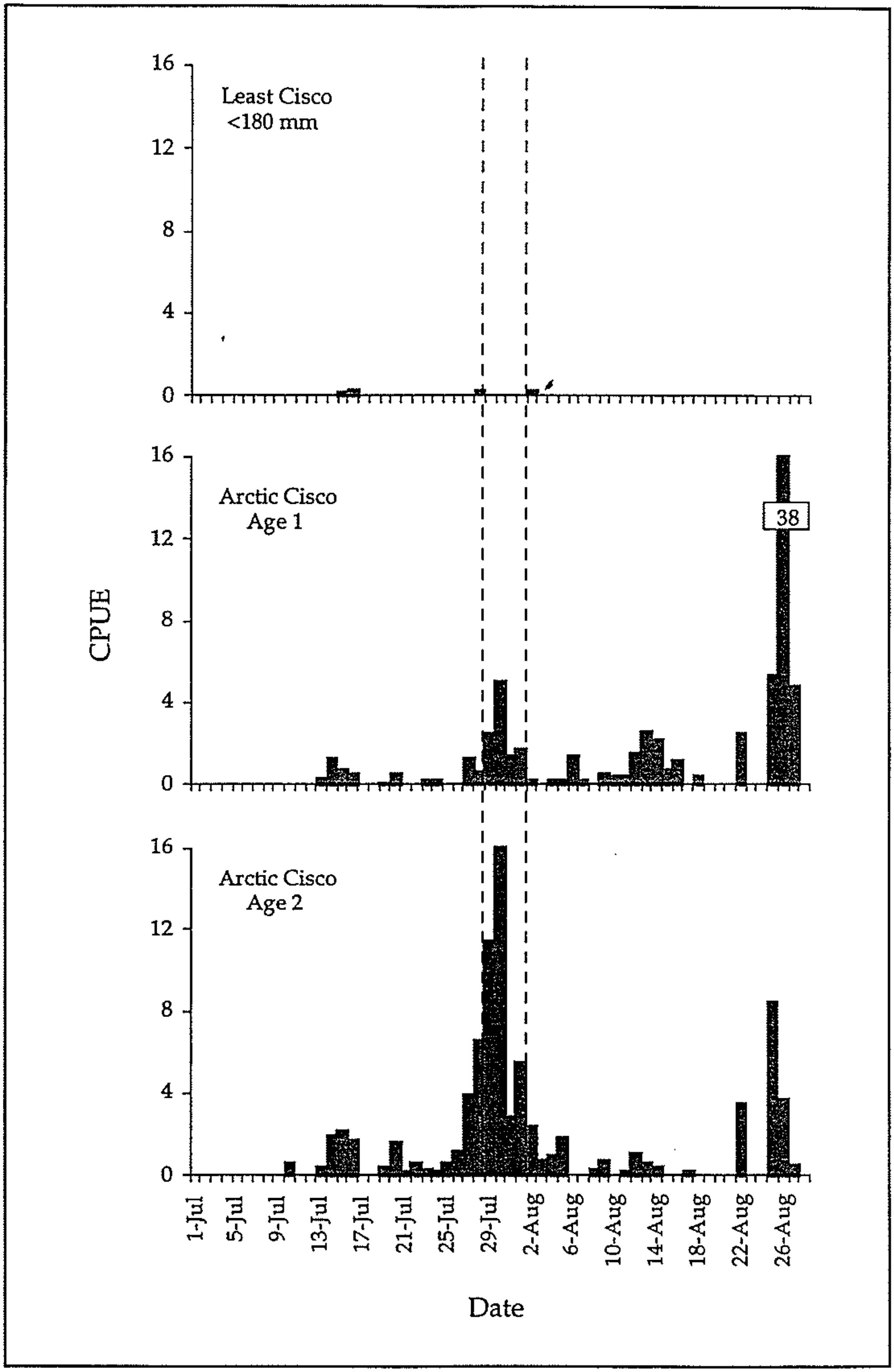

Figure 6. Catch-per-unit-effort (CPUE: fish/net/24 h) for small least cisco (<180 mm), age-1 Arctic cisco (Cohort 2), and age-2 Arctic cisco (Cohort 3) assuming that the 211 least cisco caught from 29 July to 1 August were actually mis-identified Arctic cisco. Vertical dashed lines denote the four day period when most of the "juvenile least cisco" were collected. Least cisco were classified as either age-1 or age-2 Arctic cisco based upon size as denoted in Figure 4.

For statistical analysis, CPUE for all Prudhoe Bay nets were pooled over all locations and years. Since no survey was conducted at Prudhoe Bay in 1999, no direct comparison could be made for the 1999 season. Pooled data inherently combine all sources of long- and short-term variability in CPUE. Long-term variability would include changes in catch due to fluctuating population size and strengths of individual year classes within populations, and to intra-year differences in broad-scale migratory patterns associated with specific meteorological and oceanographic conditions. Short-term variability would include differences in CPUE attributable to net location and oscillations in fine-scale movement patterns caused by hydrographic variability.

Preliminary analysis indicated that Prudhoe Bay CPUE data for all pertinent species and age/size cohorts were not normally distributed (Lilliefors test; P <1.0 E-9). Problems with normality can often be overcome by log-transformation of the catch data. CPUE is first increased by a value of 1 (i.e., CPUE + 1) to prevent negative logarithmic values that may approach - for CPUE <1. This approach is inherently biased, however, when CPUE are very low which was sometimes the case at Prudhoe Bay. For example, the median CPUE for age-3 and older broad whitefish at Prudhoe Bay across all years and stations was about 3 fish/net/24 h with over 30% of all observations being ≤2 fish/net/24 h. In such cases, adding 1 for the purpose of transformation could artificially increase catch by 30 to 50%. Because of this bias, the non-parametric Wilcoxin-Mann-Whitney-U test (Sprent 1993) was used to test for differences in catch rates in all cases.

The Wilcoxin signed rank test (Ott 1988) was used to compare seasonal directionality of CPUE (i.e., east verses west) at each fyke net for the abundant diadromous species.

It must be noted that the use of multiple statistical tests inflates the overall probability of committing a type-1 error; i.e., of incorrectly rejecting a null hypothesis within the entire group of tests. For multiple tests of the same question, omnibus meta-statistical methods can be used to adjust probabilities (Hedges and Olkin 1985). For multiple-problem, multiple-test scenarios (as is the case here) either a Bonferroni (Miller 1981) or a sequential Bonferroni (Holm 1979; Rice 1989) adjustment may be employed. The problem is that any of those techniques reduce the power of the test to detect a difference among populations being tested; i.e., increases the probability of committing a type-II error (accepting a false null hypothesis) (Rice 1989). To address the issue of reducing the power of the statistical tests we have made no adjustments to accommodate multiple usage. We felt this was the more acceptable alternative. The reader should be aware that one test in twenty will incorrectly reject the null hypothesis based merely upon chance probability.

RESULTS AND DISCUSSION

Effort

A total of 191.8 net-days of fishing effort was expended during the 1999 Point Thomson study (Appendix Table A1). Sampling commenced on 3 July at temporary station 600 (abandoned on 10 July) and between 9 and 13 July at the four primary mainland stations (stations 601, 602, 603, and 604). Sampling commenced on 17 July at Station 605 located on the lagoon side of a barrier island adjacent to Mary Sachs Entrance (see Fig. 1).

Field sampling was suspended from 19 to 24 August because of a strong east-wind storm (Fig. 7). Sampling was scheduled to continue through 26-27 August; however, when the storm subsided the nets at sites 601 and 603 were destroyed. To repair and re-deploy the nets would have resulted in only 1 day each of additional fishing effort; therefore they were not reinstalled. Stations 601, 602, and 605 were in more protected locations and were easily reset after the storm. Station 605 was sampled through 26 August and station 602 and 603 through 27 August.

Species Composition

A total of 67,770 fish representing 17 species, 9 families, and 7 orders were collected during the 1999 Point Thomson study (Tables 1 and 2). Nearly 97% of the total catch was attributed to seven species: three marine (fourhorn sculpin, saffron cod, and Arctic cod), one freshwater (ninespine stickleback) and three diadromous (Arctic cisco, Dolly Varden, and least cisco). The most abundant species was Arctic cisco due primarily to a strong recruitment of young-of-the-year. Of 15,549 total Arctic cisco taken during the summer, 13,512 (86.9%) were age-0 fish.

Fyke Net Fish Mortality

There were 1,275 mortalities recorded during the 1999 study (Table 3). This level of mortality was fairly low compared with other similar studies conducted in the Prudhoe Bay region in past years (PBS 1982-1999). The highest number of mortalities was for Arctic cisco (n = 657) of which nearly all were young-of-the- year. Nearly half of the Arctic cisco mortalities occurred during a four day period from 14 to 17 August. During that time, large numbers of jellyfish (300 mm diameter bells) were taken in the fyke nets and killed many of the small fish.

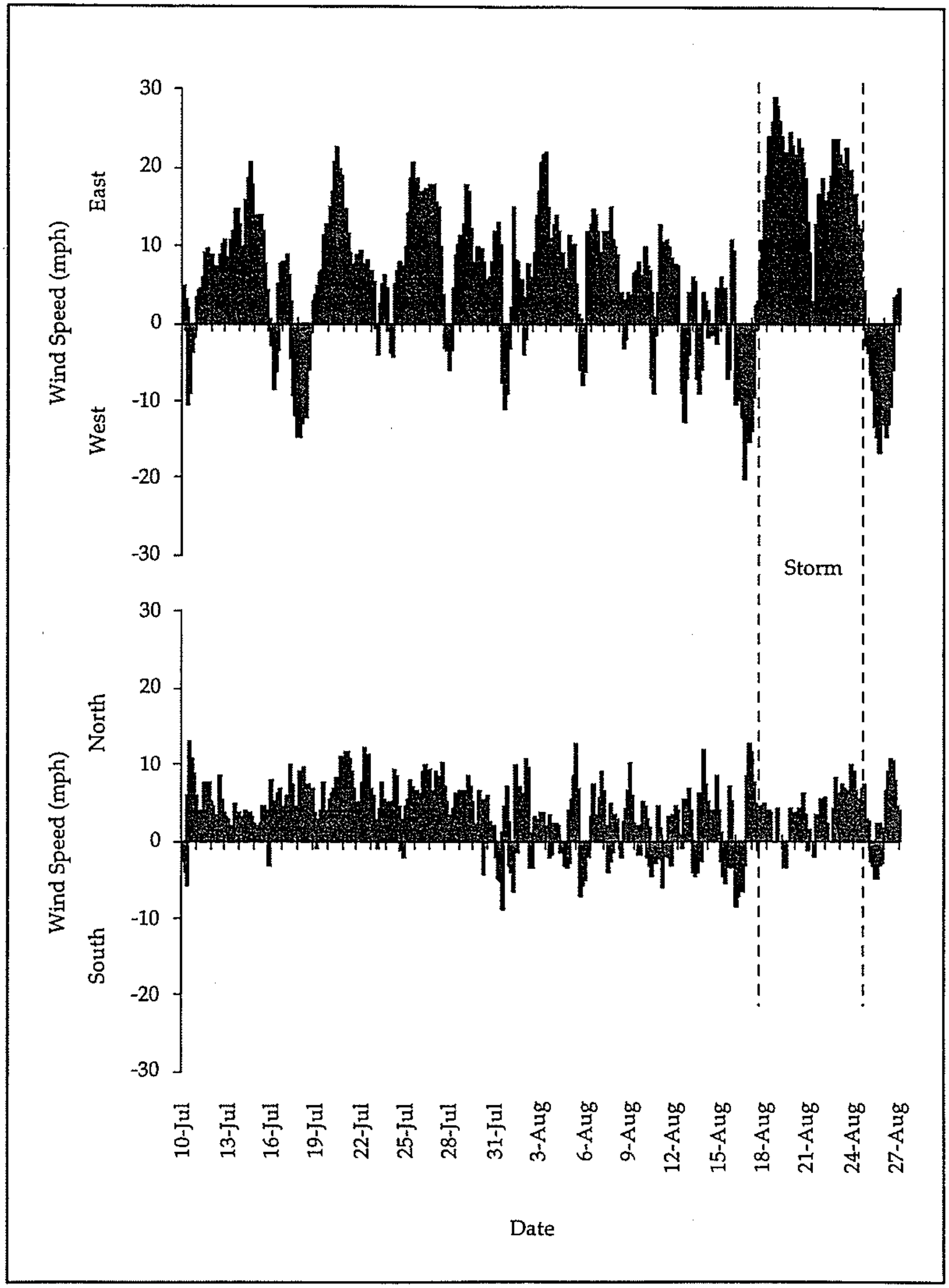

Figure 7. Average hourly east/west (top panel) and north/south (bottom panel) wind speeds recorded at the Point Thomson meteorological station operated by URS. Vertical dashed lines denote the period when storm conditions shut down field operations.

Table 1. Fish species collected during the 1999 Point Thomson study.

Clupeiformes		
	Clupeidae	
		Pacific herring *Clupea pallasi*
Salmoniformes		
	Osmeridae	
		Rainbow smelt *Osmerus mordax*
	Salmonidae	
		Arctic cisco *Coregonus autumnalis*
		Broad whitefish *Coregonus nasus*
		Least cisco *Coregonus sardinella*
		Humpback whitefish *Coregonus pidschian*
		Dolly Varden *Salvelinus malma*
		Round whitefish *Prosopium cylindraceum*
		Pink salmon *Oncorhynchus gorbuscha*
		Arctic grayling *Thymallus arcticus*
Gadiformes		
	Gadidae	
		Arctic cod *Boreogadus saida*
		Saffron cod *Eleginus navaga*
Gasterosteiformes		
	Gasterosteidae	
		Ninespine stickleback *Pungitius pungitius*
Scorpaeniformes		
	Cottidae	
		Fourhorn sculpin *Myoxocephalus quadricornis*
	Cyclopteridae	
		Snailfish *Liparis* sp.
Perciformes		
	Zoarcidae	
		Eelpout *Lycodes* sp.
Pleuronectiformes		
	Pleuronectidae	
		Arctic flounder *Pleuronectes glacialis*

Table 2. Species composition by net for fish collected during the 1999 Point Thomson study.

Scientific Name	Common Name	Station						
		600	601	602	603	604	605	Total
Coregonus autumnalis	Arctic cisco	2	1,935	8,674	2,018	1,753	1,167	15,549
Myoxocephalus quadricornis	Fourhorn sculpin	410	2,366	1,723	3,751	4,128	768	13,146
Salvelinus malma	Dolly Varden	710	2,865	1,644	1,306	1,000	1,934	9,459
Coregonus sardinella	Least cisco	48	2,775	1,505	2,608	2,027	44	9,007
Eleginus navaga	Saffron cod	15	850	688	1,800	2,329	3,017	8,699
Pungitius pungitius	Ninespine stickleback	21	444	3,020	1,438	1,904	65	6,892
Boreogadus saida	Arctic cod	0	487	650	953	955	184	3,229
Pleuronectes glacialis	Arctic flounder	6	85	119	269	304	164	947
Coregonus nasus	Broad whitefish	17	147	84	149	90	4	491
Osmerus mordax	Rainbow smelt	1	45	9	125	29	6	215
Coregonus pidschian	Humpback whitefish	1	39	14	29	17	1	101
Thymallus arcticus	Arctic grayling	0	2	1	10	3	1	17
Prosopium cylindraceum	Round whitefish	1	2	0	3	7	0	13
Clupea pallasi	Pacific herring	1	1	0	0	0	0	2
Zoarcidae	Eelpout	0	0	0	1	0	0	1
Oncorhynchus gorbuscha	Pink salmon	0	0	0	0	1	0	1
Cyclopteridae	Snailfish	0	0	1	0	0	0	1
Total		1,233	12,043	18,132	14,460	14,547	7,355	67,770

Table 3. Fyke net mortalities.

Species	Number
Arctic cisco	657
Ninespine stickleback	254
Arctic cod	234
Saffron cod	76
Rainbow smelt	35
Fourhorn sculpin	14
Arctic flounder	3
Least cisco	2
Total	1,275

Table 3 does not include fish killed during the 19-24 August storm. When field crews were able to reach the collapsed nets on 24 August there were large numbers of dead fish in nets 601 and 604. These mortalities included adult Dolly Varden, least cisco, and Arctic cisco, and an assortment of marine species. Because of the degree of decomposition, accurate counts were not possible.

Arctic Cisco

Arctic cisco found in the Alaskan Beaufort Sea are believed to originate from spawning grounds in the Mackenzie River system of Canada (Gallaway et al. 1983, 1989). In spring, newly hatched young-of-the-year (age-0) fish are flushed downriver to ice-free coastal waters adjacent to the Mackenzie Delta. During summers characterized by strong and persistent east winds, large numbers of these fish are transported westward by wind-driven coastal currents (Gallaway et al. 1983; Fechhelm and Fissel 1988; Moulton 1989; Fechhelm and Griffiths 1990; Schmidt et al. 1991; Underwood et al. 1995; Colonell and Gallaway 1997). Once in Alaska, they take up overwintering residence in some of the larger North Slope drainages like the Colville and Sagavanirktok rivers (PBS 1982-1999). While the Sagavanirktok River may provide overwintering habitat for juvenile fish during their first 2-3 years, the Colville River is the only Alaskan drainage large enough to support populations of subadult and adult Arctic cisco throughout the winter (Schmidt et al. 1989; Adams and Cannon 1987). The Colville River population supports the subsistence fishery at Nuiqsut and the Helmericks commercial fishery which operates in the lower Colville Delta (Moulton 1994, 1995; Moulton and Field 1988, 1989, 1992; Moulton et al. 1992, 1993). Arctic cisco remain in the Colville River until the onset of sexual maturity beginning at about age 7, at which point they migrate back to the Mackenzie River to spawn (Gallaway et al. 1983).

Based upon the size structure of the Arctic cisco population that has been monitored at Prudhoe Bay from 1985-1996 (see Fig. 3), analysis has historically focused on four size cohorts: Cohort 1 (age-0 or young-of-the-year), Cohort 2 (age-1), Cohort 3 (age-2), and Cohort 4 (≥age-3). This protocol is maintained for this report.

Young-of-the-year Arctic cisco were first collected on 7 August following a sustained period of east winds (Fig. 8). On 12 August CPUE surged to 221.9 and 211 fish/24 h at stations 601 and 602, respectively, but remained low at the other sites: stations 603 (42.1 fish/24 h), 604 (0.0 fish/24 h), and 605 (0.0 fish/24 h). We suspect that young-of-the-year were transported by wind-driven currents into Lions Bay via Mary Sachs Entrance and were sampled more intently by the two closest nets (see Fig. 1). During the next six days, young-

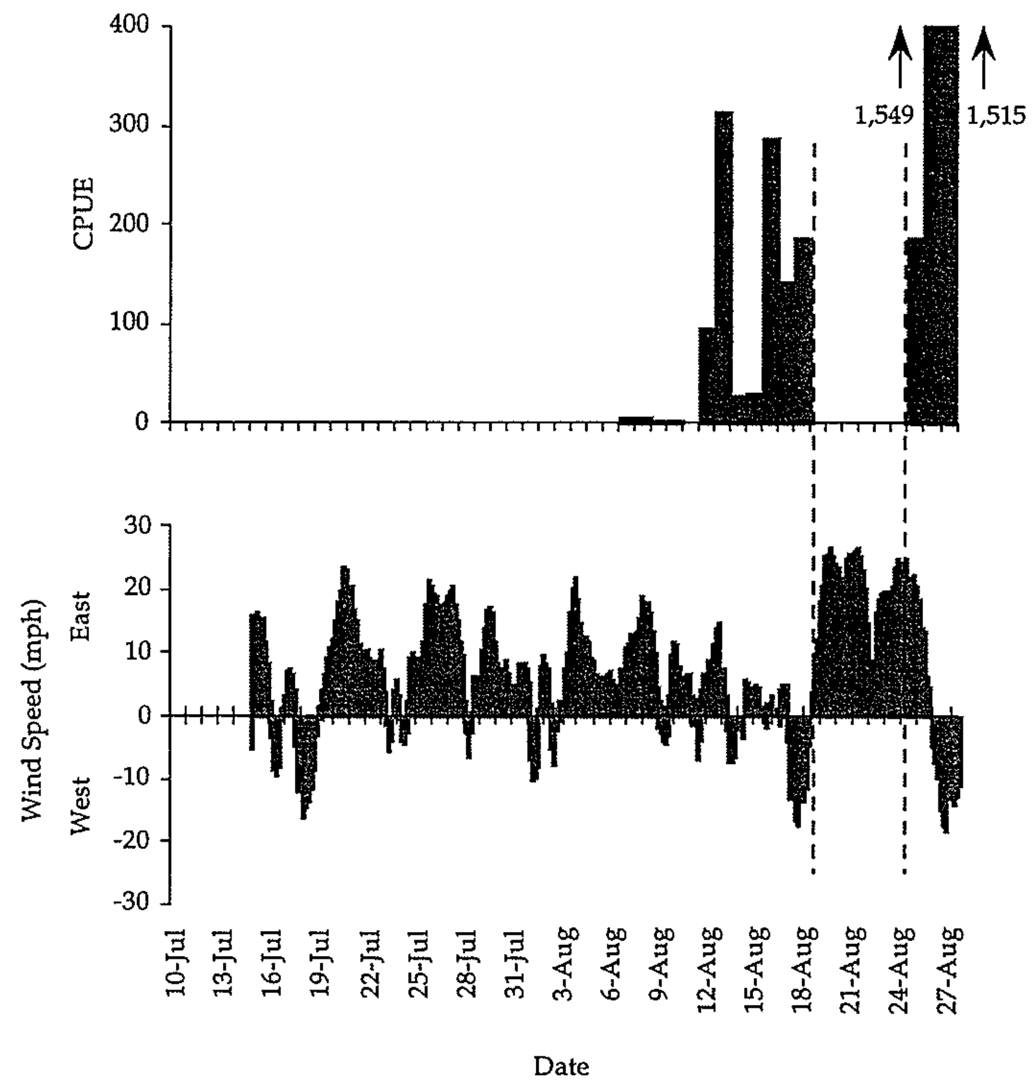

Figure 8. Catch-per-unit-effort (CPUE: fish/net/24 h) for age-0 (Cohort 1) Arctic cisco collected at Point Thomson in 1999 (top panel) and average hourly east/west wind speed by date (bottom panel). Vertical dashed lines denote the period when fyke nets were not operational.

of-the-year dispersed throughout the bay and were collected at all nets. Following the 7 August arrival, CPUE for the remainder of the summer ranged from a high of 568.8 fish/24 h at station 602 to a low of 35.7 fish/24 h at Station 605. A total of 13,512 age-0 Arctic cisco were collected during the study.

A total of 275 age-2 and 392 age-3 Arctic cisco (including misidentified "least cisco") were collected at Point Thomson in 1999. Most age-2 fish were collected from 27 July to 2 August following a nine day period of primarily east winds (Fig. 9). While juvenile Arctic cisco are probably less affected by passive transport than young-of-the-year, the appearance of age-2 fish 155-205 mm in length following a period of east winds suggests that fish may have moved into the area from the east. The largest surge in the CPUE of yearlings occurred immediately after the east wind storm of 19-24 August, again suggesting that juvenile fish moved into the area from the east.

The 1999 Point Thomson study provided an opportunity to test whether coastal areas in the Point Thomson/Canning River region might provide overwintering grounds for young-of-the-year and possibly juvenile Arctic cisco. Recruitments of age-0 fish were reported at Prudhoe Bay in 1997 (LGL 1999a) and 1998 (LGL 1999b) and thus recruitment naturally would have occurred at points east of Prudhoe Bay. Had large numbers of yearling and two-year-old cisco been collected at Point Thomson, particularly early in the summer, it would have provided strong evidence of overwintering in the Point Thomson/Canning River region. The catch of both age classes was low relative to what has been observed at Prudhoe Bay following years of good recruitment. Table 4 lists the overall catch rates of different year classes of Arctic cisco at different ages reported for the Prudhoe Bay studies and at Point Thomson in 1999. (It should be reiterated that the Sagavanirktok River adjacent to Prudhoe Bay is a major overwintering area for Arctic cisco less than three years of age.) At Prudhoe Bay, the three weakest year classes—1988, 1989, and 1993—were followed by catch rates of ≤6.2 fish/net/24 h as yearlings and ≤2.5 fish/net/24 h as two-year-olds. The comparably low catch rates of age-1 and age-2 fish at Point Thomson is consistent with poorly recruited year classes. But since there were good recruitments in 1997 and 1998, the low catches at Point Thomson initially suggest poor overwintering capacity in the Point Thomson/Canning River area.

The low catch of two-year-olds at Point Thomson is not conclusive with regard to the overwintering question. The 1985 year class was strongly recruited to Prudhoe Bay, yet by the time they were two-year-olds, CPUE during the summer of 1987 was a mere 1.2 fish/net/24 h (see Table 4). A similar trend occurred with the 1995 year class. There is,

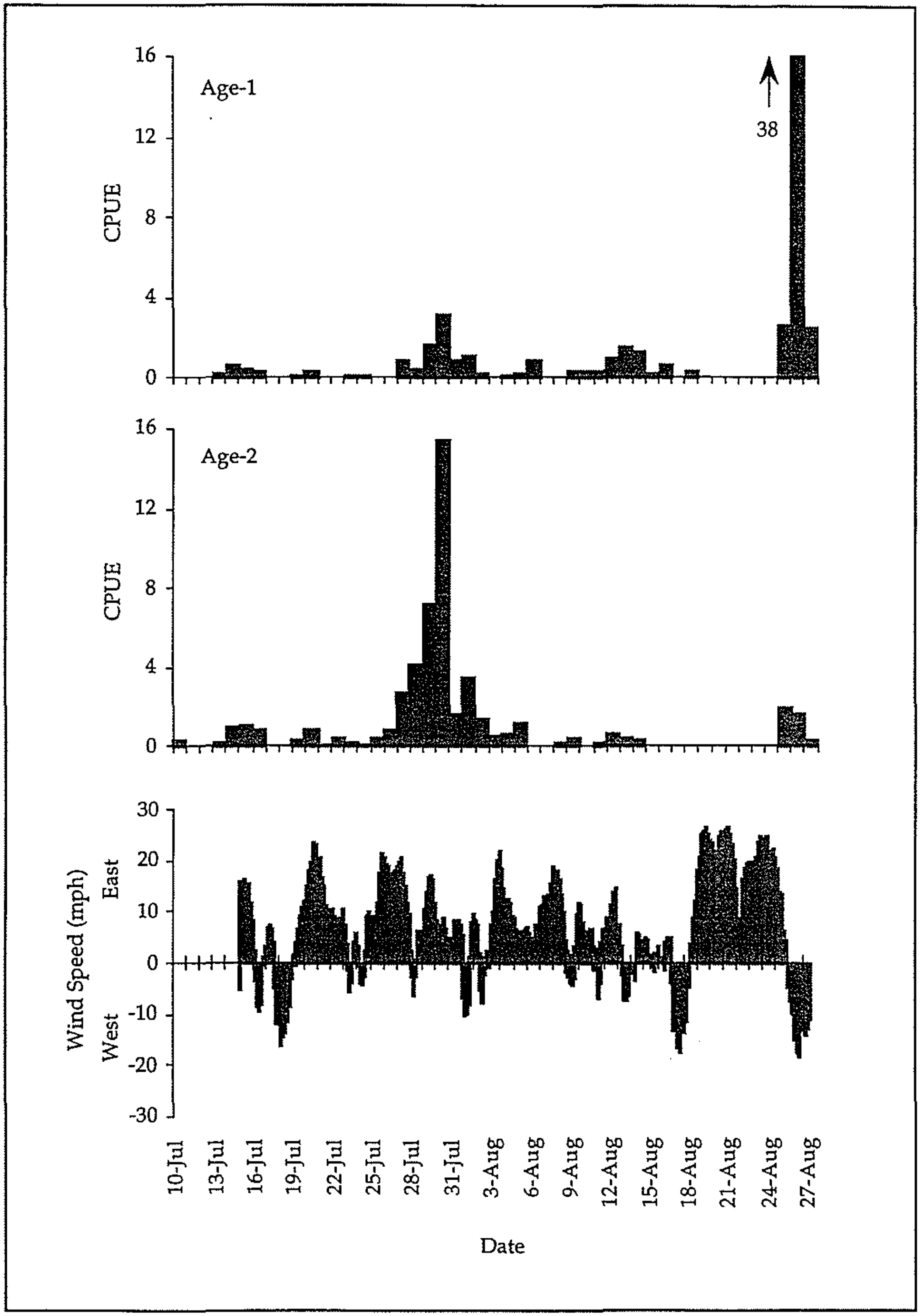

Figure 9. Catch-per-unit-effort (CPUE: fish/net/24 h) for age-1 (Cohort 2) and age-2 (Cohort 3) Arctic cisco collected at Point Thomson in 1999 (top panels) and average hourly east/west wind speed by date (bottom panel).

Table 4. Overall catch-per-unit-effort (fish/net/24 h) for different year classes of Arctic cisco collected at different ages. The designation "na" indicates that there were too few fish to distinguish within the population.

Area	Year Class	CPUE Age 0	Age 1	Age 2
Prudhoe Bay	1985	88.9	16.8	1.2
	1986	130.7	47.0	33.0
	1987	44.9	76.5	15.4
	1988	1.4	1.1	na
	1989	4.2	6.2	1.2
	1990	330.9	74.3	15.4
	1991	0.0	21.0	2.2
	1992	42.1	45.3	41.0
	1993	0.0	2.3	2.5
	1994	0.5	32.3	7.3
	1995	11.2	39.0	1.0
	1996	0.1	11.0	na
	1997	38.8	65.5	-
	1998	20.7	-	-
Pt. Thomson	1997	-	-	2.1
	1998	-	1.5	-

therefore, ample precedent that low abundances of two-year olds can follow good recruitment into an area known to have overwintering grounds. The catch rate of 2.1 fish/net/24 h for two-year-olds at Point Thomson does not disprove the possible presence of local overwintering areas.

The catch rates of yearling Arctic cisco at Prudhoe Bay typically exceeds 15.0 fish/net/24 h following years of good recruitment (see Table 4). The catch rate of 1.5 fish/net/24 h for yearlings at Point Thomson—an order of magnitude lower than that observed at Prudhoe Bay following good recruitments—provides a strong argument for poor overwintering in the region. However, even this low catch rate is suspect. Although there was a recruitment of young-of-the-year Arctic cisco into Alaska in the summer of 1998, it was one of the most unusual ever recorded at Prudhoe Bay. Figure 10 illustrates the residency periods of young-of-the-year Arctic cisco near Prudhoe Bay by year. The recruitment in 1998 was the earliest ever reported with the first fish arriving on 27 July. This arrival was preceded by nearly three weeks of strong, sustained northeast winds, conditions that probably accounted for the early arrival. However, the persistence of east winds also raises other factors concerning the passive transport of age-0 cisco along the coast.

The hypothesis that young-of-the-year Arctic cisco are transported westward into Alaska from Canada is well documented (Gallaway et al. 1983; Fechhelm and Fissel 1988; Moulton 1989; Fechhelm and Griffiths 1990; Schmidt et al. 1991; Underwood et al. 1995; Colonell and Gallaway 1997). Yet there is little information regarding the nearshore/offshore distribution of fish as they move westward along the coast. Nearshore currents along the Beaufort Sea coast are governed primarily by winds (Niedoroda and Colonell 1989, 1990a, 1990b). East winds generate westerly flowing surface currents that are deflected to the right (offshore) because of Coriolis forces. The offshore deflection of surface waters causes a depression of sea level (negative storm surge), which is partially compensated for by an onshore movement of bottom marine water. Conversely, west winds cause surface currents to flow eastward with a resultant onshore Coriolis deflection of surface water. The onshore transport of surface waters is balanced by an offshore transport of bottom water, resulting in a region-wide downwelling along the coast. Hypothetically, this mechanism raises the possibility that age-0 fish being transported westward under east winds may also be held offshore by the seaward deflection of surface waters. This possibility of an offshore distribution has never been studied in detail because it is difficult and costly to sample in deep water. Houghton and Whitmus (1988) conducted an offshore trawl study during the summer 1988 specifically to address this issue but there was no recruitment that year. Jarvela and Thorsteinson (1999) reported catching young-of-the-year Arctic cisco (described as

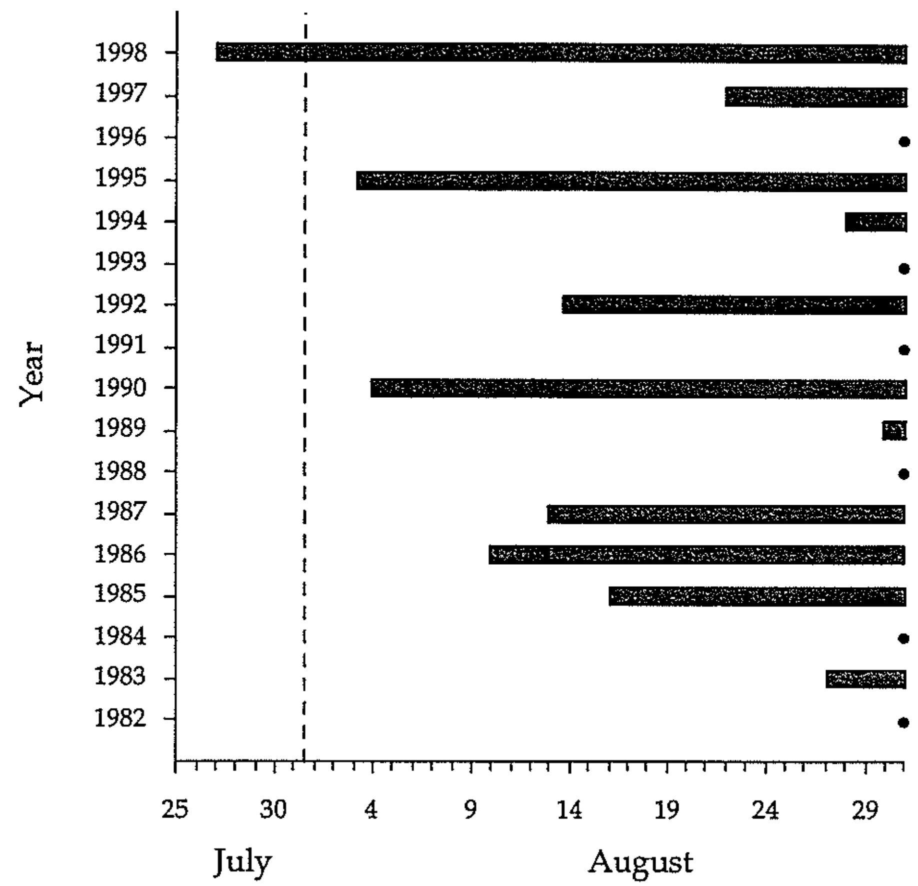

Figure 10. Residency periods of age-0 (young-of-the-year) Arctic cisco in the Prudhoe Bay area by year based upon fyke net catch rates. Symbol (•) indicates no recruitment reported. Sources: PBS (1981-1998). Vertical dotted line delineates July and August.

vigorous and in good condition) by tow net as far as 11 km from shore. Unfortunately results of their study can not be directly compared to fyke net catch rates because of the difference in gear types. There are, however, intuitive indications of an onshore/offshore component to the transport process.

If the idea that persistent east winds hold young-of-the-year offshore as they are being transported eastward, then it follows that the cessation of east winds, or the onset of west winds, would be required for fish to move onshore and be captured in the fyke nets. Figure 11 illustrates the wind and recruitment pattern of Arctic cisco reported for Mikkelsen Bay in 1995 (Fechhelm et al. 1996). While the first fish appeared in the fyke nets on 9 August, during a period of east winds, the largest surge in CPUE to 130 fish/net/24 h among the four operational fyke nets occurred in the midst of a three day period of west winds. The second largest surge occurred from 19 to 22 August during another west wind event. In 1998, the arrival of young-of-the-year at Prudhoe Bay (Fig. 12) occurred during the cessation of east winds. The arrival of fish at Point Thomson in 1999 during this study occurred within a period of mixed east/west winds (see Fig. 8). To be certain, there have been years in which young-of-the-year have arrived in the midst of sustained east winds (e.g., at Prudhoe Bay in 1986). Thus there is conflicting evidence for an onshore/offshore component to the recruitment process. However, if the possibility is considered, then wind conditions during July of 1998 would have been ideal for holding new recruits offshore as they were transported eastward. From 7 to 27 July, 1998, winds blew almost exclusively from the east at an average velocity of 14.2 nph (see Fig. 12). Of the 485 hourly wind observations reported by the National Weather Service for Deadhorse Airport for this period, wind blew from the east in 470 (96.9%) instances. If recruits were held offshore for three weeks in July 1998, it is possible that much of the recruitment may have bypassed the Point Thomson area, a situation that would lead to low numbers of yearlings in 1999. Because of this possibility, the issue of overwintering remains unresolved.

A total of 1,507 Cohort 4 (≥age-3) Arctic cisco were collected at Point Thomson in 1999 of which 1,341 (89.0%) were adults ≥300 mm in length (see Fig. 4). Seasonal catch ranged from 4.1 to 7.5 fish/24 h at nets 602-605 but was 17.6 fish/24 h at Station 601. Much of the higher catch at Station 601 was associated with several large single days surges in CPUE. There was no distinguishing temporal pattern in catch rates (Fig. 13).

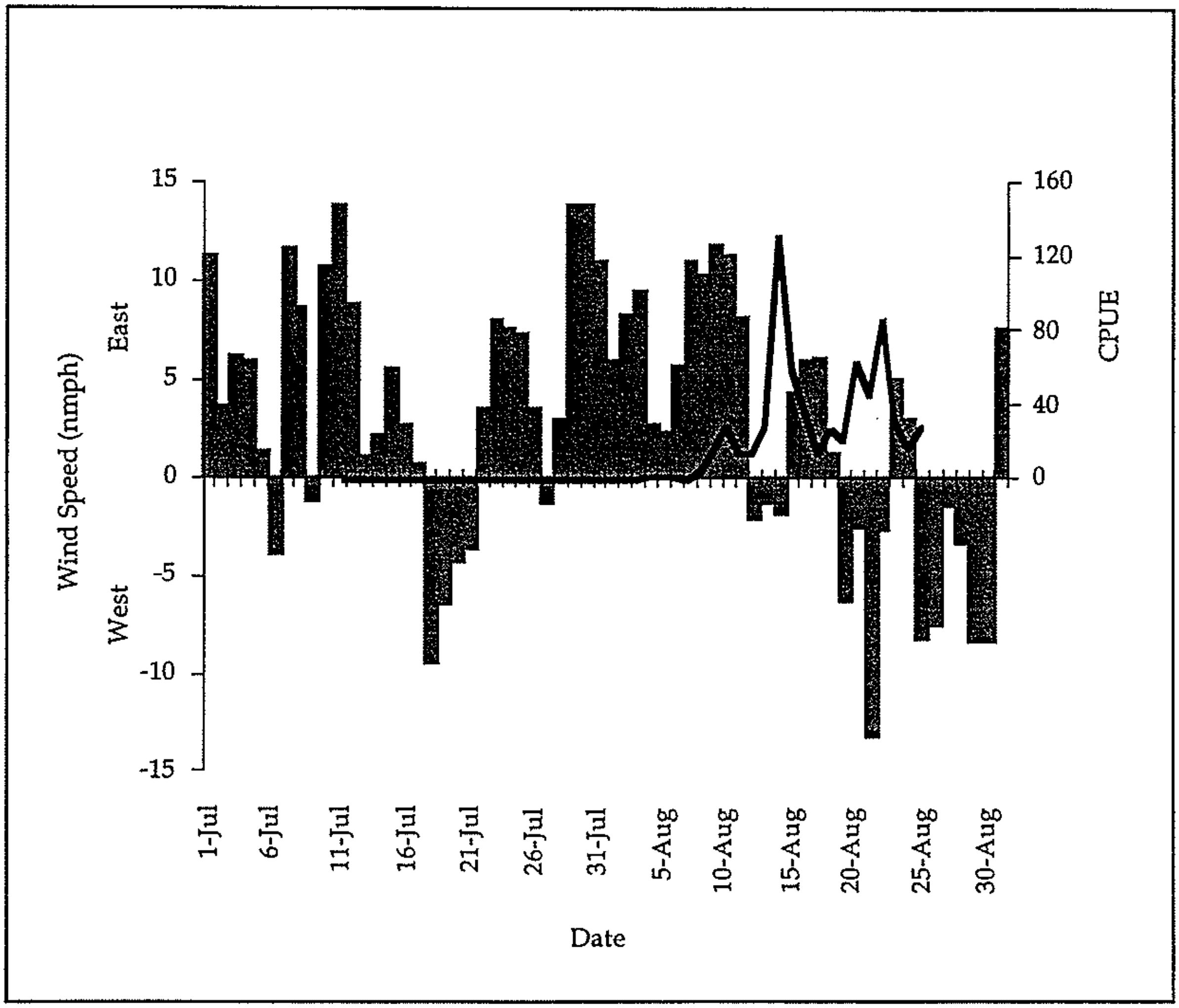

Figure 11. Daily mean east/west wind speeds recorded at Deadhorse Airport and daily mean CPUE (fish/net/24 h) of age-0 Arctic cisco for Mikkelsen Bay fyke nets (solid line) for July-August, 1995.

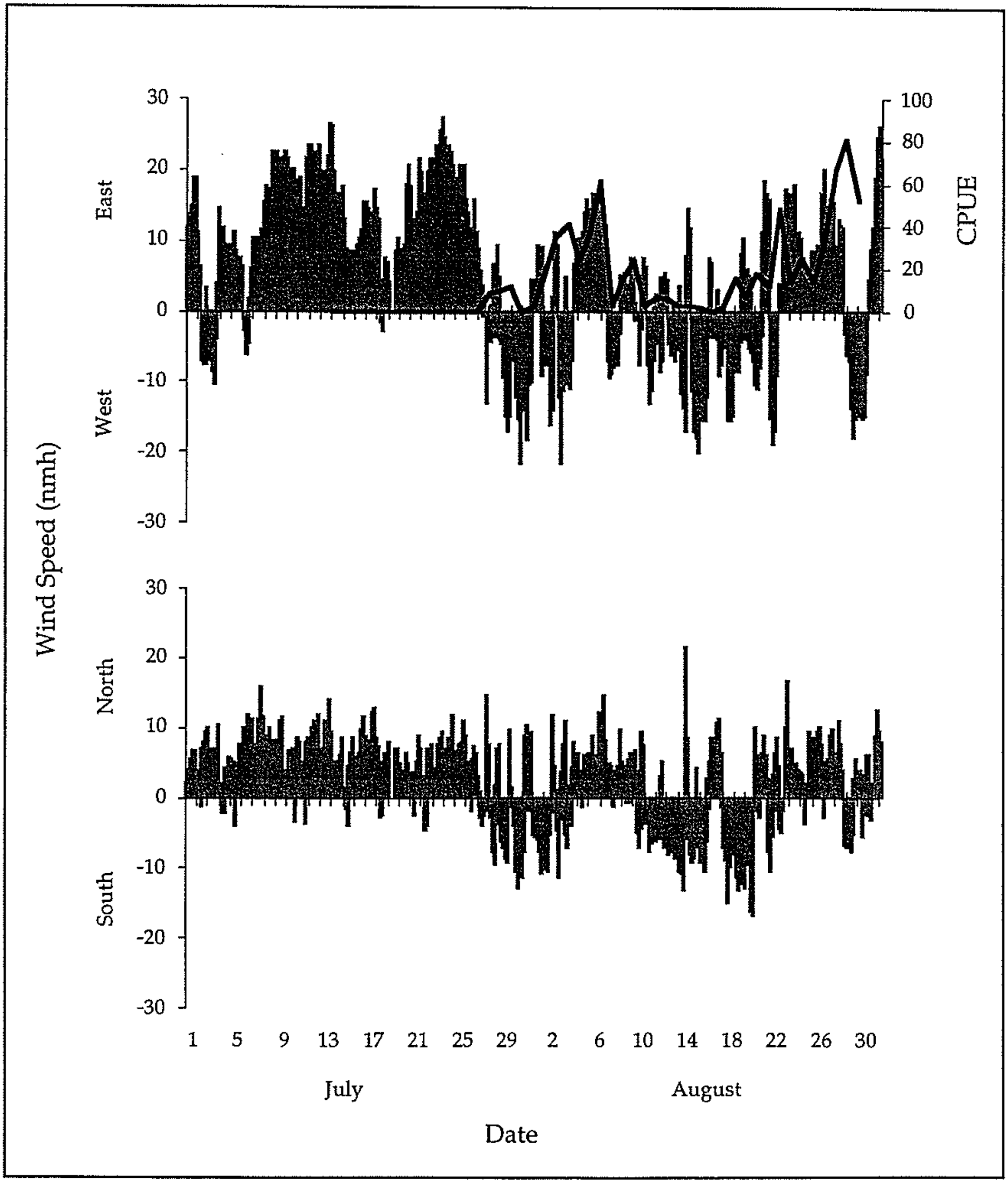

Figure 12. Hourly wind speed and direction for July-August 1998 showing east-west and north-south components. Superimposed on the top panel is the catch-per-unit-effort (CPUE: fish/net/24 h) of young-of-the-year Arctic cisco collected that summer at Prudhoe Bay.

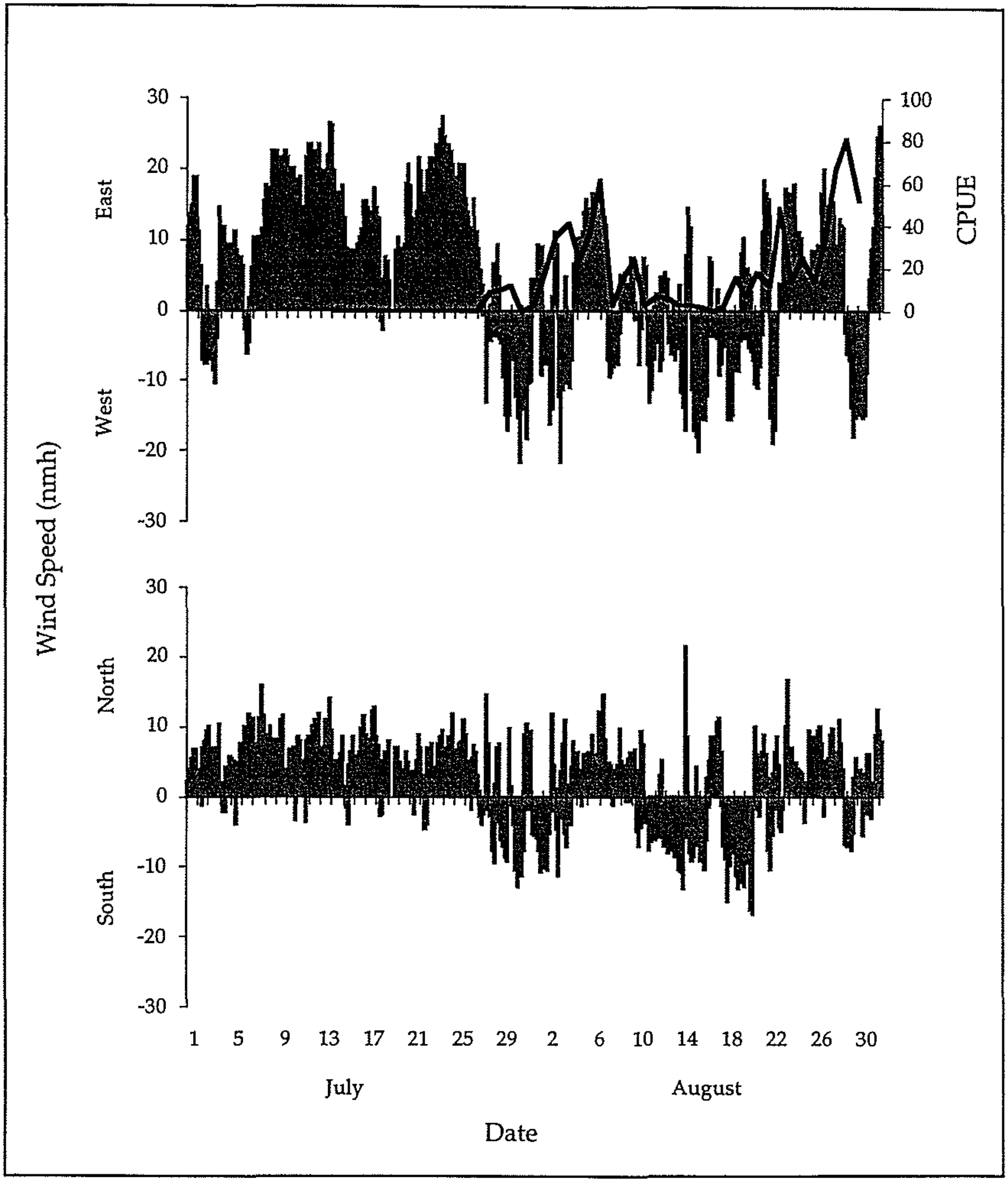

Figure 12. Hourly wind speed and direction for July-August 1998 showing east-west and north-south components. Superimposed on the top panel is the catch-per-unit-effort (CPUE: fish/net/24 h) of young-of-the-year Arctic cisco collected that summer at Prudhoe Bay.

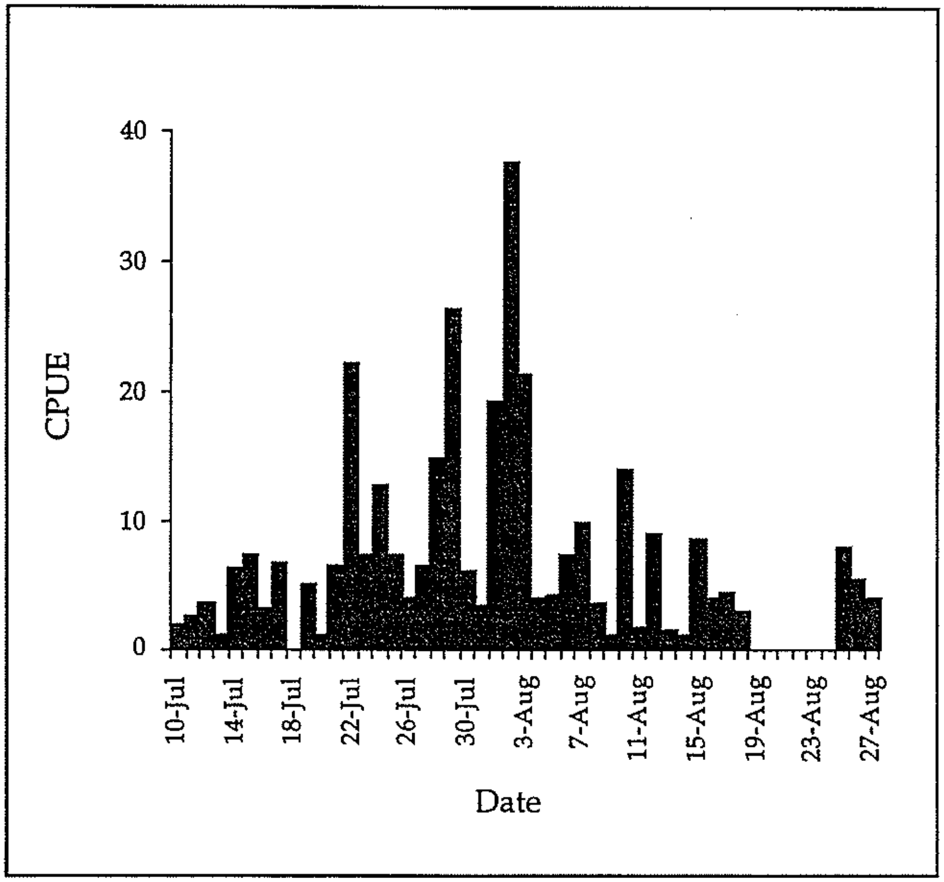

Figure 13. Catch-per-unit-effort (CPUE: fish/net/24 h) by date for ≥age-3 Arctic cisco collected at Point Thomson, 1999.

The catch rates of adult Arctic cisco at Point Thomson are consistent with most other fyke net studies conducted along the Alaskan Beaufort Sea coast (Fig. 14). Large Arctic cisco range for considerable distances along the coast during summer and are taken in moderate numbers everywhere. Some of these fish may actually be sexually mature fish migrating back to spawning grounds in the Mackenzie River drainage (Gallaway et al. 1983).

Broad Whitefish

There are two main population centers of broad whitefish in the Alaskan/Canadian Beaufort Sea. Alaskan populations are typically associated with "tundra" rivers that lie west of and include the Sagavanirktok River, while Canadian populations are associated with the Mackenzie River (Craig and McCart 1975; Craig 1984; Craig 1989). There are no known spawning populations of broad whitefish in the "mountain" rivers along the 300 km of coastline between the Sagavanirktok River and Canada. Based upon this distribution pattern and the distances involved, it is assumed that most broad whitefish observed in the Point Thomson region are primarily from the Sagavanirktok River and to a lesser extent the Colville River.

A total of 491 broad whitefish were captured during the 1999 study of which all except three were greater than 280 mm in length. Based upon otolith age analyses of Prudhoe Bay broad whitefish, individuals collected at Point Thomson are likely age-4 and older (Fig. 15). The clearest distinction between the population age structure observed in this study compared to that typically observed at Prudhoe Bay was the absence of young fish (i.e., ≤age-3) at Point Thomson. Young-of-the-year and juvenile fish historically make up large proportions of the catches reported for the Prudhoe Bay region (PBS 1982-1999) and their presence reflects the proximity of the spawning broad whitefish population that inhabits the Sagavanirktok River (Fig. 16). Also, these young fish tend to remain within the warmer, low salinity waters of the Sagavanirktok Delta during summer, presumably because of their intolerance of high salinities (Griffiths et al. 1992). The absence of juveniles at Point Thomson was thus consistent with the limited summer dispersal of these size classes from the Sagavanirktok River.

CPUE for adult broad whitefish >280 mm ranged from 2.2 to 4.0 fish/net/24 h at the four mainland stations but was negligible (0.1 fish/net/24 h) at barrier island Station 605. There was no significant difference in the CPUE for this size group (≥280 mm) at the four mainland sites compared to that reported for Prudhoe Bay from 1985 to 1998 ($P = 0.87$) or

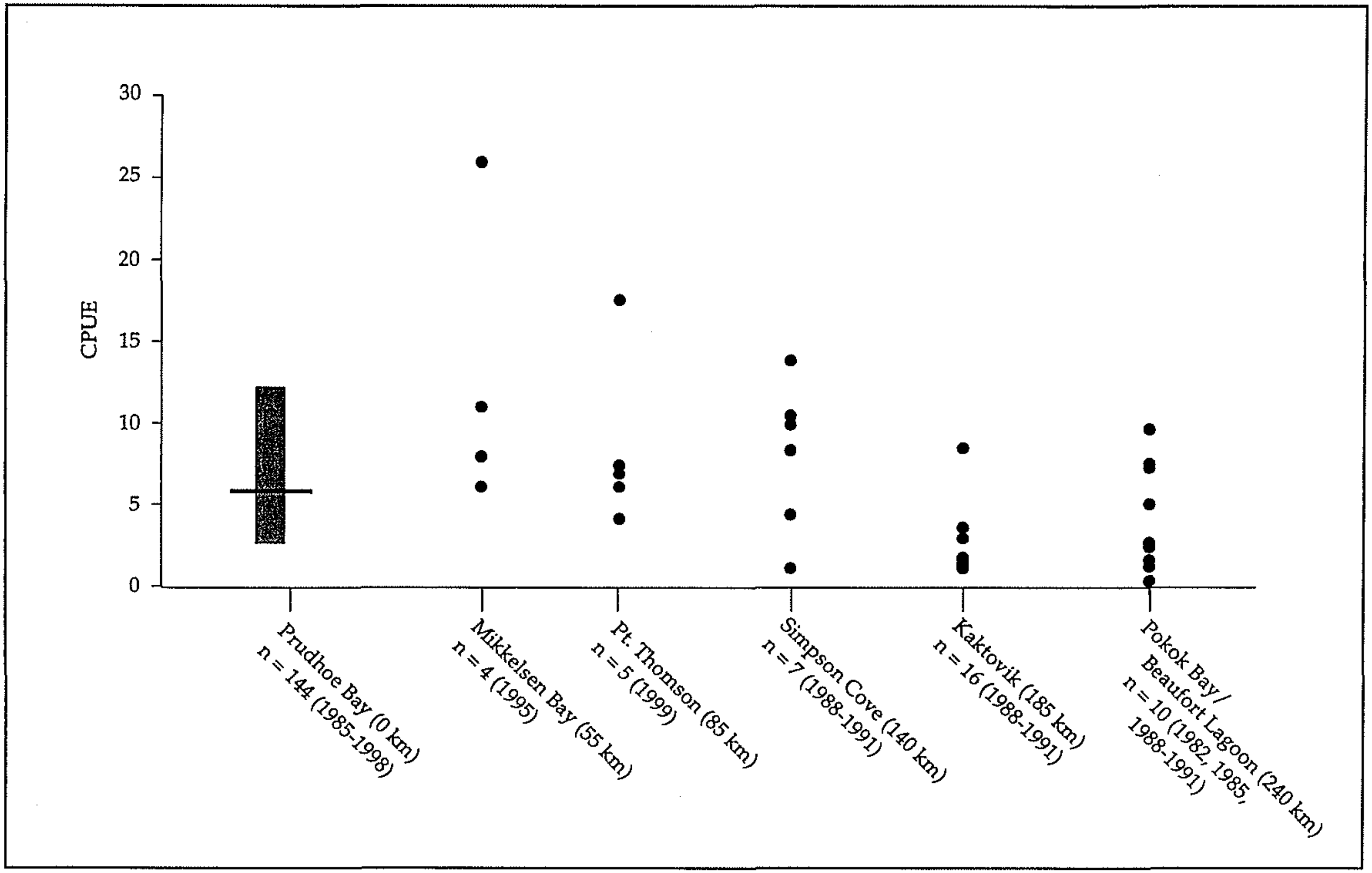

Figure 14. Catch-per-unit-effort (CPUE: fish/net/24 h) of Arctic cisco (≥ 200 mm) collected by fyke net along the Beaufort Sea coast from Prudhoe Bay to the U.S./Canadian border. Locations are scaled to the approximate distance from Prudhoe Bay (0 km). Sample size (n) denotes the total number of fyke nets sampled followed parenthetically by the years during which sampling took place. Data for Prudhoe Bay expressed as median and interquartile range. Sources: Prudhoe Bay (Cannon et al. 1987; Glass et al. 1990; LGL 1990, 1991, 1992, 1993, 1994a, 1994b, 1998, 1999; Reub et al. 1991; and Griffiths et al. 1995, 1996, 1997), Mikkelsen Bay (Fechhelm et al. 1995), Pt. Thomson (this study), Simpson Cove (Underwood et al. 1995), Kaktovik (Underwood et al. 1995), Pokok Bay/Beaufort Lagoon (Griffiths 1983; West and Wiswar 1985; Underwood et al. 1995).

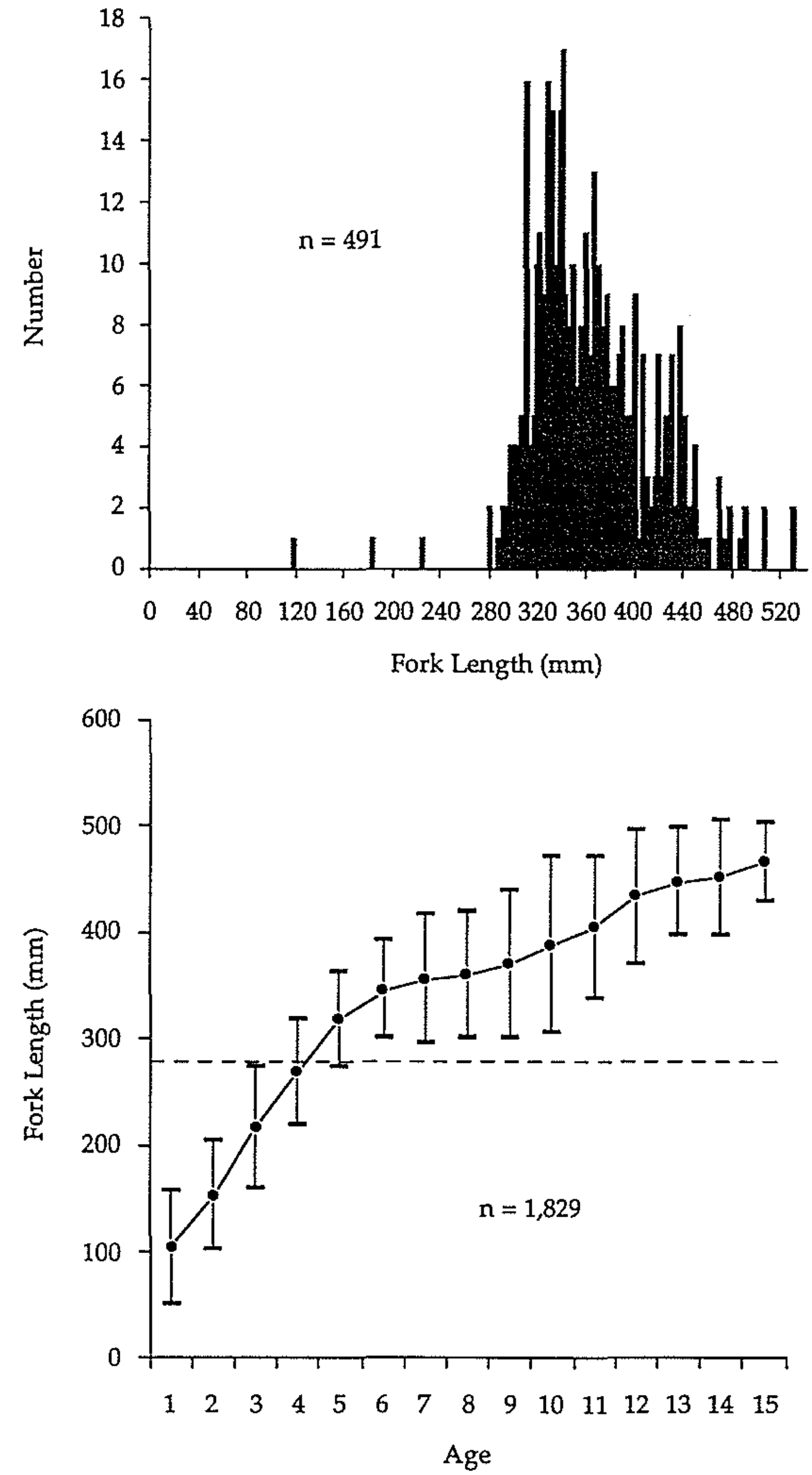

Figure 15. Length-frequency distribution of broad whitefish collected at Point Thomson in 1999 (top panel). Mean length (± 2 SD) by age for broad whitefish collected at Prudhoe Bay from 1988 to 1993 (bottom panel). Age estimates are based upon analysis of saggital otoliths. Horizontal dashed line in bottom panel indicates minimum length of the majority of broad whitefish collected at Point Thomson in 1999.

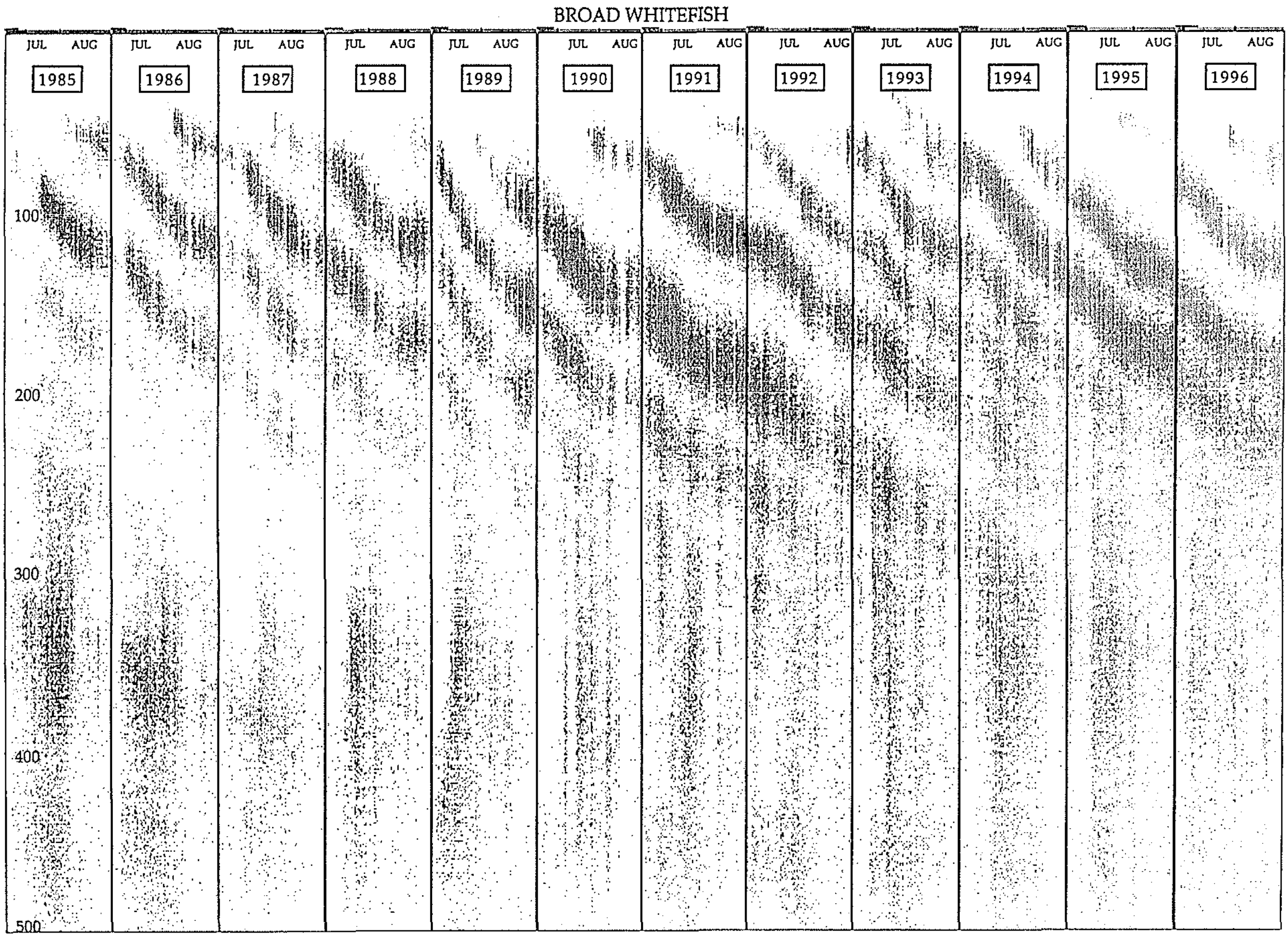

Figure 16. Catch by length data for broad whitefish collected at Prudhoe Bay during the summers 1985-1996.

Mikkelsen Bay (P = 0.63) in 1995 (Fig. 17). The comparable catches suggest that Point Thomson is within the summer dispersal range of adult broad whitefish from the Sagavanirktok River. Large broad whitefish have been documented to move between the Sagavanirktok River and the Colville River area, at times covering coastal distances in excess of 100 km (Moulton et al. 1986, 1992, 1993; Moulton and Field 1994) and so the presence of this size group at Point Thomson, 85 km east of Prudhoe Bay, is certainly reasonable. Studies conducted east of Point Thomson at Simpson Cove, Kaktovik, and Pokok Bay/Beaufort Lagoon reported catching few broad whitefish of any size (Fig. 17) further suggesting that the summer dispersal terminates somewhere between Point Thomson and Simpson Cove.

The low catch of broad whitefish at Station 605 relative to that at the mainland nets most likely resulted from fish migrating along the mainland shore rather than along the barrier islands.

Least Cisco

Background information for least cisco is discussed above in Data Correction.

A total of 9,007 least cisco were collected at Point Thomson in 1999 making them the fourth most abundant species. CPUE ranged from 38.9 to 71.5 fish/net/24 h at the mainland nets but was only 3.1 fish/24 h at barrier island Station 605. Nearly all least cisco were adults >200 mm FL (Fig. 18). As discussed above in Data Correction, the absence of juvenile least cisco at Point Thomson was expected given its distance from the Colville River. Catch of adult fish was highest in early summer and decreased steadily throughout July. Nearly 85% of the total catch occurred before 31 July (Fig. 19). The lower catch in August may reflect fish emigrating from the area on their way back to overwintering grounds in the Colville River.

Twenty-seven tagged least cisco were collected during the study (Table 5). All were tagged in the Prudhoe Bay area during the summers 1990 to 1993. These data provide additional support for the hypothesis that least cisco found at Point Thomson are of Colville River origin.

Historic survey data reported along the Alaskan Beaufort Sea coast suggests that, like adult broad whitefish, the eastward dispersal of adult least cisco may terminate somewhere between Point Thomson and Simpson Cove (Fig. 20). Summer CPUE reported for points east of Point Thomson (i.e., Simpson Cove, Kaktovik, and Pokok Bay and Beaufort Lagoon) is negligible relative to that reported for Prudhoe Bay, Mikkelsen Bay, and Point Thomson.

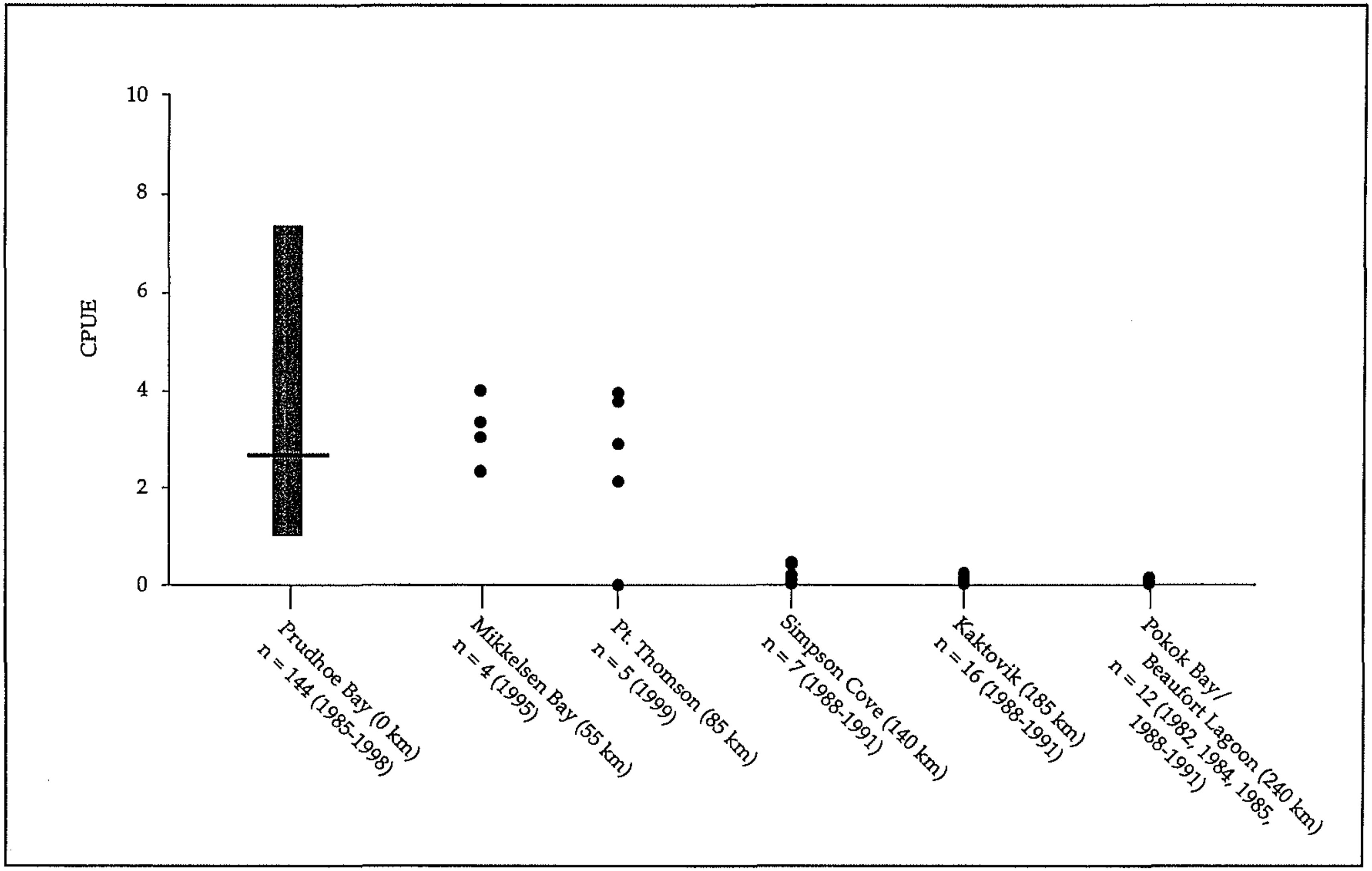

Figure 17. Catch-per-unit-effort (CPUE: fish/net/24 h) of adult broad whitefish (≥ 280 mm) collected by fyke net along the Beaufort Sea coast from Prudhoe Bay to the U.S./Canadian border. (Studies for Simpson Cove, Kaktovik, and Pokok Bay reported catches for all broad whitefish and it was assumed that all were adults). Locations are scaled to the approximate distance from Prudhoe Bay (0 km). Sample size (n) denotes the total number of fyke nets sampled followed parenthetically by the years during which sampling took place. Data for Prudhoe Bay expressed as median and interquartile range. Sources: Prudhoe Bay (Cannon et al. 1987; Glass et al. 1990; LGL 1990, 1991, 1992, 1993, 1994a, 1994b, 1998, 1999; Reub et al. 1991; and Griffiths et al. 1995, 1996, 1997), Mikkelsen Bay (Fechhelm et al. 1995), Pt. Thomson (this study), Simpson Cove (Underwood et al. 1995), Kaktovik (Underwood et al. 1995), Pokok Bay/Beaufort Lagoon (Griffiths 1983; West and Wiswar 1985; Wiswar and West 1987; Underwood et al. 1995).

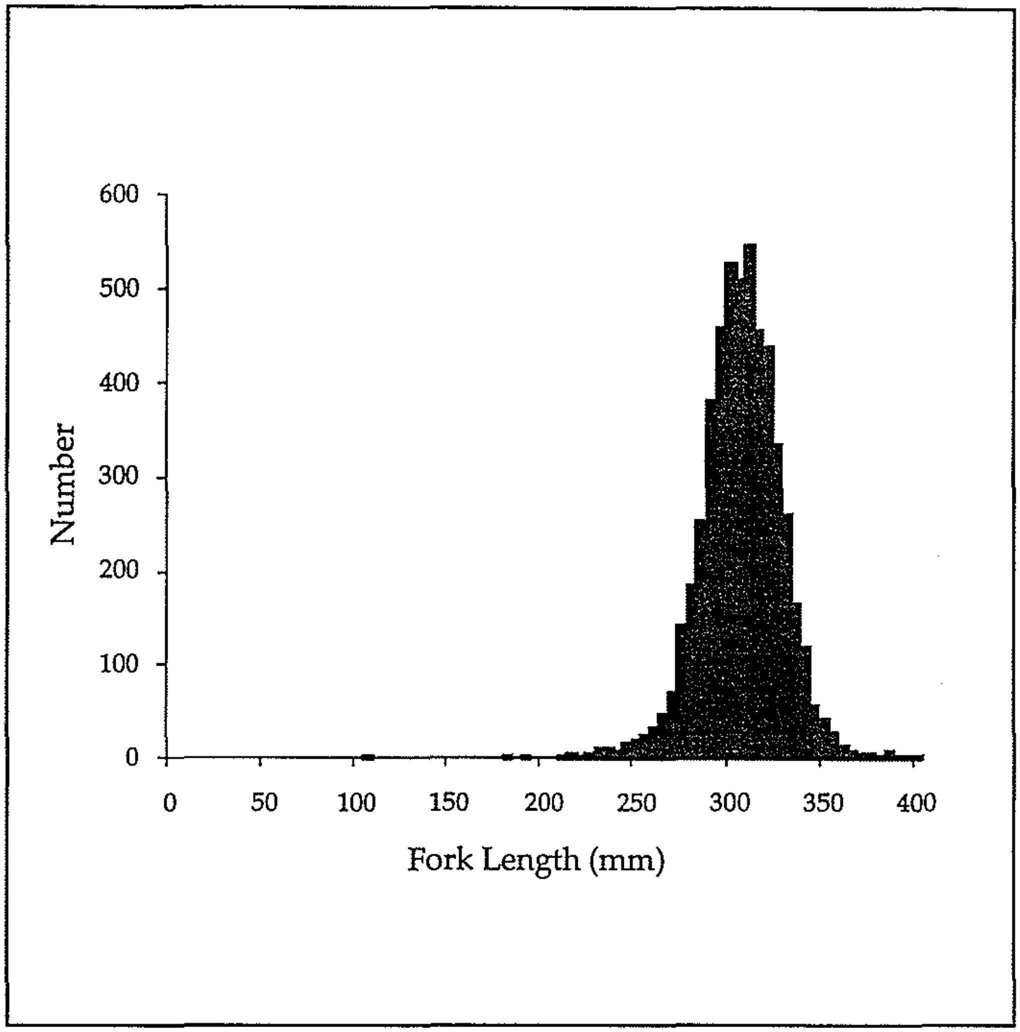

Figure 18. Length-frequency distribution of least cisco collected at Point Thomson, 1999.

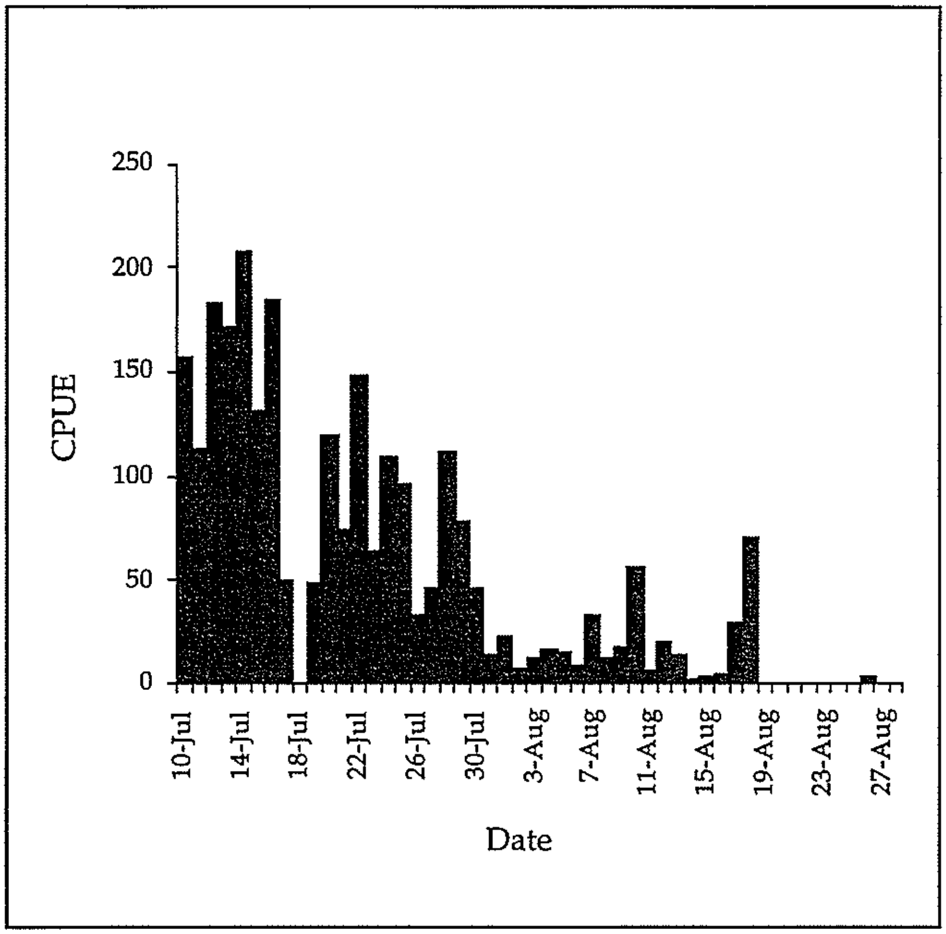

Figure 19. Catch-per-unit-effort (CPUE: fish/net/24 h) by date for adult least cisco collected at Point Thomson, 1999.

Table 5. Mark-recapture data for least cisco collected at Point Thomson in 1999.

Tagging Date	Tagging Site	Recapture Date	Recapture Site	Tag Length (mm)	Recapture Length (mm)
20-Jul-90	West Prudhoe Bay	23-Jul-99	603W	299	315
7-Aug-90	West Sagavanirktok Delta	11-Jul-99	603E	304	320
9-Aug-90	East Sagavanirktok Delta	15-Jul-99	601E	363	301
9-Jul-91	Kuparuk Delta	15-Aug-99	602W	314	340
23-Jul-91	East Sagavanirktok Delta	22-Jul-99	603E	286	314
23-Jul-91	West Sagavanirktok Delta	14-Jul-99	604W	288	318
24-Jul-91	West Base of West Dock	10-Jul-99	602W	310	345
25-Jul-91	West Prudhoe Bay	14-Jul-99	604E	260	312
28-Jul-91	Stump Island	10-Jul-99	602W	278	315
1-Aug-91	East Sagavanirktok Delta	10-Jul-99	601W	314	358
8-Jul-92	West Base of West Dock	12-Aug-99	601E	327	348
14-Jul-92	Kuparuk Delta	16-Jul-99	601E	348	355
4-Aug-92	West Sagavanirktok Delta	16-Jul-99	603W	250	320
7-Aug-92	West Base of West Dock	28-Jul-99	604E	253	315
10-Aug-92	West Sagavanirktok Delta	12-Jul-99	603W	250	318
16-Aug-92	West Sagavanirktok Delta	10-Jul-99	602W	268	304
11-Jul-93	East Sagavanirktok Delta	2-Aug-99	603W	458	477
11-Jul-93	West Base of West Dock	23-Jul-99	604W	285	310
12-Jul-93	West Sagavanirktok Delta	18-Aug-99	604E	308	330
13-Jul-93	West Sagavanirktok Delta	11-Jul-99	604W	300	327
16-Jul-93	East Sagavanirktok Delta	14-Jul-99	603E	318	330
20-Jul-93	West Sagavanirktok Delta	23-Jul-99	603E	284	326
20-Jul-93	West Sagavanirktok Delta	23-Jul-99	603W	279	318
21-Jul-93	East Sagavanirktok Delta	11-Jul-99	604W	255	303
5-Aug-93	East Sagavanirktok Delta	10-Jul-99	602W	250	325
6-Aug-93	West Sagavanirktok Delta	22-Jul-99	602W	265	304
19-Aug-93	East Sagavanirktok Delta	14-Jul-99	603E	272	348

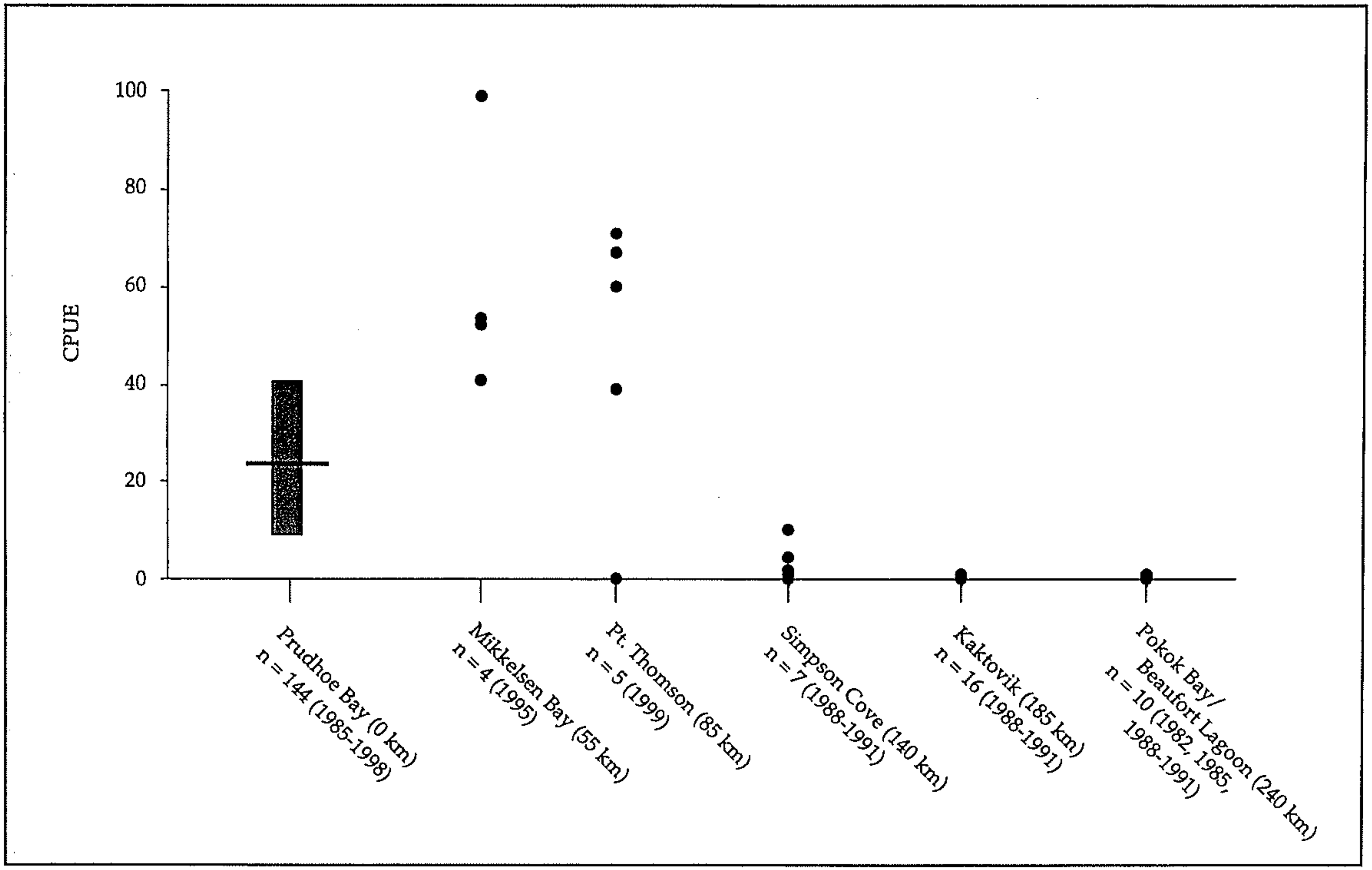

Figure 20. Catch-per-unit-effort (CPUE: fish/net/24 h) of adult least cisco (>180 mm) collected by fyke net along the Beaufort Sea coast from Prudhoe Bay to the U.S./Canadian border. (Studies for Simpson Cove, Kaktovik and Pokok Bay reported catches of all least cisco and it was assumed that they were adults). Locations are scaled to the approximate distance from Prudhoe Bay (0 km). Sample size (n) denotes the total number of fyke nets sampled followed parenthetically by the years during which sampling took place. Data for Prudhoe Bay expressed as median and interquartile range. Data exclude 178 "juvenile least cisco" collected by West and Wiswar (1984) at Beaufort Lagoon in August, 1984. Sources: Prudhoe Bay (Cannon et al. 1987; Glass et al. 1990; LGL 1990, 1991, 1992, 1993, 1994a, 1994b, 1998, 1999; Reub et al. 1991; and Griffiths et al. 1995, 1996, 1997), Mikkelsen Bay (Fechhelm et al. 1995), Pt. Thomson (this study), Simpson Cove (Underwood et al. 1995), Kaktovik (Underwood et al. 1995), Pokok Bay/Beaufort Lagoon (Griffiths 1983; West and Wiswar 1985; Underwood et al. 1995).

Excluding the catch at barrier island Station 605, CPUE for least cisco at Point Thomson in 1999 and at Mikkelsen Bay in 1995 were both significantly higher ($P = 0.03$ in each case) than historical catch at Prudhoe Bay (see Fig. 20). The reason for the higher catch rates at coastal locations east of Prudhoe Bay (i.e., more distant from the Colville River) may be partially attributable to net location. Catch tends to be highest at fyke nets located along continuous expanses of coastline (PBS 1982-1999) and lowest when situated on islands, at mid water sites, or in isolated backwaters. The rationale is that primary shorelines concentrate the flow of fish along the coast; thereby increasing the effectiveness of passive fishing devices deployed along the shore. Conversely, the dispersal of fish in open water reduces the efficiency of island and open water nets. Net locations at Point Thomson and at Mikkelsen Bay in 1995 can be considered primary shoreline sites. Nearly a third of the fishing effort expended at Prudhoe Bay from 1985-1998 was by island and open water nets and may have instilled a downward bias in the Prudhoe Bay data. The major problem with this hypothesis is that one would expect the other species to be affected in a similar fashion. The catch rates of Dolly Varden, large broad whitefish, and large Arctic cisco were not higher at Point Thomson compared to Prudhoe Bay.

If the higher catch rates at Mikkelsen Bay and Point Thomson are not anomalies associated with fyke net efficiency, data could indicate greater overall concentrations of fish in those areas. Those concentrations could be in response to areas of higher productivity. The primary reason for the summer dispersal of all diadromous fishes into coastal waters is to feed in a more food-rich environment (Craig 1989).

Dolly Varden

A total of 9,459 Dolly Varden were collected during the study making them the second most abundant species behind fourhorn sculpin. The high abundance of Dolly Varden in the Point Thomson area is consistent with this species' distribution. These fish spawn in many of the "mountain streams" located between and including the Colville and Mackenzie rivers (Glova and McCart 1974; Craig and McCart 1975, 1975; Smith and Glesne 1982; Craig 1977a, b; Daum et al. 1984; Craig 1984; Everett and Wilmot 1987) and they are common in Beaufort Sea coastal waters during summer (Griffiths et al. 1975; Griffiths et al. 1977; Bendock 1979; Craig and Haldorson 1981; PBS 1981-1996; West and Wiswar 1985; Wiswar and West 1987; Fruge et al. 1989; Underwood et al. 1995, 1996).

The length-frequency distribution of Dolly Varden indicated the presence of several size modes, the most distinctive occurring at about 160-190 mm (Fig. 21). This size mode is

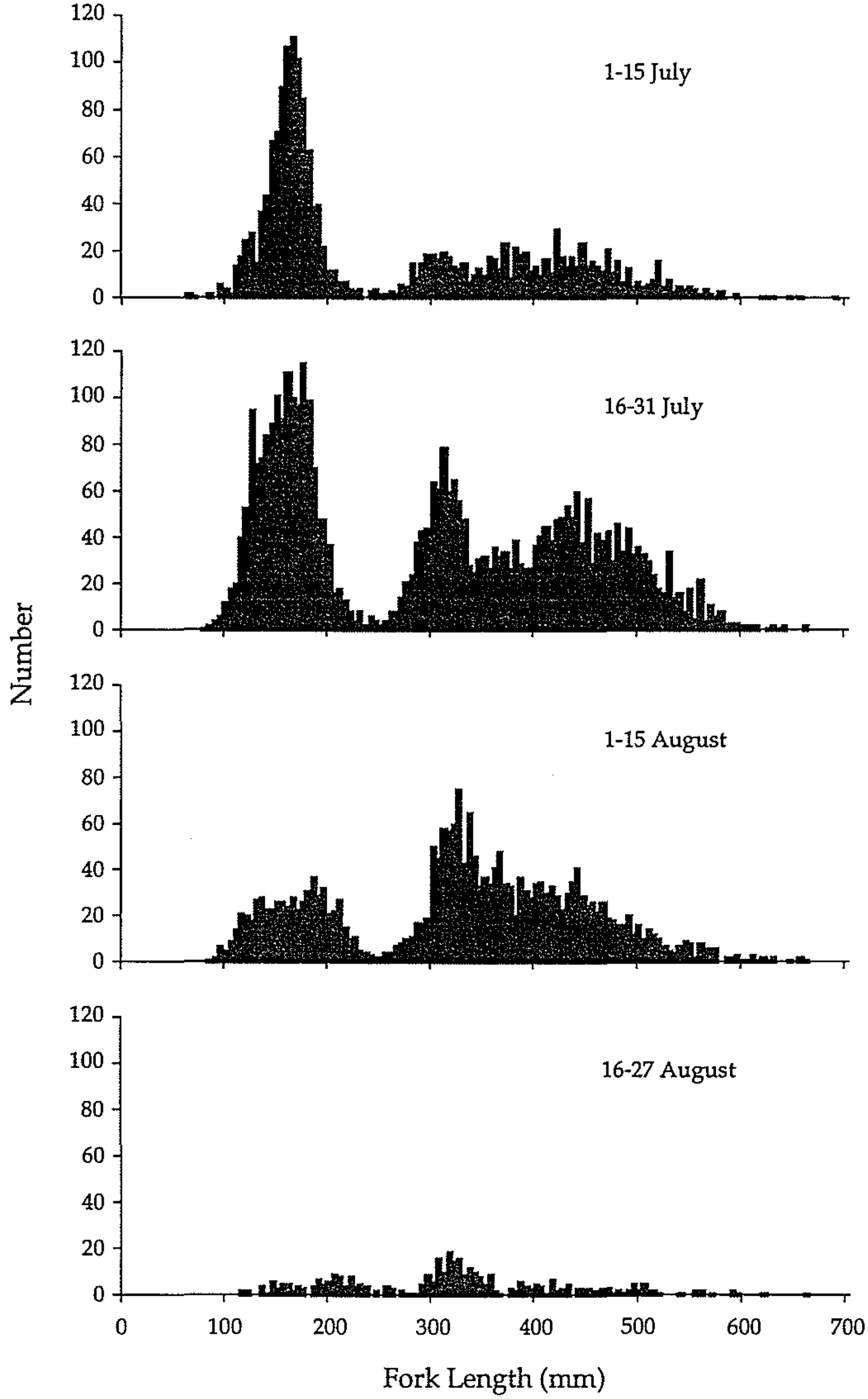

Figure 21. Length frequency distributions of Dolly Varden collected at Point Thomson, 1999.

typically reported for the Sagavanirktok River population (PBS 1981-1996) and is likely composed of smolts. After hatching, juvenile Dolly Varden remain within their natal streams for several years prior to their first seaward migration and do not migrate into coastal waters en masse until they are 2 to 3 years of age (Craig and McCart 1976; Craig 1977a, b; 1989). The cohort representing Dolly Varden smolts in the Prudhoe Bay region typically grows to a modal length of 200-240 mm by late summer (Fechhelm et al. 1999). Studies conducted farther to the east along the Arctic National Wildlife Refuge (ANWR) coast at Simpson Cove, Kaktovik, and Beaufort Lagoon indicate a similar presence of smolt cohorts at the same approximate size intervals (Underwood et al. 1995, 1996).

CPUE for both small (<350 mm) and large (≥350 mm) Dolly Varden[1] was highest in July and gradually declined to summer lows by mid-August (Fig. 22). The trend of declining CPUE from early to mid summer is typically reported for the Prudhoe Bay area (Fig. 23) and probably represents the early summer outmigration from overwintering areas in the Sagavanirktok River (high early summer catch) followed by dispersal away from the immediate sampling area, possibly along the coast and/or out to sea (mid-summer lows in CPUE). The same migratory patterns likely affect seasonal CPUE all along the coast, including Point Thomson. The CPUE of small Dolly Varden, and to a lesser extent large fish, typically increases in late summer at Prudhoe Bay as fish migrate back to overwintering areas in the Sagavanirktok River. No clear late summer increase in CPUE was observed at Point Thomson, but this trend may have been obscured by the late summer storm.

Overall CPUE at Point Thomson in 1999 was high compared to previous fyke net studies conducted along the Beaufort Sea coast, although there was no significant ($P = 0.67$) difference when compared directly to historic CPUE at Prudhoe Bay (Fig. 24). Whether this high CPUE is merely an anomaly associated with the 1999 season or is actually indicative of a coastal area exploited by greater numbers of fish is unknown. Higher abundance could reflect enhanced productivity (more fish inhabiting the area) or the presence of a primary migratory corridor (more fish passing through the area).

[1] Since 1988, the Prudhoe Bay studies (i.e., LGL 1990, 1991, 1992, 1993, 1994a, 1994b, 1999a, 1999b; Griffiths et al. 1995, 1996, 1997) have segregated Dolly Varden into two size cohorts for more detailed analysis: <350 mm and ≥350 mm. This delination is arbitrary and does not segregate the population into distinct age classes as is the case with Arctic cisco and broad whitefish. This report (including appendix tables) uses the same two-cohort subdivision to maintain continuity with the Prudhoe Bay studies.

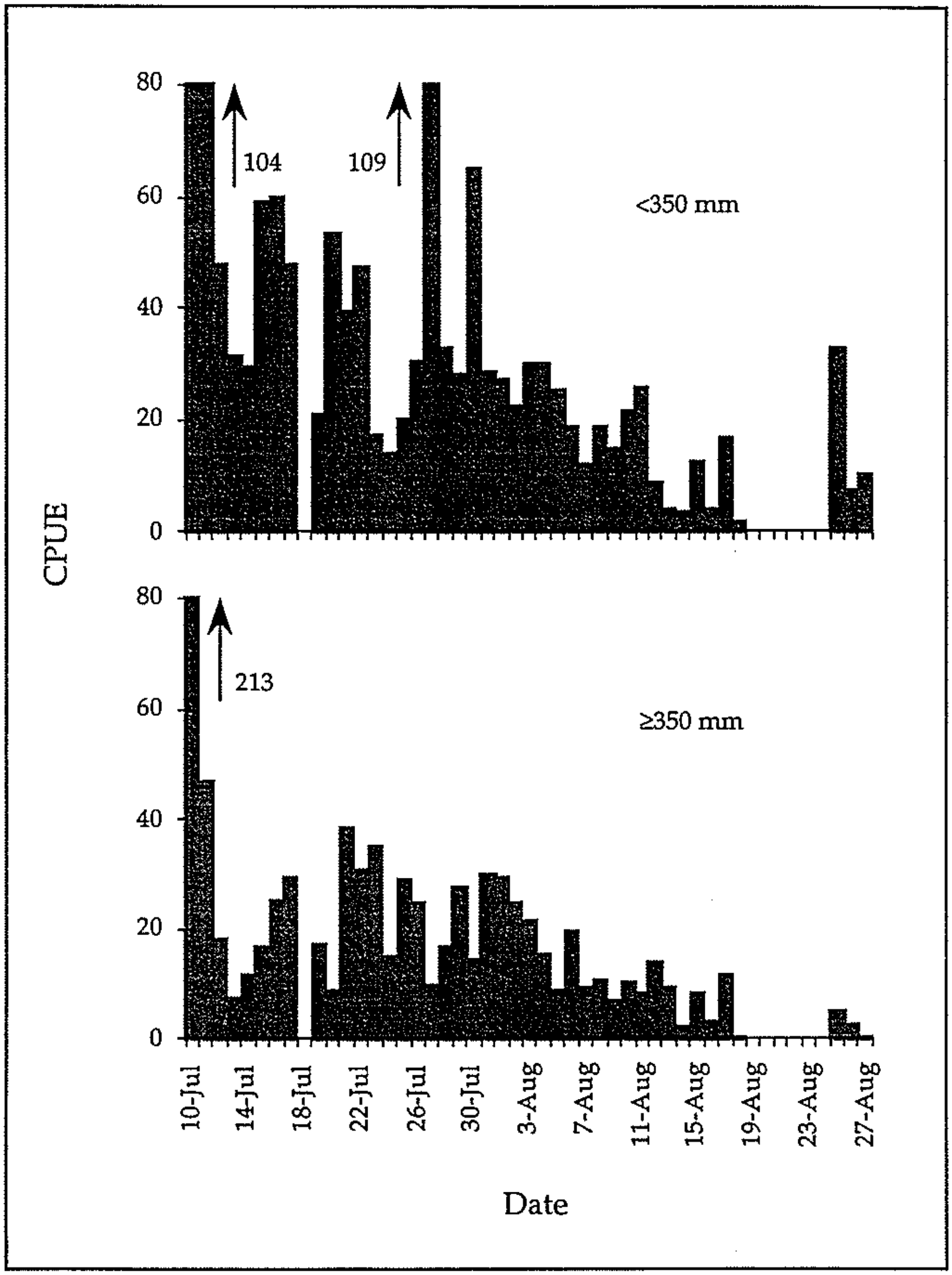

Figure 22. Catch-per-unit-effort (CPUE: fish/net/24 h) by date for Dolly Varden collected at Point Thomson, 1999.

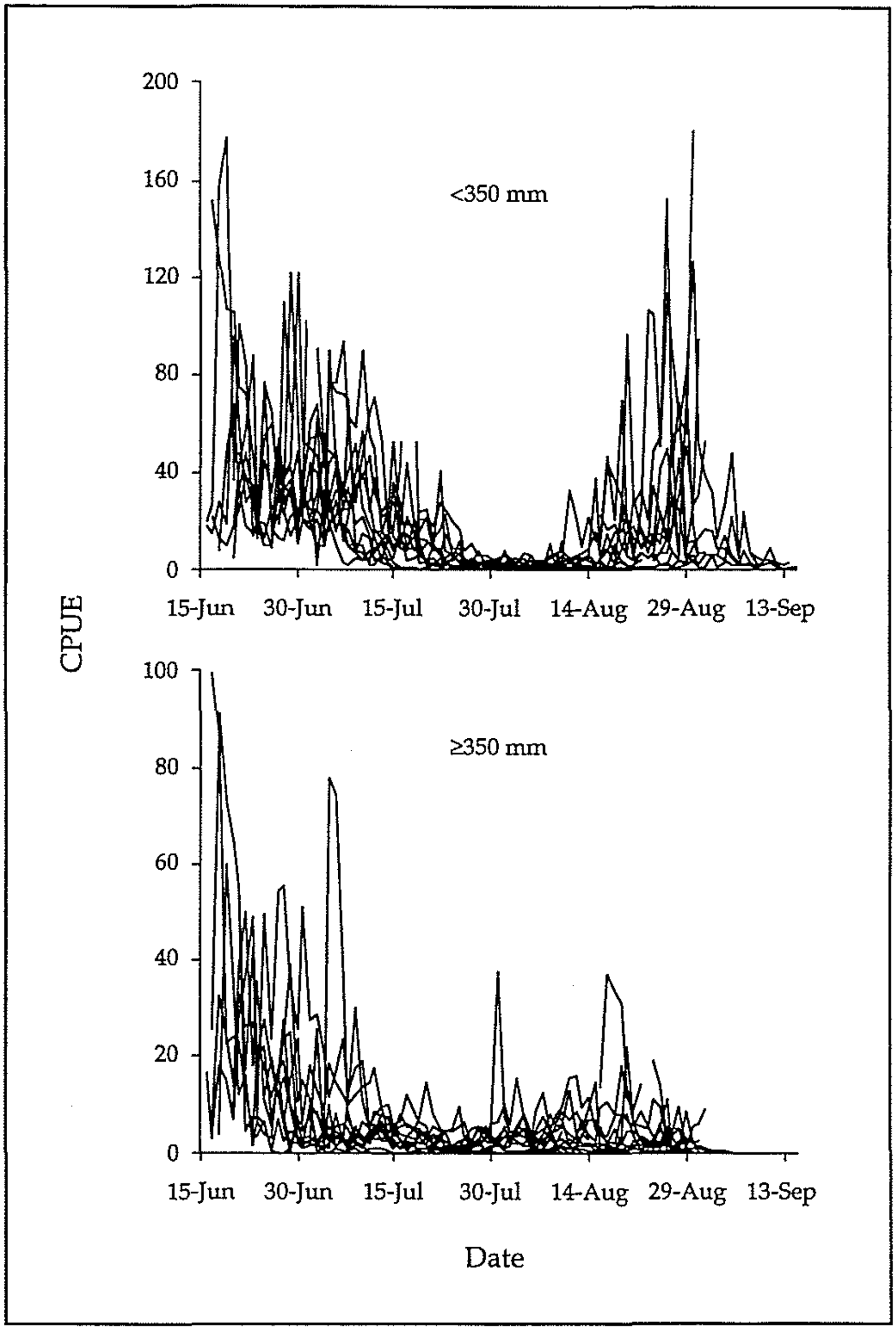

Figure 23. Catch-per-unit-effort (CPUE: fish/net/24 h) by date of small and large Dolly Varden collected at Prudhoe Bay, 1985-1998.

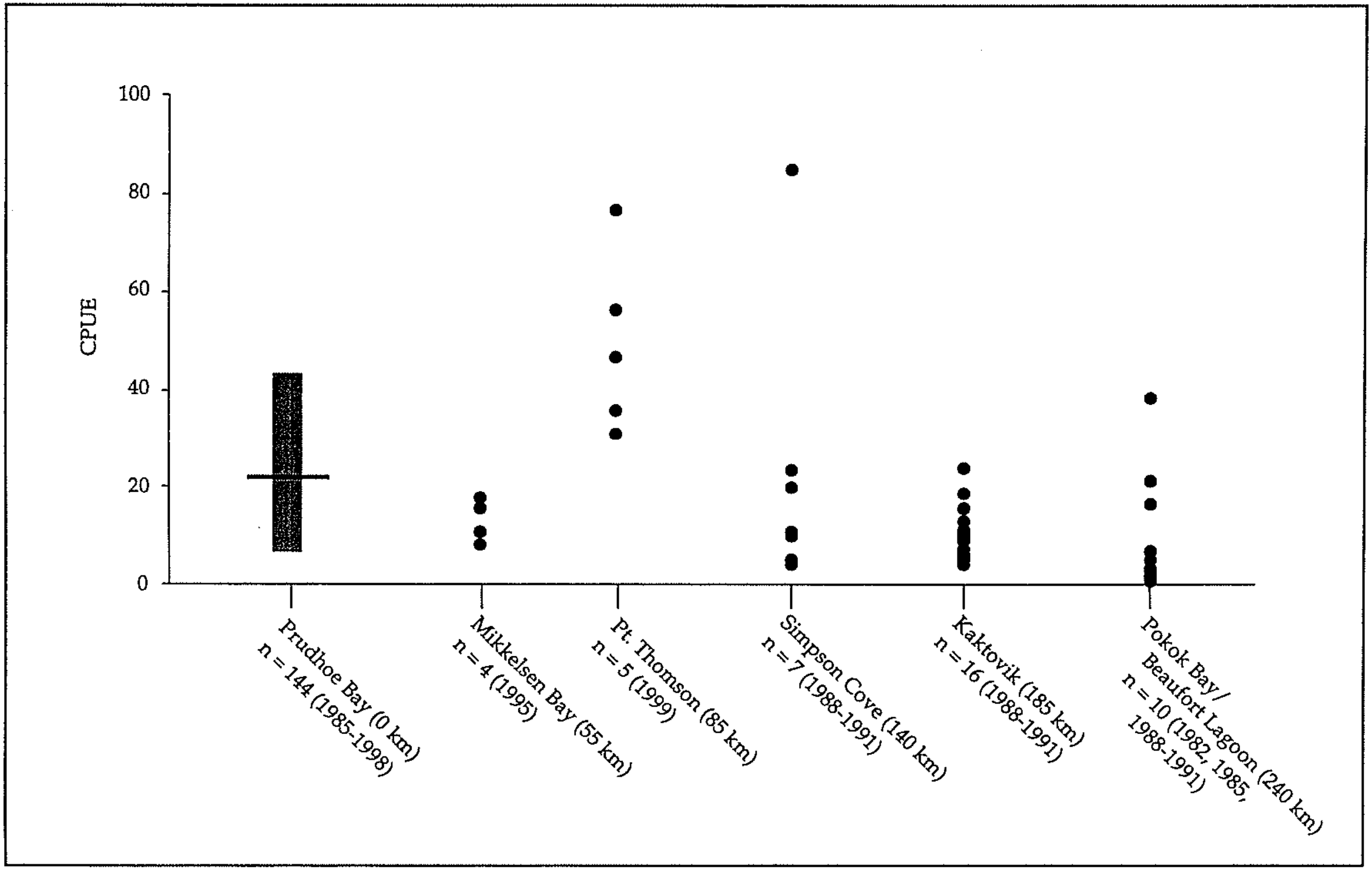

Figure 24. Catch-per-unit-effort (CPUE: fish/net/24 h) of Dolly Varden (all ages) collected by fyke net along the Beaufort Sea coast from Prudhoe Bay to the U.S./Canadian border. Locations are scaled to the approximate distance from Prudhoe Bay (0 km). Sample size (n) denotes the total number of fyke nets sampled followed parenthetically by the years during which sampling took place. Data for Prudhoe Bay expressed as median and interquartile range. Sources: Prudhoe Bay (Cannon et al. 1987; Glass et al. 1990; LGL 1990, 1991, 1992, 1993, 1994a, 1994b, 1998, 1999; Reub et al. 1991; and Griffiths et al. 1995, 1996, 1997), Mikkelsen Bay (Fechhelm et al. 1995), Pt. Thomson (this study), Simpson Cove (Underwood et al. 1995), Kaktovik (Underwood et al. 1995), Pokok Bay/Beaufort Lagoon (Griffiths 1983; West and Wiswar 1985; Underwood et al. 1995).

Humpback Whitefish

The humpback whitefish has historically been considered an "incidental species" with regard to fish monitoring programs conducted in the Prudhoe Bay region (PBS 1982-1999). The species has a discontinuous distribution in the river systems of the Beaufort Sea: eastern populations are associated with the Mackenzie River while western populations are found in the Colville River, and numerous rivers further to the west (Craig 1984). There are no known populations inhabiting the rivers between the Colville River and the U.S.-Canadian border, a distance of some 380 km (Craig 1984). Western humpbacks (presumably of Colville River origin or points west) were collected regularly at Prudhoe Bay, but in insufficient numbers for them to be considered a key species of environmental concern (PBS 1982-1999).

Recently, there has been speculation that prior to 1996, the eastward summer dispersal of humpback whitefish along the Beaufort Sea coast had been blocked by the West Dock causeway located just west of Prudhoe Bay (Fechhelm 1999). In the winter of 1995-1996, a 200-m-wide breach was constructed near the base of West Dock. During the following two summers the catch rates of humpback whitefish increased significantly east of the causeway relative to what had been reported in any previous year of study. It was hypothesized that West Dock had prevented humpbacks from dispersing eastward along the coast but that the new breach now provides a migratory passageway that enables humpbacks to extend their distribution farther to the east (Fechhelm et al. 1999).

The relevance of the "breach" hypothesis to the Point Thomson study is that while only 101 humpback whitefish (291-395 mm FL) were collected in 1999 (Fig. 25), the number is higher than what might have been expected based upon the pre-West Dock breach sampling history at Prudhoe and Mikkelsen bays. CPUE at Point Thomson actually exceeded seasonal catch rates of humpback whitefish at Prudhoe Bay (sites east of West Dock) in all 11 pre-breach years from 1985 to 1995 (Table 6). Compared to pooled pre-breach Prudhoe Bay catch, CPUE at Point Thomson was significantly higher ($P = 0.02$; Wilcoxin-Mann-Whitney-U test), despite Point Thomson being located some 85 km farther east of the Colville River point of origin than Prudhoe Bay. Further, in 1995, 168 days of fishing effort at Mikkelsen Bay (55 km east of Prudhoe Bay; 30 km west of Point Thomson) yielded only 10 fish, suggesting minimal dispersal east of the Sagavanirktok Delta in that year. Given the pre-1996 catch data, we had expected few humpback whitefish at Point Thomson. If the West Dock breach has allowed humpbacks to extend their dispersal farther east, it could account for the higher than expected catches at Point Thomson in 1999.

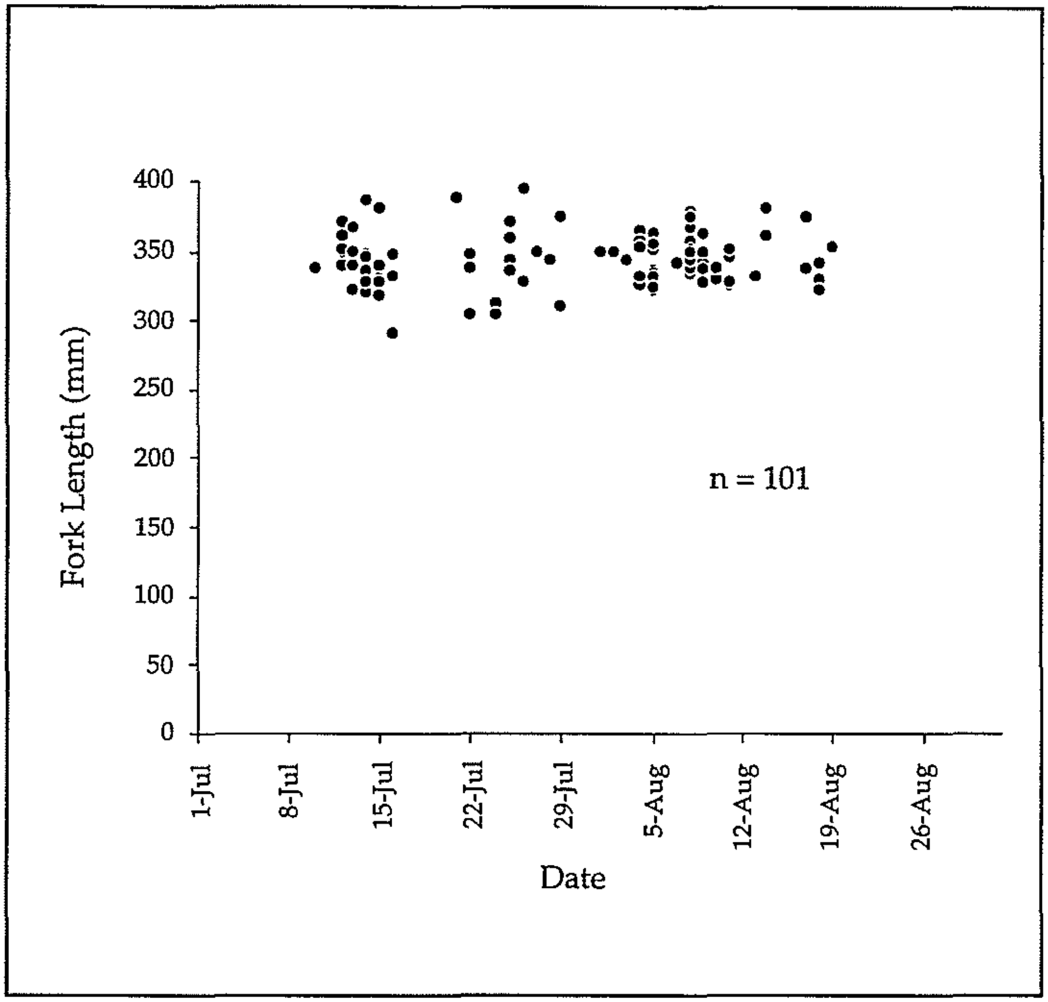

Figure 25. Fork lengths of all humpback whitefish collected by date at Point Thomson, 1999.

Table 6. Humpback whitefish catch and fishing effort data for studies conducted at Prudhoe Bay (i.e., Endicott studies), Mikkelsen Bay, and Point Thomson. Prudhoe Bay nets include only those sites located east of West Dock

West Dock	Study Location	Year	No. Nets	Effort Days (24 h)	No. Fish	CPUE
Pre-breach	Prudhoe Bay	1985	17	1,014	7	0.01
		1986	25	1,211	93	0.08
		1987	16	789	47	0.06
		1988	8	491	23	0.05
		1989	9	576	155	0.27
		1990	6	296	110	0.37
		1991	10	549	130	0.24
		1992	10	562	52	0.09
		1993	10	542	150	0.28
		1994	7	356	141	0.40
		1995	7	407	169	0.42
	Mikkelsen Bay	1995	4	168	10	0.06
Post-breach	Prudhoe Bay	1996	5	305	1252	4.10
		1997	1	41	253	6.19
	Pt. Thomson	1999	4 *	155	101	0.65

* Mainland nets only (i.e., excludes Station 605 located on the barrier island). No humpback whitefish were collected at Station 605.

Secondary Species

Of the 14 additional fish species collected during the Point Thomson survey, five comprised the majority (99%) of the catch: fourhorn sculpin (n = 13,146), ninespine stickleback (n = 6,876), saffron cod (n = 8,700), Arctic cod (n = 3,229), and Arctic flounder (n = 947). Sculpins, flounder, and both cod species are marine fish that share a common characteristic of moving onshore during summer into areas of warm, low salinity water (Morrow 1980). All four species are regularly taken in the shallow coastal water of the Beaufort during summer with fourhorn sculpin and Arctic flounder often among the most abundant species (Craig and Haldorson 1981; PBS 1982-1999; Griffiths 1983; West and Wiswar 1985; Wiswar and West 1987; Underwood et al. 1995).

The ninespine stickleback is a small (up to 90 mm FL), freshwater fish that inhabits coastal rivers of the North Slope. Ninespine stickleback can tolerate high salinities and are often found in brackish to high salinity coastal waters (Scott and Crossman 1973: Morrow 1980). The presence of stickleback in coastal waters is more likely a case of a distribution overlap into the marine environment along the periphery of its freshwater environment as opposed to a true diadromous migration.

Patterns of Catch

Figures 26-29 illustrate CPUE by side of net for the most abundant of the diadromous species/cohorts: Arctic cisco ≥age-3, adult least cisco, Dolly Varden <350 mm, and Dolly Varden ≥350 mm. At Station 605, CPUE of Arctic cisco and both size classes of Dolly Varden were significantly higher on the east side of the net (Table 7). This pattern was probably the result of net location. Station 605 was located on the lagoon side of a barrier island just east of Mary Sachs Entrance (see Fig. 1). Fish moving westward along the inside of the barrier islands would likely follow the shoreline and encounter the east side of the net. Fish approaching from the west would first have to traverse the open expanse of the inlet and there would be no shoreline to guide them to Station 605.

Seasonal CPUE at Station 604 was significantly higher in the west side of the net for all four groups. Given that the pattern was observed for all four species, it is possible that CPUE was affected by localized bathymetric or topological features of the main shoreline. Undetected shoals west of the net could have deflected schools seaward and interfered with catch in the eastern cod end. During periods of extreme low water, there was a notable

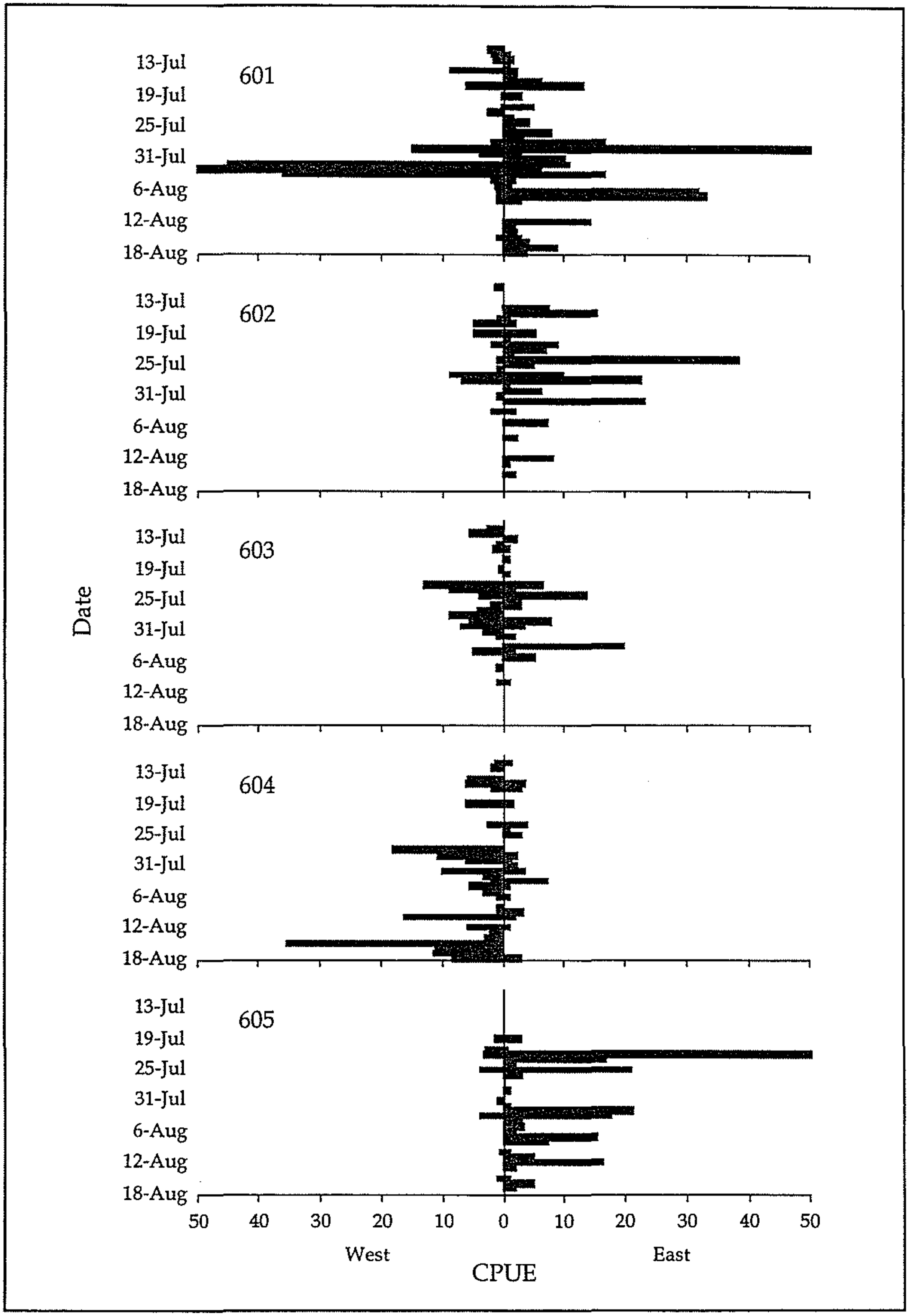

Figure 26. Catch-per-unit-effort (CPUE: fish/net/24 h) by side of net for Cohort 4 (≥age-3) Arctic cisco collected at Point Thomson through 18 August 1999 (the last sampling day prior to the end-of-season). storm).

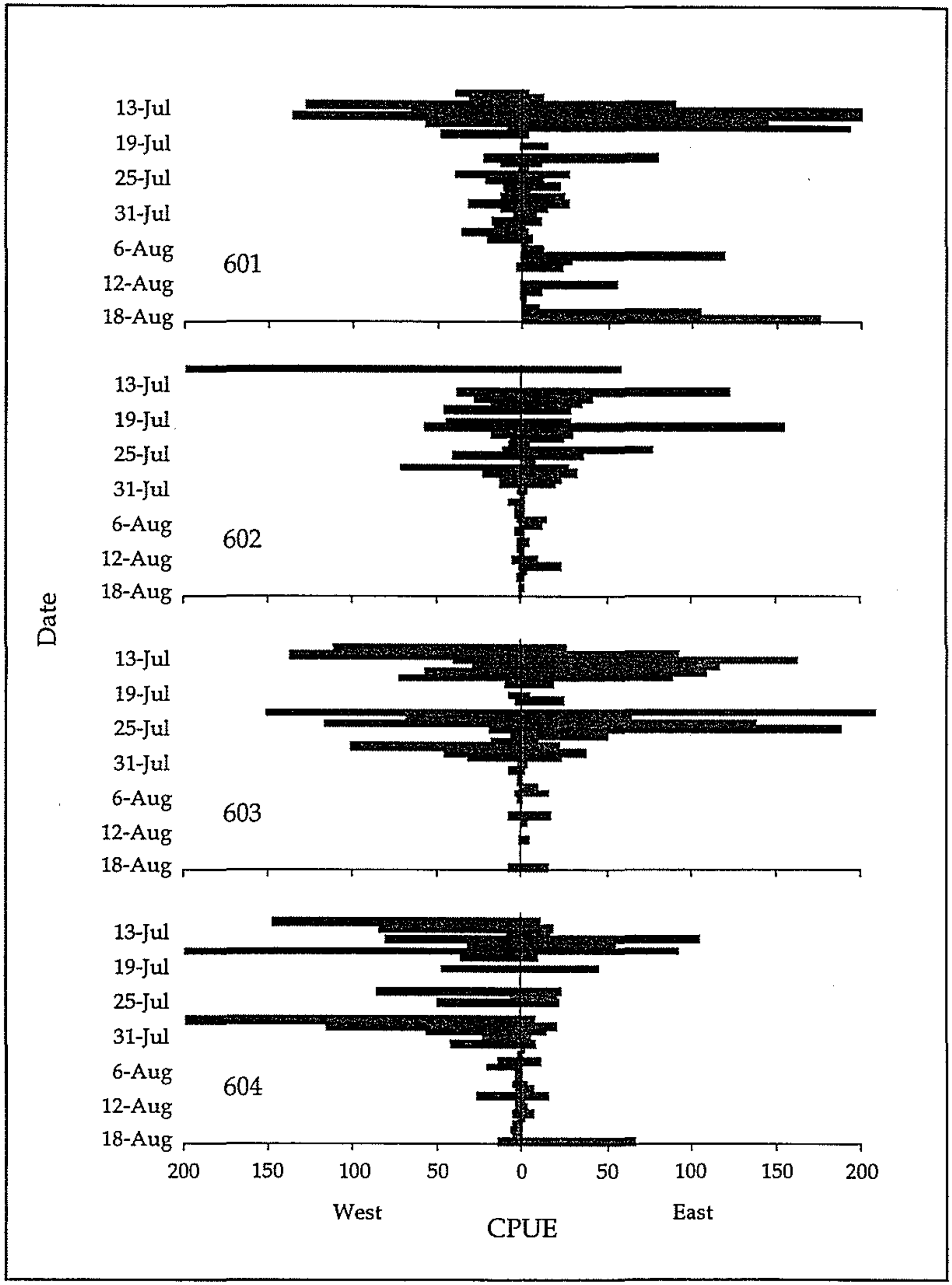

Figure 27. Catch-per-unit-effort (CPUE: fish/net/24 h) by side of net for large (≥200 mm) least cisco collected at Point Thomson through 18 August 1999 (the last sampling day prior to the end-of-season storm). Data are not presented for Station 605 because few least cisco were taken at that net.

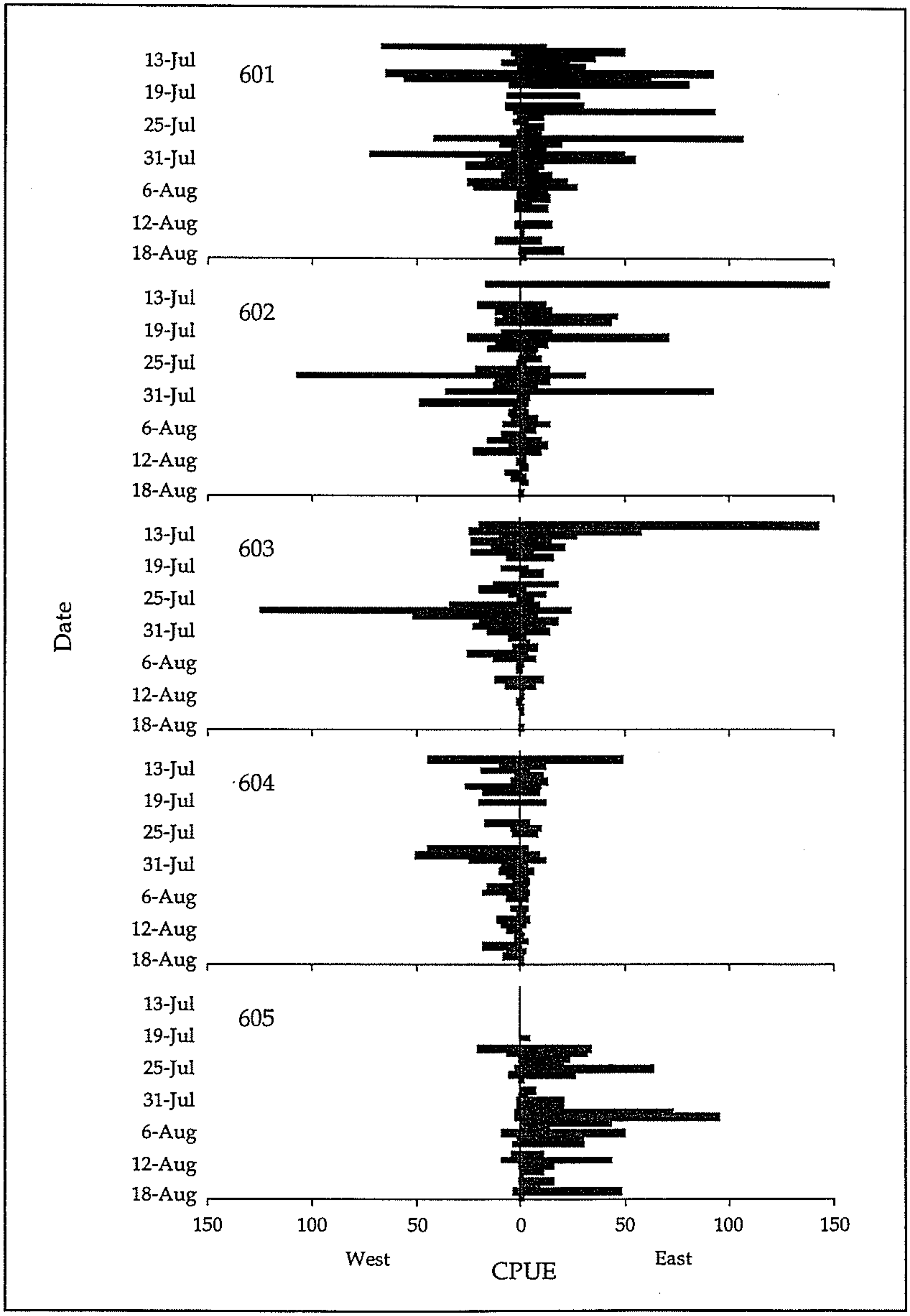

Figure 28. Catch-per-unit-effort (CPUE: fish/24 h) by side of net for small (<350 mm) Dolly Varden collected at Point Thomson through 18 August 1999 (the last sampling day prior to the end-of-season storm).

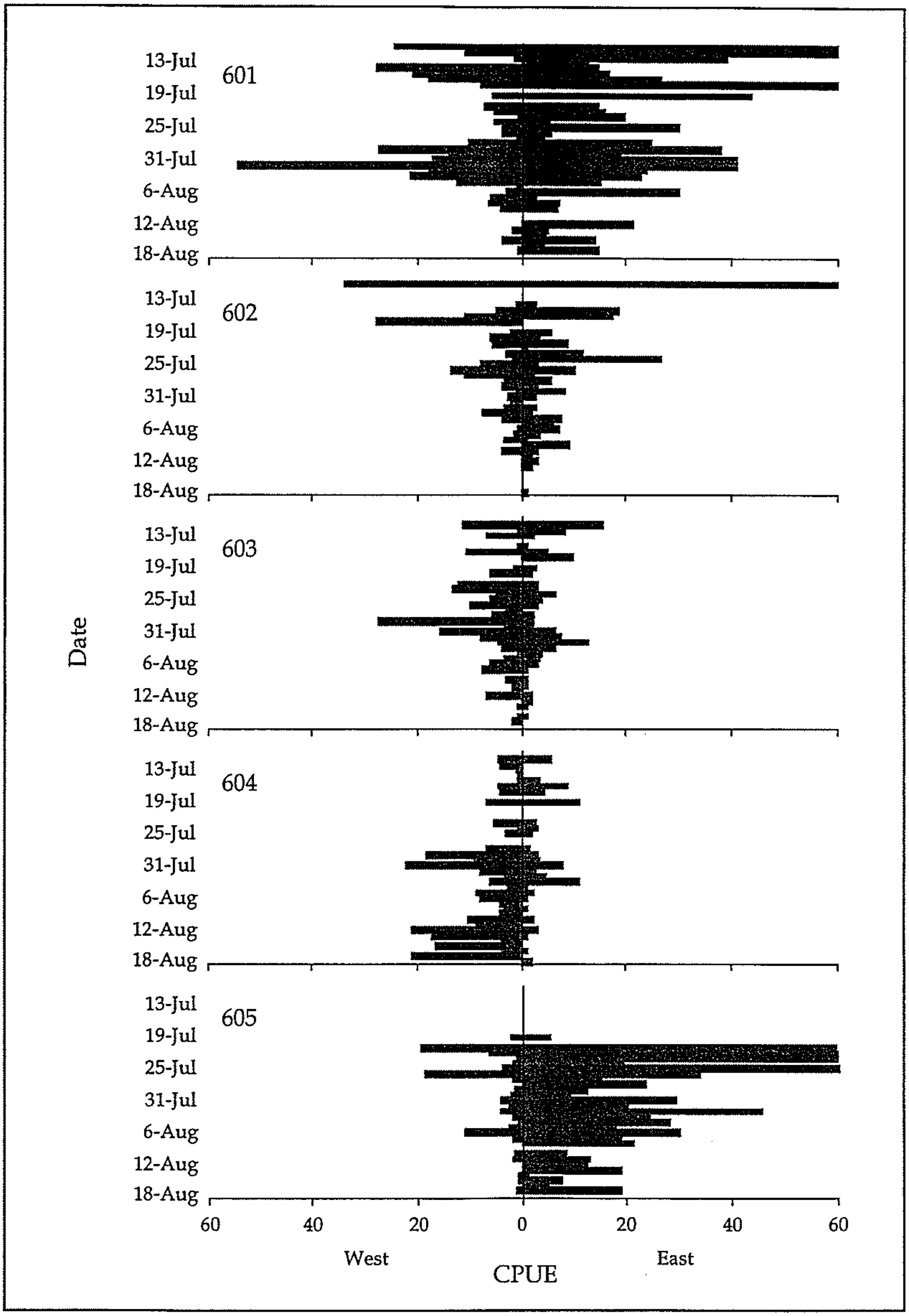

Figure 29. Catch-per-unit-effort (CPUE: fish/24 h) by side of net for large (≥350 mm) Dolly Varden collected at Point Thomson through 18 August 1999 (the last sampling day prior to the end-of-season storm).

Table 7. Summary statistics for Wilcoxin sign ranks test comparing side of net CPUE by net and species. The catch of least cisco at Station 605 was too low to support a statistical test.

	Arctic Cisco =Age-3		Least Cisco		Dolly Varden <350mm		Dolly Varden =350mm	
Station	Side of Net	Probability	Side of Net	Probability	Side of Net	Probability	Side of Net	Probability
601	E>W	0.02	-	0.11	E>W	3.63 E-4	E>W	7.62 E-4
602	E>W	1.32 E-4	-	0.28	-	0.53	-	0.09
603	-	0.45	-	0.25	-	0.38	-	0.04
604	W>E	7.58 E-4	W>E	3.80 E-3	W>E	1.12 E-3	W>E	7.64 E-4
605	E>W	5.71 E-5			E>W	8.33 E-6	E>W	2.58 E-6

extension of a mainland spit west of Station 604. Overall, none of the other nets provided corroborative evidence of directed eastward movement through Lions Bay.

With the exception of Arctic cisco at Station 602, there were no significant differences in catch by side of net for any of the groups at stations 602 or 603. Seasonal catch was significantly higher in the east side of Station 601 for Dolly Varden and Arctic cisco. All four groups were taken primarily in the east cod end after 5 August, but again this might be a localized phenomenon since none of the other nets provided supporting evidence of directed movement.

Hydrography

The following section provides a generalized discussion of water quality as it pertains to the fish monitoring study. For the detailed analysis of the Point Thomson hydrographic study the reader is directed to the hydrographic report prepared by URS (2000).

Figure 30 illustrates daily depth-averaged temperature and salinity measurements recorded at each fyke net. A major trend evident throughout the summer was that salinities tended to be higher at stations 601 and 602 relative to conditions at stations 603, 604, and 605, the average daily differential being 7.8 ppt. Temperatures averaged a degree lower at 601 and 602 than at the eastern nets. The more marine (i.e., colder, more saline) conditions in the eastern part of the sampling grid were likely a function of station location relative to the Mary Sachs Entrance and the Staines River. Winds during the 1999 summer were primarily from the east. Marine water entering through Mary Sachs Entrance would have a greater immediate influence on stations 601 and 602 (see Fig. 1). The Staines River is located at the eastern end of Lions Bay. Warm, freshwater discharge carried westward would have a greater influence on stations east of Mary Sachs Entrance, namely stations 603, 604, and 605.

Attempts at correlating water temperature and salinity against fyke net catch have been notoriously difficult except in the broadest of terms (PBS 1982-1999). Daily fyke net catches are extremely variable with a variety of factors affecting CPUE on any given day. Temperature and salinity likewise can fluctuate considerably from day to day and location to location. Even the once-a-day sampling schemes for collecting hydrographic and biological data can affect the perceived relationship between parameters. As a result, typical correlation analyses usually provide little insight into the effects of water quality on fish distribution and abundance and can even lead to erroneous conclusions.

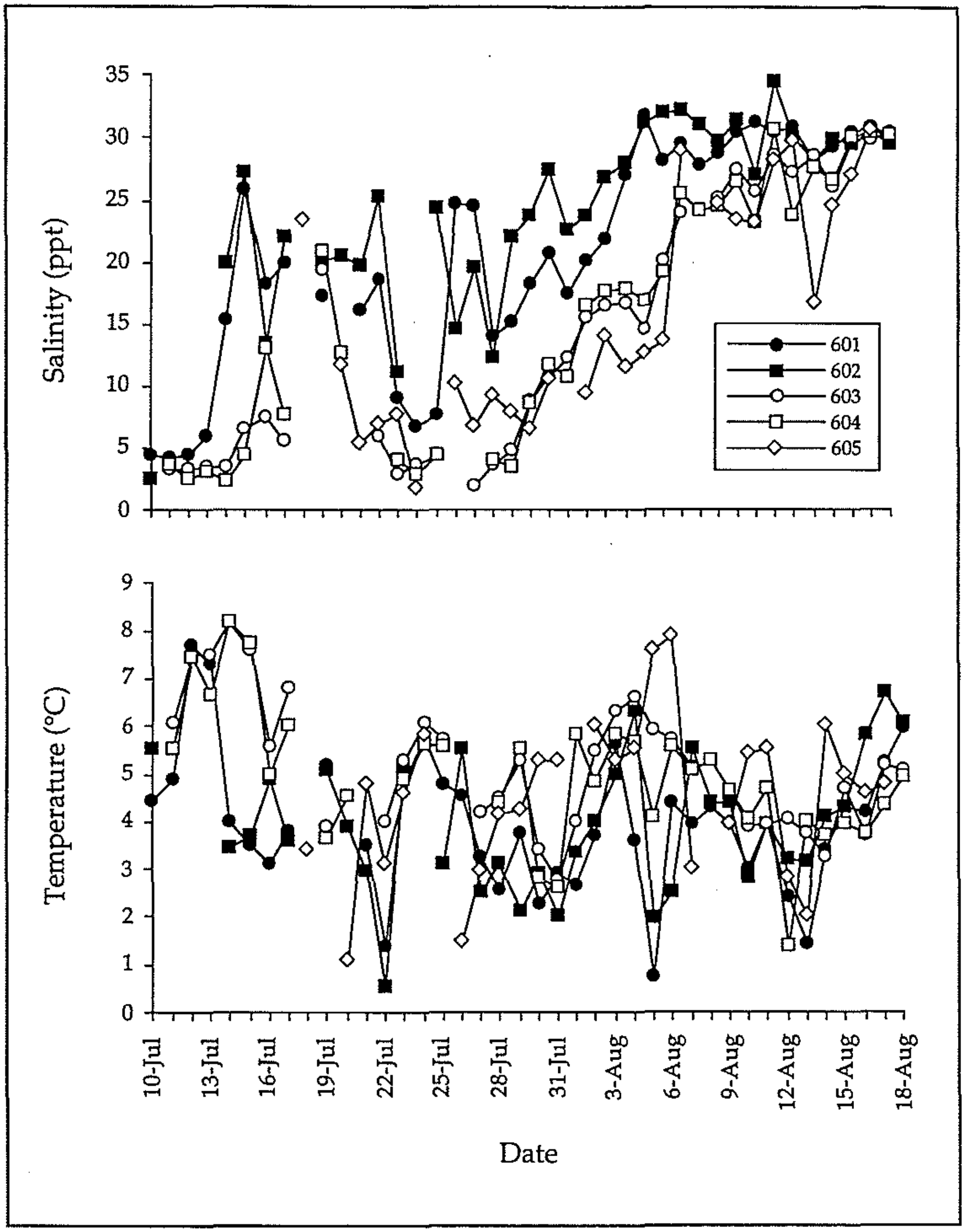

Figure 30. Depth averaged temperature and salinity measurments taken at the five primary fyke net sites at Point Thomson, 1999.

The spatial segregation of water quality at the eastern versus western fyke net sites throughout most of the summer provided a broader based possibility for analysis. The western end of the sampling grid was consistently more marine than the eastern end. We analyzed CPUE for the fish groups that were most abundant in the Point Thomson area throughout the summer: small (≤350 mm) and large (≥350 mm) Dolly Varden, adult least cisco, and adult (Cohort ≥3 age-2, Cohort 4) Arctic cisco. For the summer, CPUE at western stations 601 and 602 was higher than at eastern stations 603, 604, and 605 for all four groups: least cisco (58.2 versus 45.3 fish/net/24 h), small Dolly Varden (36.9 versus 26.6 fish/net/24 h), large Dolly Varden (25.1 versus 15.8 fish/net/24 h), adult Arctic cisco (12.2 versus 6.1 fish/net/24 h). These differences may merely reflect random variability given the pulsed migratory movements of these fish during summer, coupled with the topographic features of the Lions Bay relative to net location. Large Arctic cisco, Dolly Varden, and to a lesser extent adult least cisco, migrate extensively along the Beaufort Sea coast suggesting that they are well adapted to endure marine conditions.

In general, we could detect no patterns in the data that would indicate a relationship between fish abundance and hydrographic conditions in Lions Bay.

Wind Patterns

Analysis of recruitment patterns of young-of-the-year Arctic cisco have relied on meteorological data collected at Deadhorse Airport. Wind data collected at Point Thomson during the study showed a pattern quite similar to that recorded at Deadhorse (Fig. 31), suggesting that meteorological data collected at the airport provides a reasonable estimate of wind conditions along large segments of the Beaufort Sea coast.

Summers characterized by average wind speeds >5 km/h out of the east typically result in a good recruitment of young-of-the-year Arctic cisco to Prudhoe Bay and the overwintering grounds in the Sagavanirktok and Colville rivers (Fig. 32). Although no fishery study was conducted in Prudhoe Bay during the summer 1999, the average daily Deadhorse wind speed for the summer was 8.4 km/h from the east. Accordingly, we would predict that the 1999 year class was strongly recruited to the Prudhoe Bay area and that this year class will ultimately contribute to the subsistence fishery at Nuiqsut.

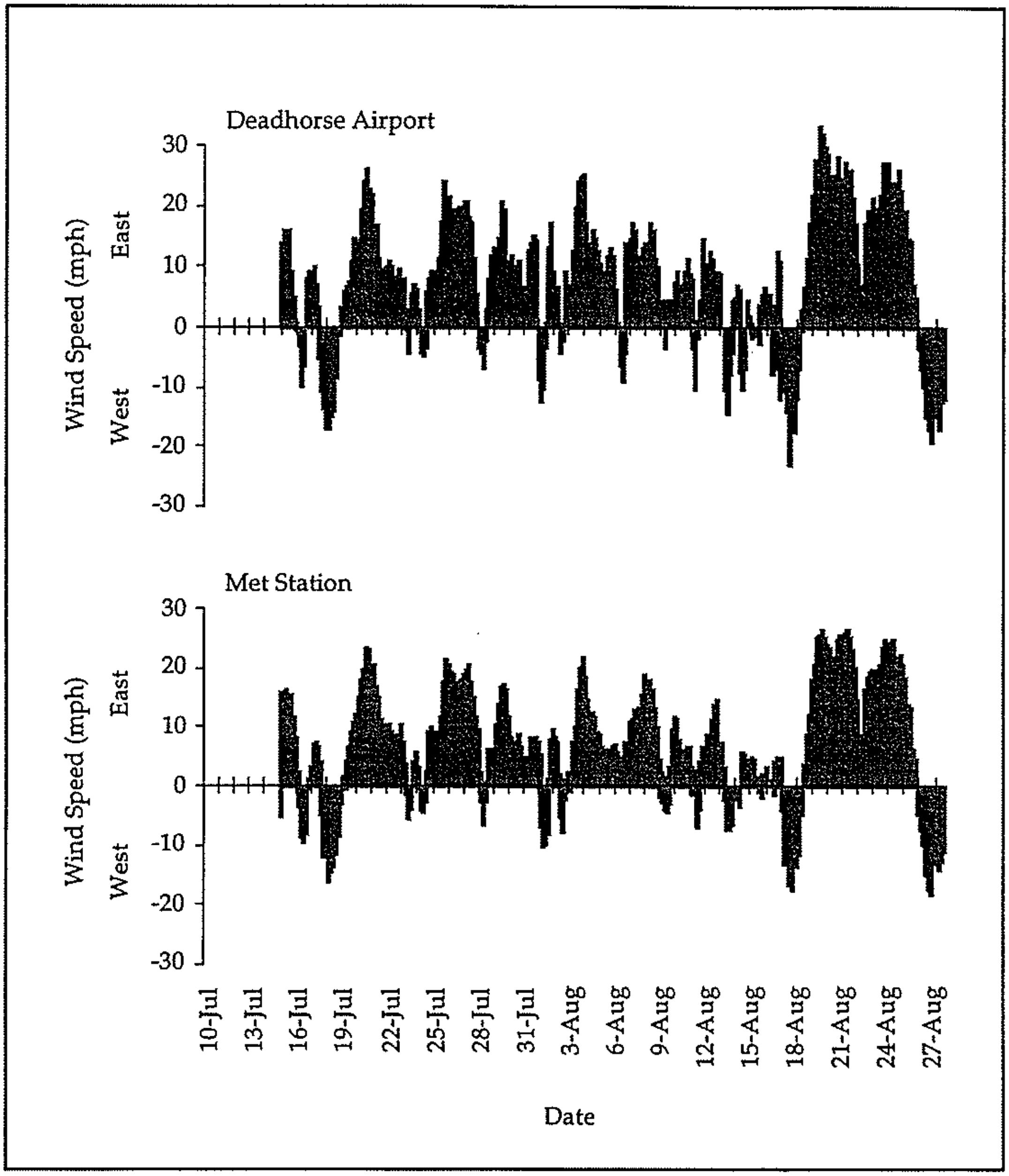

Figure 31. Average hourly east/west wind speeds recorded at Deadhorse Airport and the Point Thomson meteorological (Met) station during summer, 1999. Point Thomson data courtesy of URS.

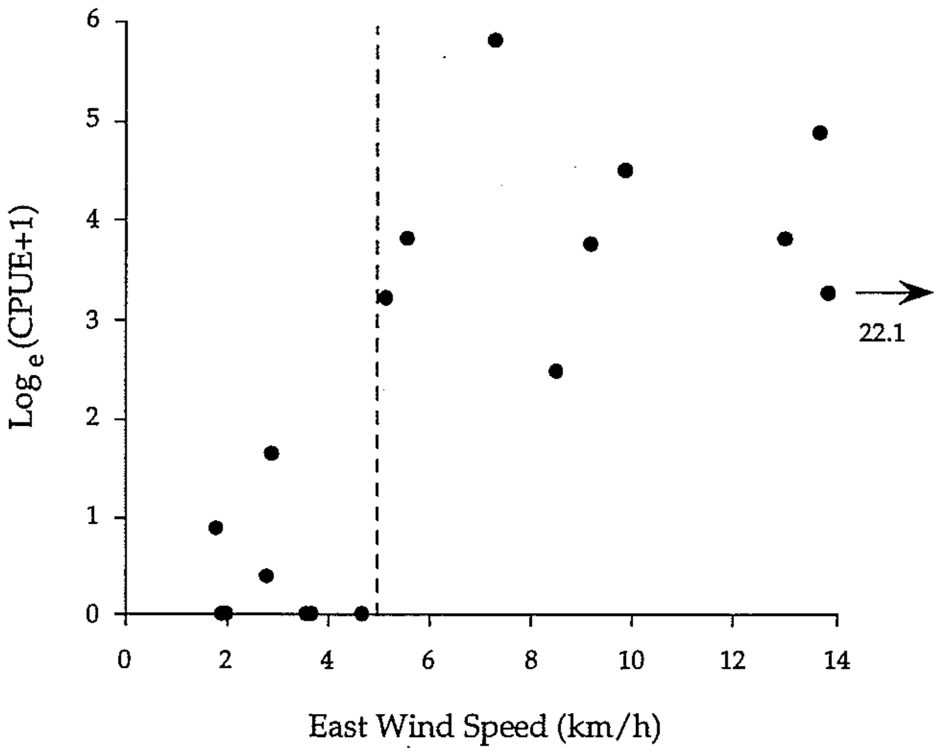

Figure 32. Natural log of CPUE of young-of-the-year Arctic cisco collected at at Prudhoe Bay for the years 1982-1998 versus average hourly wind speed for the months of July and August of each year. Wind data from Deadhorse Airport. Data illustrate that large recruitments of Arctic cisco in the Prudhoe Bay area typically require an average summer wind speed out of the east > 5 km/h (vertical dashed line). The average easterly wind speed for summer 1999 at Deadhorse Airport was 8.4 km/h.

SUMMARY

Some of the major findings of the 1999 Point Thomson fish studies are listed below.

- There was a strong recruitment of age-0 (young-of-the-year) Arctic cisco in early August. The recruitment was consistent with historical patterns for the Alaskan Beaufort Sea in that the 1999 summer was characterized by a sustained period of east winds. East winds enhance the westward dispersal of age-0 fish from Canada to Alaska.

- Few juvenile Arctic cisco (i.e., age-1 and age-2) were collected during the study. These results initially indicate that young-of-the-year transported into Alaska in 1997 and 1998 did not overwinter in substantial numbers in the nearby Canning and Staines rivers. However, analysis of historical data also indicate that other factors may have accounted for the low catch rates of these two year classes. The question of overwintering in the Point Thomson area remains unanswered. There was a notable increase in the catch of juvenile Arctic cisco (i.e., age-1 and age-2) following two east-wind events suggesting that limited overwintering of juvenile fish may take place somewhere to the east of Point Thomson.

- Adult Arctic cisco (≥age-3) were abundant in the area. This result was expected since adult Arctic cisco are typically collected in large numbers all along the Alaskan and Canadian Beaufort Sea coasts during summer.

- Virtually no juvenile (i.e., ≤age-3 or <280 mm) broad whitefish were collected during the study, a result that is consistent with this species' biology. The nearest population center is in the Sagavanirktok River and juvenile fish, which are intolerant of high salinities, remain close to the delta throughout the summer. Point Thomson is well outside their normal summer foraging range.

- Adult broad whitefish (>280 mm) were collected at rates comparable to those previously reported for the Prudhoe Bay and Mikkelsen Bay regions. Compared to historic studies conducted farther east along Alaska's North Slope and assuming that the catch of adult broad whitefish at Point Thomson in 1999 was typical for this region, the eastward dispersal of adult fish >280 mm from the Sagavanirktok River likely terminates somewhere between Point Thomson and Simpson Cove in Camden Bay.

- Virtually no juvenile (i.e., <200 mm) least cisco were collected during the study, a result that is consistent with this species' biology. Least cisco originate from the Colville River and juveniles reach West Dock in only one of every two years. Given the additional distance, it is unlikely that these smaller individuals regularly reach Point Thomson in substantial numbers. Point Thomson is outside their normal summer foraging range.

- Large numbers of adult least cisco >200 mm in length were collected during the study and their abundance throughout the summer in Lions Bay suggests that the Point Thomson region is well within their normal summer foraging range from the Colville River.

- Catch rates of Dolly Varden at Point Thomson in 1999 were high compared to previous fyke net studies conducted along the Beaufort Sea coast. Whether this high catch is merely an anomaly associated with the 1999 season or is actually indicative of a coastal area exploited by greater numbers of fish is unknown.

- The catch of adult humpback whitefish (291-395 mm FL) was higher than expected (n = 101) based upon previous studies conducted at Prudhoe and Mikkelsen bays. The higher than anticipated catch at Point Thomson may reflect an extended eastward dispersal resulting from the 1995-1996 construction of the West Dock breach.

- Four marine species—fourhorn sculpin, Arctic and saffron cod, and Arctic flounder—were common in Lions Bay. Ninespine stickleback, which is a salinity-tolerant freshwater species, was also abundant.

- We found no relationship between abundances of diadromous fishes and water quality within Lions Bay.

- Based upon summer wind patterns, we would predict that the 1999 year class of Arctic cisco was strongly recruited to the Prudhoe Bay area and that this year class will ultimately contribute to the subsistence fishery at Nuiqsut.

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