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VARIATION IN THE ABUNDANCE OF ARCTIC CISCO IN THE COLVILLE RIVER: ANALYSIS OF EXISTING DATA AND LOCAL KNOWLEDGE

VOLUME II: FINAL REPORT APPENDICES

November 2007

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Appendix A.

Arctic Cisco Bibliography

APPENDIX A: ARCTIC CISCO BIBLIOGRAPHY

Acronyms used in references in Appendix A:

AAI = ARCO Alaska, Inc.
BPXA = BP Exploration (Alaska) Inc.
CPAI = ConocoPhillips Alaska, Inc.
FWS = Fish and Wildlife Service
MMS = Minerals Management Service
NOAA = National Oceanic and Atmospheric Administration
OCS = Outer Continental Shelf
OCSEAP = Outer Continental Shelf Environmental Assessment Program
PAI = PHILLIPS Alaska, Inc.
USDOC = U.S. Department of Commerce
USDOI = U.S. Department of Interior

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Appendix B.

Data Manual for the Analysis of Variation in Abundance of Arctic Cisco in the Colville River

OCS Study MMS 2007-042

ANALYSIS OF VARIATION IN ABUNDANCE OF ARCTIC CISCO IN THE COLVILLE RIVER

DATA MANUAL

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INTRODUCTION

The purpose of this study is to evaluate existing data to increase scientific understanding of the variability in abundance of Arctic cisco (*Coregonus autumnalis*) in the Colville River. The information is needed to support environmental risk assessments, Environmental Impact Statements for potential oil and gas leasing, and for other post-leasing decisions documents in the Beaufort Sea Planning Area.

This database gathers existing appropriate biotic and abiotic multidisciplinary data relevant to Arctic cisco abundance in the Colville River. Data gathered included fisheries research conducted on the Colville Delta, in the Arctic National Wildlife Refuge (ANWR), in Prudhoe Bay, and in the Peel River Canada as well as oilfield related development activities, oceanographic, hydrographic, and weather data.

THEMES

We divided the various datasets within the database into seven themes based on different fisheries research projects (ANWR, Colville, Peel River, and Prudhoe Bay) or different types of data (Development, Environmental, and Weather).

ANWR- Fisheries data collected during research conducted by the U.S. Fish and Wildlife (USFWS) in the Arctic National Wildlife Refuge (ANWR) conducted during 1988–1991.

Colville–Fisheries data collected during ongoing research conducted by MJM Research on the Colville River Delta, Alaska. This includes Arctic Cisco catch by subsistence and commercial fisheries.

Development–A summary of human activities related to oil development between the Canadian Border and Cape Halkett that may affect Arctic Cisco.

Environmental–Environmental data from various sources, including oceanographic and hydrographic data.

Peel River–Fisheries data collected during research conducted on the Peel River, Canada 1998–2002.

Prudhoe Bay–Fisheries data collected during research conducted by LGL Research in Prudhoe Bay, Alaska.

Weather–Various weather related data sets. Including temperature and wind data from Deadhorse, Barrow, Nuiqsut, and the Mackenzie River.

NAMING CONVENTIONS

Table Names start with either TBL for data tables, DM for Domain tables or LU for Lookup Tables. The Lookup Tables contain information related to codes within the data tables, typically either location information or species information. The names then contain the theme name or an abbreviation of the theme name, such as Env for environmental themes. The next part of the table name is a brief description of the data.

DATA DESCRIPTIONS

THEME—ANWR

Table B-1. TBL_ANWR_CATCH

Data Abstract: This file contains USFWS catch, length, weight, and mark recapture data for Fyke Nets in various ANWR locations sampled in 1988–1991.

Data Fields: The following fields are included in the Table.

Field_Name	Data_Type	Units	Description	Relationships
Obj_ID	Autonumber		Autonumber	
Site_Code	Text		Station Code	A1
Date	Date/Time		Date	
SpeciesCode	Text		Species Code	A4
Effort	Number	hours	Effort in hours	
Type	Text		S=Standard fyke net, P=Experimental (portable) fyke net	
NetSide	Text		L=Left, R=Right	
Count	Number		Number of fish in sample	
Length	Number	mm	Length of fish	
Weight	Number	G	Weight of fish	
DyeMark	Text		RP=right pelvic, LP=left pelvic, CP=caudal peduncle, BLUELP= blue dye, left pelvic	DM1
DyeRecap	Text		RP=right pelvic, LP=left pelvic, CP=caudal peduncle, AD=adipose fin, C=fin clip, BLUELP=blue dye, left pelvic, BLACKRD=?, BLACKLD=?	DM2
TagNum	Text		Tag Number	
TagRecap	Text		Tag Recaptured	
Remarks	Text		Remarks	
FinMark	Text		RP=right pelvic, LP=left pelvic, AD=adipose fin	DM3
FinRecap	Text		RP=right pelvic, LP=left pelvic, AD=adipose fin, C=fin clip	DM4
Ripe	Text		X=Yes	
Sex	Text		I=Immature, X=?, F=Female, M=Male	

Data Theme: ANWR
Data Type: Fishery
Data Source: Tevis Underwood, Fishery Resource Office, U.S. Fish and Wildlife Service, 101 12th Avenue, Box 17, Room 222, Fairbanks AK 99701.
Data Time Period: 1988–1991
Relevant Reports: Fruge et al. 1989, Palmer and Dugan 1990, Underwood et al.1992, Underwood et al.1994, Underwood et al. 1995.
Data Location: Arctic National Wildlife Refuge, Alaska
Data Quality: The sampling used standard fyke net gear similar to that used in other studies in the region. The same gear was used throughout the study. Raw data were processed and entered in spreadsheets by U.S. Fish and Wildlife Service personnel. Some inconsistencies in species and sex codes were fixed. No unusual length or weight measurements were found. Length-frequency data was adequate to estimate the proportion of age-0 fishes for each sampling event i.e. by (station, year, and day of sampling).

Table B-2. TBL_ANWR_CPUE

Data Abstract: This file contains USFWS CPUE data for various ANWR location Fyke Nets 1988–1991.

Data Fields: The following fields are included in the Table.

Field_Name	Data_Type	Units	Description	Relationships
Obj_ID	Autonumber		Autonumber	
Site_Code	Text		Station Code	A2
Date	Date/Time		Date	
Species_Code	Text		Species Code	A5
Catch	Number		Number Caught	
Effort	Number	Hours	Effort	
F	Number	Days	Effort/24	
CPUE	Number	Fish/d	Catch Per Unit Effort Adjusted to 24 hours	

Data Theme: ANWR
Data Type: Fishery
Data Source: Tevis Underwood, Fishery Resource Office, U.S. Fish and Wildlife Service, 101 12th Avenue, Box 17, Room 222, Fairbanks AK 99701.
Data Time Period: 1988–1991
Relevant Reports: Fruge et al. 1989, Palmer and Dugan 1990, Underwood et al.1992, Underwood et al.1994, Underwood et al. 1995.
Data Location: Arctic National Wildlife Refuge, Alaska
Data Quality: Several erroneous entries for effort were corrected based on entries for Catch, F, and / or CPUE, which were assumed to be correct. No other unusual observations or extreme outliers were found. There were some missing values in the CPUE data (one or more days during the sampling season where catches were not reported), but the existing data were sufficient to estimate unbiased seasonal averages of CPUE.

Table B-3. LU_ANWR_SPECIES

Data Abstract: This file includes species names and associated species code from ANWR studies.

Data Fields: The following fields are included in the Table.

Field_Name	Data_Type	Units	Description	Relationships
Obj_ID	Autonumber		Autonumber	
Species_Code	Text		Species ID Code	A4, A5
Species_Name	Text		Species Common Name	

Data Theme: ANWR
Data Type: Fishery
Data Source: Tevis Underwood, Fishery Resource Office, U.S. Fish and Wildlife Service, 101 12th Avenue, Box 17, Room 222, Fairbanks AK 99701.
Data Time Period: 1988–1991
Relevant Reports: Fruge et al. 1989, Palmer and Dugan 1990, Underwood et al.1992, Underwood et al.1994, Underwood et al. 1995.
Data Location: Arctic National Wildlife Refuge, Alaska
Data Quality: NA

Table B-4. LU_ANWR_LOCS

Data Abstract: Location and effort by year of sampling location sites during the ANWR Arctic Cisco studies.

Data Fields: The following fields are included in the Table.

Field_Name	Data_Type	Units	Description	Relationships
Obj_ID	Autonumber		Autonumber	
Site_Code	Text		Station Code	A1,A2,A3
Site_Name	Text		Area Name	
Latitude	Number	dd	Latitude (no datum specified)	
Longitude	Number	dd	Longitude (no datum specified)	
Theme	Text		Theme Name (always ANWR)	
Data Type	Text		Data Type	
EffortDays1988	Number	days	Number of days of effort in 1988	
EffortDays1989	Number	days	Number of days of effort in 1989	
EffortDays1990	Number	days	Number of days of effort in 1990	
EffortDays1991	Number	days	Number of days of effort in 1991	

Data Theme: ANWR
Data Type: Location
Data Source: Tevis Underwood, Fishery Resource Office, U.S. Fish and Wildlife Service, 101 12th Avenue, Box 17, Room 222, Fairbanks AK 99701.
Data Time Period: 1988–1991
Relevant Reports: Fruge et al. 1989, Palmer and Dugan 1990, Underwood et al.1992, Underwood et al.1994, Underwood et al. 1995.
Data Location: Arctic National Wildlife Refuge, Alaska
Data Quality: The sampling design was not consistent between years, but five standard stations were sampled each year, while three additional stations were sampled in 3 out of 4 years (1989-1991). These were used as index stations for estimating average annual catch-per-unit-effort of age-0 Arctic cisco.

THEME—COLVILLE

Table B-5. TBL_COLVILLE_AGE

Data Abstract: This file contains the age frequency of Arctic Cisco caught in 76 mm mesh nets in the Colville fishery from 1976–1978 and 1984–2002. Taken from commercial fishery samples, but is interpreted to represent the entire fishery.

Data Fields: The following fields are included in the Table.

Field_Name	Data_Type	Units	Description	Relationships
Obj_ID	Autonumber		Autonumber	
Year	Number		Year data collected	
Age3	Number	Percent	Percent of sample in age 3 category	
Age4	Number	Percent	Percent of sample in age 4 category	
Age5	Number	Percent	Percent of sample in age 5 category	
Age6	Number	Percent	Percent of sample in age 6 category	
Age7	Number	Percent	Percent of sample in age 7 category	
Age8	Number	Percent	Percent of sample in age 8 category	
Age9	Number	Percent	Percent of sample in age 9 category	
Age10	Number	Percent	Percent of sample in age 10 category	
Age11	Number	Percent	Percent of sample in age 11 category	
Count	Number		Sample size for each year	
Comment	Text		Comments	

Data Theme: Colville
Data Type: Fishery
Data Source: Larry Moulton MJM Research, 1012 Shoreland Drive, Lopez Island, WA 98261
Data Time Period: 1976–1978 and 1984–2002
Relevant Reports: Moulton
Data Location: Colville River Delta
Data Quality: Age frequencies in the entire fishery were estimated from relatively small samples (ranging from 31-215 individuals) of Arctic cisco sampled in the commercial fishery. It is assumed that the age composition is the same throughout the Colville River Delta, which is a reasonable assumption. Age-composition in 1984, 1985, 1989, and 2003 was estimated by comparing the length-frequencies of fish caught by gillnet in the fall Colville fishery to those of aged fish that were caught with fyke nets in Prudhoe Bay during summer. This assumes that size-at-age is the same or similar for these groups of fish, which is not unreasonable because they both represent the same population. However, changes in size between the summer and fall are not accounted for, with unknown effects. Generally, the estimates of age composition are likely to have considerable error, but uncertainty in the percentages cannot easily be quantified.

Table B-6. TBL_COLVILLE_ANNUAL_CPUE_CV

Data Abstract: This file contains the annual catch and effort totals for Arctic cisco caught in the Colville Delta commercial (Helmericks) fishery from 1967 to 2002 (effort in net-days of 46 m net)

Data Fields: The following fields are included in the Table.

Field_Name	Data_Type	Units	Description	Relationships
Obj_ID	Autonumber		Autonumber	
Year	Number		Year	
Effort	Number	net-days	effort in net-days of 46 m net	
Number	Number		Number of Arctic cisco per year	
CPUE	Number	Fish/net-day	Number of Arctic cisco caught per net-day	
Site_Code	Text		Location Code, link to Location table	C4

Data Theme: Colville
Data Type: Fishery
Data Source: Larry Moulton MJM Research, 1012 Shoreland Drive, Lopez Island, WA 98261
Data Time Period: 1967–2002
Relevant Reports: Moulton and Seavey (2004)
Data Location: Colville Village, Colville River Delta, AK (70.42793, -150.38038)
Data Quality: Data was self-reported by the operator of the fishery, thus data quality is difficult to evaluate. However, interannual patterns in CPUE agree very well with those estimated from the subsistence fishery, suggesting that the data are of similar quality. These data provide the only consistent annual index of abundance in years prior to 1985. Interannual variability in CPUE is assumed to primarily reflect real changes in abundance. The strong correlations between CPUE in the commercial and subsistence fishery suggest that CPUE in the commercial fishery is reflective of changes across the entire Colville Delta.

An important caveat to the use of raw CPUE data is the apparent depletion that occurs in the fishery. This means that in years with high effort the overall average CPUE tends to be lower, which is presumably due to the removal of fish from the population. Therefore, to obtain a CPUE-based index that reflects abundance at the beginning of the fishing season, an effort-adjusted CPUE was used as described in Moulton and Seavey (2005). However, the evidence for depletion is not clear and we used both an effort-adjusted and the unadjusted CPUE in analyses.

Sampling uncertainty in average annual CPUE is likely to be high because of very high variability in dayily CPUE values (see TBL_Colville_Daily_CPUE_CV)

Table B-7. TBL_COLVILLE_CPUE

Data Abstract: This file contains catch and effort data for each subsistence net check in the Nuiqsut subsistence fishery.

Data Fields: The following fields are included in the Table.

Field_Name	Data_Type	Units	Description	Relationships
Obj_ID	Autonumber		Autonumber	
SetNo	Text		Set number – a number assigned to each net check, used to relate information from different files.	C5
Year	Number		year of measurement	
Site_Code	Text		Location Code	C3
Code	Number		Numeric code of fisherman ID, consistent across years	
Net	Text		alphabetic code to identify each net used by a fisherman during a season	
NetID	Text		combination of year, fisherman code and net code used to identify a unique location where fishing occurred	
Enddate	Date/Time		Date the net was checked	
Netlen	Number	m	length of net in meters	
Mesh	Number	mm	gill net mesh size in millimeters	
Dur	Number	hours	duration of set in hours	
Species	Text		species of fish caught (all Arctic cisco in this file)	
Catch	Number		number of fish caught	
Effort	Number	net-days	effort in net-days per 18 meters of net	
CPUE	Number	net-days	fish per net-day per 18 meters of net	

Data Theme: Colville
Data Type: Fishery
Data Source: Larry Moulton MJM Research, 1012 Shoreland Drive, Lopez Island, WA 98261
Data Time Period: 1986–2004
Relevant Reports: Moulton and Seavey (2005) and references therein.
Data Location: Nuiqsut, AK
Data Quality: Data quality is considered high because all data have been collected using a rigorous sampling design and because a large proportion of the fishery is covered. However, there are several sources of uncertainty that may have a large effect on catch rates and should be considered when using the data. These relate to (1) uncertainties in fishing effort, (2) possible effects of depletion, (3) effects of salinity on CPUE, and (4) changes in fishing locations over time:

(1) There is likely to be considerable uncertainty in CPUE values related to uncertainty in fishing effort as discussed under ‘TBL_Colville_Effort’.

(2) As in the commercial fishery, the raw CPUE values have to be interpreted with caution because of the possible effect of depletion on CPUE, which is evident in negative correlations between CPUE and effort, both on a daily basis and on an inter-annual basis. For this reason we used both effort-adjusted CPUE values (Moulton and Seavey 2005) as well as unadjusted CPUE values in the analysis.

(3) Previous work and our analyses suggest that the availability of Arctic cisco to the fishery is also affected by local salinities, therefore changes in CPUE reflect not only changes in abundance but also changes in local salinity. We therefore obtained an index of CPUE that adjusts for the effects of salinity.

(4) Fishing locations have shifted considerably over time, thus inter-annual changes in catch rates may be in part be due to changes in fishing location if CPUE differs among location. The effect of location was evaluated by comparing catch rates among locations within a year and the effect of location is confounded with effects of local salinities. Therefore, salinity-adjusted CPUE values (see above) may account for differences among locations.

A final caveat relates to differences in mesh size, which strongly affects the size of fishes that are caught and their catch rates. The most commonly used mesh size was 3 inches (76mm) and catch rates based on 76 mm mesh nets provide the most reliable indicator of abundance. Comparisons among daily CPUE estimates between different mesh sizes showed that they were moderately to highly correlated (correlations ranging from 0.52 to 0.65).

Table B-8. TBL_COLVILLE_DAILY_CPUE_CV

Data Abstract: This file contains daily catch, number of 76mm nets, and effort, of Arctic cisco (ARCS) and Least cisco (LSCS) caught by in the commercial (Helmericks) fishery 1967-2002

Data Fields: The following fields are included in the Table.

Field_Name	Data_Type	Units	Description	Relationships
Obj_ID	Autonumber		Autonumber	
Date	Date/Time		Date nets were checked	
Num_Nets	Number		number of 3" (76mm) mesh nets fished	
Tot_ARCS	Number		Total catch of arctic cisco for 3" mesh for that day	
Tot_LSCS	Number		Total catch of least cisco for 3" mesh for that day	
EffortDays	Number	days	Number of days net fished	
CPUE_ARCS	Number	Fish/net-day	CPUE of Arctic cisco per net day	
Site_Code	Text		Location Code	C6

Data Theme: Colville
Data Type: Fishery
Data Source: Larry Moulton MJM Research, 1012 Shoreland Drive, Lopez Island, WA 98261
Data Time Period: 1967–2002
Relevant Reports: Moulton
Data Location: Colville Village, Colville River Delta, AK (70.42793, -150.38038)
Data Quality: See TBL_COLVILLE_ANNUAL_CPUE_CV for general assessment. Daily catch rates (CPUE) are highly variable and show no obvious or consistent trends within a season. Uncertainty in daily CPUE cannot be quantified and it is unclear whether the large variability is due to true fluctuations in abundance from day-to-day or to sampling uncertainty. The within-season variability in CPUE is large relative to interannual differences in CPUE, implying that uncertainty in annual average CPUE may be high.

Table B-9. TBL_COLVILLE_EFFORT

Data Abstract: This file contains effort and location data for each Nuiqsut fisher identified as participating in the fall fishery from 1986 to 2004.

Data Fields: The following fields are included in the Table.

Field_Name	Data_Type	Units	Description	Relationships
Obj_ID	Autonumber		Autonumber	
Code	Number		Numeric code of fisherman ID, consistent across years	
NetID	Text		combination of year, fisher code and net code used to identify a unique location where fishing occurred	
Site_Code	Text		Location Code	C2
Net	Text		alphabetic code to identify each net used by a fisher during a season	
RKm	Number	km	river kilometer on the Niġliq Channel where the net was set (nets not on the Niġliq Channel are left blank)	
NetLen	Number	m	length of net in meters	
Mesh	Number	mm	gill net mesh size in millimeters	
SetDate	Date/Time		Date net was set	
EndDate	Date/Time		Date the net was pulled	

Data Theme: Colville
Data Type: Fishery
Data Source: Larry Moulton MJM Research, 1012 Shoreland Drive, Lopez Island, WA 98261
Data Time Period: 1986–2004
Relevant Reports: Moulton
Data Location: Nuiqsut, AK
Data Quality: All effort data are based on interviews with fisher and, at least in recent years, cover approximately 85-90% of the total fishing effort (Larry Moulton, pers. comm.). Effort is converted to net-days per 18 m net. However, nets used in the fishery are of variable length (mostly 18 and 24 m) and the duration that the net is fishing (soak time) differs from less than 20 hours to over 100 hours. Standardization to net days per 18 m assumes that (1) catch is proportional to net length and (2) catch is proportional to soak time.
Both assumptions were tested with the available data and neither assumption appeared to be met.
(1) CPUE did not increase in proportion with net length but at a slower rate. For example, the average difference between catches in an 18-m net and a 24-m net (all else being equal) was only 10%.
(2) CPUE did not appear to increase at all after a soak time of about 20 hours. The average CPUE of nets that had been soaked for 2 or 3 days did not increase over those that soaked for one day only.
Therefore CPUE values for nets longer than 18m and durations over 24 hours will underestimate abundances. There is considerable variation in average soak duration among years, which could affect estimates of annual average CPUE. However, relatively low catches for sets with long soak times may be a consequence of fishermen increasing their soak time during periods when catches are low. This issue has not been fully explored and it may not be possible to resolve it with existing data.

Table B-10. TBL_COLVILLE_LENGTH

Data Abstract: This file contains lengths of Arctic cisco caught in the Nuiqsut fishery.

Data Fields: The following fields are included in the Table.

Field_Name	Data_Type	Units	Description	Relationships
Obj_ID	Autonumber		Autonumber	
SetNo	Text		Set number – a number assigned to each net check, used to relate information from different files.	C5
Species	Text		species of fish measured (all Arctic cisco in this file)	
Length	Number	mm	fork length in millimeters	
NetID	Text		Net_ID	

Data Theme: Colville
Data Type: Fishery
Data Source: Larry Moulton MJM Research, 1012 Shoreland Drive, Lopez Island, WA 98261
Data Time Period: 1986–2004
Relevant Reports: Moulton and Seavey (2005) and references therein
Data Location: Nuiqsut, AK
Data Quality: The quality of length measurements is likely to be high and should accurately reflect the size composition of Arctic cisco in the fishery catches. Samples are representative of the catches as a whole because subsamples were obtained daily throughout the main fishing season. It is assumed that size composition does not show any strong trends within a season. An examination of the trends suggests a slight decrease in average size from mid-October through the end of November that may affect estimates of age composition in years where it was estimated from length-frequencies.

Table B-11. LU_COLVILLE_LOCS

Data Abstract: This file shows locations for the main fishing areas used by the subsistence fishery with approximate coordinates for the center of the areas.

Data Fields: The following fields are included in the Table.

Field_Name	Data_Type	Units	Description	Relationships
Obj_ID	Autonumber		Autonumber	
Site_Code	Text		ABR code unique location identifier	C1, C2, C3, C4, C6
Site_Name	Text		Name from original file	
Latdd83	Number		Latitude NAD 1983 of center of area	
Londd83	Number		Longitude NAD 1983 of center of area	
Theme	Text		Theme Name (always Colville)	
Data_Type	Text		Type of Data recorded at location	
Loc_Comments	Text		Comments	
Loc_OrigCode	Text		Location code of original data	

Data Theme: Colville
Data Type: Location
Data Source: Larry Moulton MJM Research, 1012 Shoreland Drive, Lopez Island, WA 98261
Data Time Period: NA
Relevant Reports: Moulton and Seavey (2005) and references therein
Data Location: Nuiqsut, AK
Data Quality: Locations of centers of fishing operation are approximate and are used for display purposes only.

Table B-12. TBL_COLVILLE_RKM

Data Abstract: This file contains the location of river kilometer markers (RKM) along the Niġliq Channel of the Colville River Delta, Alaska.

Data Fields: The following fields are included in the Table.

Field_Name	Data_Type	Units	Description	Relationships
Obj_ID	Autonumber		Autonumber	
RKM_Code	Number		Kilometer markers along the Niġliq channel of the Colville River Delta	
LAT_NAD83	Number		Latitude NAD 1983	
LON_NAD83	Number		Longitude NAD 1983	
RKM_Comments	Text		Comments	

Data Theme: Colville
Data Type: Location
Data Source: Larry Moulton MJM Research, 1012 Shoreland Drive, Lopez Island, WA 98261
Data Time Period: NA
Relevant Reports: Moulton and Seavey (2005) and references therein
Data Location: Nuiqsut, AK
Data Quality: NA

Table B-13. TBL_COLVILLE_SALINITY

Data Abstract: This file contains salinity measurements on the Niġliq Channel taken in conjunction with fishing activity on the channel. Typically, 3 sites are monitored (610: Upper Niġliq; 650: Nanuk Lake outlet; 670: Niġliq Delta at Woods Camp). In several years in the early 1990s, site 630 (Uyagagvik) was also monitored but was dropped because the values were quite similar to the Upper Niġliq and provided little additional information.

Data Fields: The following fields are included in the Table.

Field_Name	Data_Type	Units	Description	Relationships
Obj_ID	Autonumber		Autonumber	
Year	Number		Year of Data	
Comment	Text		Comments	
Site_Code	Text		Area Code, links to Location Table	C1
Rkm	Number		River Kilometer, as measured from the mouth of Niġliq Channel	
SiteID	Text		Site ID, not listed most years	
Date	Date/Time		Date of data collection	
Depth	Number	m	Depth in meters from the upper surface of ice	
Salinity	Number	ppt	Salinity	

Data Theme: Colville
Data Type: Environmental
Data Source: Larry Moulton MJM Research, 1012 Shoreland Drive, Lopez Island, WA 98261
Data Time Period: 1986–2004
Relevant Reports: Moulton and Seavey (2005) and references therein
Data Location: Nuiqsut, AK
Data Quality: Data quality is high as salinities were measured at standard sampling locations throughout the water column and repeatedly throughout the season. Measurements provide a detailed picture of seasonal and interannual trends in salinity. The high temporal resolution and the close proximity of salinity stations to fishing areas allowed us to relate catch rates to local salinity conditions.

THEME—DEVELOPMENT

Table B-14. TBL_DEV_BEAUFORT

Data Abstract: This file contains a summary of oil development related human activities between the Canadian Border and Cape Halkett that may affect Arctic Cisco. Data were compiled from multiple different sources.

Data Fields: The following fields are included in the Table.

Field_Name	Data_Type	Units	Description	Relationships
Obj_ID	Autonumber		Autonumber	
Year	Number		Year	
Coastal section	Text		Location along coast, 3 broad areas	
Season	Text		Season	
Sea surface state	Text		(Open=Open Water, Frozen=Ice)	
Activity start date	Text		Start Date	
Activity end Date	Text		End Date	
Broad location	Text		General location description	
Location	Text		Location	
Well name / fine scale location	Text		Location Name	
Structure	Text		Structure	
Activity	Text		Activity	
Activity sub-category	Text		activity sub-category	
Duration	Number	Hours	Duration of activity	
Seismic/acoustic lines	Number	Km	Length of seismic or acoustic lines	
5 km blocks seismic	Number		Number of 5 km blocks	
OCS blocks seismic	Number		Number of OCS blocks	
Disturbance potential ranking	Text		ABR ranking of potential disturbance	

Data Theme: Development
Data Type: Development
Data Source: Alaska Department of Natural Resources and U.S. Minerals Management Service
http://www.dog.dnr.state.ak.us/oil/products/data/npra/wellnpra.xls
http://www.dog.dnr.state.ak.us/oil/products/data/Excel_files/www_well_lat_lon.xls
http://www.dog.dnr.state.ak.us/oil/products/data/Excel_files/www_well_adl_status.xls
http://www.dog.dnr.state.ak.us/oil/products/data/Excel_files/www_well_date_permit.xls
http://www.dog.dnr.state.ak.us/oil/products/data/fields/fields.xls
http://www.dog.dnr.state.ak.us/oil/products/data/wells/display_well_data_1990_to_Present.htm
http://www.mms.gov/alaska/fo/wellhistory/BS_WELLS.htm
Data Time Period: 1970–2006
Relevant Reports: NA
Data Location: Beaufort Sea
Data Quality: These data should be used with caution. They are not comprehensive although they are likely to include at least all of the major documented activities. Activities were classified into broad qualitative categories such as drilling operations, construction activities, or seismic activities that were rarely adequately quantified. There is no objective measure of disturbance that can be assigned to individual activities or to the combined activities that occur within a given season and region.

THEME—ENVIRONMENTAL

Table B-15. TBL_ENV_ARCTIC_OSCILLATION

Data Abstract: This file contains the Arctic Oscillation Index from NCEP reanalysis data. Monthly composite AO values were calculated where the daily AO index is constructed by projecting the daily (00Z) 1000mb height anomalies poleward of 20°N onto the loading pattern of the AO. The loading pattern of the AO is defined as the leading mode of Empirical Orthogonal Function (EOF) analysis of monthly mean 1000mb height during 1979–2000 period. 1950–present.

Data Fields: The following fields are included in the Table.

Field_Name	Data_Type	Units	Description	Relationships
Obj_ID	Autonumber		Autonumber	
Year	Number		Year	
Month	Number		Month	
AO	Number	Unitless	Arctic Oscillation	

Data_Theme: Environmental
Data Type: Environmental
Data Source: NOAA National Weather Service Climate Prediction Center
http://www.cpc.ncep.noaa.gov/products/precip/CWlink/daily_ao_index/ao_index.html
Data Time Period: 1950–2004
Relevant Reports: NA
Data Location: >20° N
Data Quality: See data source for quality assessment. The AO reflects the major mode of climate variability in the Arctic but it should be kept in mind that it is a large-scale statistical summary of air pressure anomalies that may or may not have an interpretable relationship with regional conditions in the coastal Beaufort Sea.

Table B-16. TBL_ENV_BERING_TRANSPORT

Data Abstract: This file contains values of water transport (Sv) through the Bering Strait from wind forcing.

Data Fields: The following fields are included in the Table.

Field_Name	Data_Type	Units	Description	Relationships
Obj_ID	Autonumber		Autonumber	
Year	Number		Year	
Transport	Number	Sv	Estimated water transport through Bering Strait in Sverdrups (106 m^3 s-1)	

Data_Theme: Environmental
Data Type: Oceanography
Data Source: Unaami Data Collection, http://www.unaami.noaa.gov/dataselect/
Data Time Period: 1946–1998
Relevant Reports: Roach et al, 1995
Data Location: Bering Strait
Data Quality: Described in Roach et al. 1995, Direct Measurements of Transport and Water properties through the Bering Strait, JGR v.100, no.C9, pp. 18443–18458. Recent modeling work (Wieslaw Maslowski, Naval Postgraduate School, Monterey, CA, pers. comm.) suggests that transport estimates based on moorings may be biased, but may nevertheless provide a good index of interannual variability.

Table B-17. TBL_ENV_COLVILLE_RIVER_BREAKUP

Data Abstract: This file contains a summary of breakup data obtained at the head of the Colville River Delta, 1962–2004.

Data Fields: The following fields are included in the Table.

Field_Name	Data_Type	Units	Description	Relationships
Obj_ID	Autonumber		Autonumber	
Year	Number		Year	
Date_FirstFlow	Date/Time		Approximate Date of First Flowing Water	
Peak_Elevation	Number	ft	Peak Water Surface Elevation (ft)	
Date_Peak_Elev	Date/Time		Date of Peak Water Surface Elevation	
Est_Peak_Discharge	Number	cfs	Estimated Peak Breakup Discharge (cfs)	
Notes1	Memo		Notes on data 1	
Notes2	Memo		Notes on data 2	
Notes3	Memo		Notes on data 3	
Notes4	Memo		Notes on data 4	
Notes5	Memo		Notes on data 5	

Data_Theme: Environmental
Data Type: Environmental
Data Source: Michael Baker, Jr., Inc., Alpine 2004 Spring Breakup and Hydrological Assessment Table 3-15, http://www.mbakercorp.com/
Data Time Period: 1962–2004
Relevant Reports: NA
Data Location: Colville River, AK
Data Quality: Date of first flow, date of peak discharge, and peak elevation have been recorded since 1992 with some observations from the early 1960s and early 1970s. Quality of peak discharge estimates is unknown.

Table B-18. TBL_ENV_DAILY_RIVER_DISCHARGE

Data Abstract: This file contains published daily mean streamflow data from the Kuparuk River, Sagavanirktok River, and the Colville River.

Data Fields: The following fields are included in the Table.

Field_Name	Data_Type	Units	Description	Relationships
Obj_ID	Autonumber		Autonumber	
Agency_cd	Text		Agency code	
Site_Code	Text		Station code	E2
Dv_dt	Date/Time		date of daily mean streamflow	
Dv_va	Number	cfs	daily mean streamflow value, in cubic-feet per-second	
Dv_cd	Text		daily mean streamflow value qualification code see http://waterdata.usgs.gov/nwis/help?codes_help#dv_cd	DM5

Data Theme: Environmental
Data Type: Environmental
Data Source: USGS National Water Information System, http://waterdata.usgs.gov/nwis
Data Time Period: 1970–2004
Relevant Reports: NA
Data Location: North Slope, AK
Data Quality: Discharge at a given location may be accurately measured, but does not always reflect total discharge into the coastal Beaufort Sea because the gauge may be located far upstream. There is relatively good agreement between different gauges on the same river, but poor agreement between rivers / drainages. Therefore, data from any single river should be used with caution and are unlikely to adequately reflect the influence of discharge on Arctic cisco. Only discharge records from the Sagavanirktok River were of adequate length for examining effects on Arctic cisco.

Table B-19. LU_ENV_DAILYDISCHARGE_LOCS

Data Abstract: This file contains USGS river discharge locations for data in TBL_ENV_DAILY_RIVER_DISCHARGE file.

Data Fields: The following fields are included in the Table.

Field_Name	Data_Type	Units	Description	Relationships
Obj_ID	Autonumber		Autonumber	
Site_Code	Text		Site code links to daily discharge table	E2
Site_Name	Text		Descriptive site name	
LonWGS84	Number		Longitude of site WGS84	
LatWGS84	Number		Latitude of site WGS84	
Theme	Text		Theme Name (always Environmental)	
Data_Type	Text		Type of Data recorded at location	
Site_no	Number		USGS site number	
Drainage Area	Number	Sq. miles	Area of upstream drainage	
Feet_asl	Number	ft	Elevation of sea level	
Website	Text		Website of site information	

Data Theme: Environmental
Data Type: Location
Data Source: USGS National Water Information System, http://waterdata.usgs.gov/nwis
Data Time Period: NA
Relevant Reports: NA
Data Location: North Slope, AK
Data Quality: For reference only, not used in analysis.

Table B-20. LU_ENV_DISCHARGE_LOCS

Data Abstract: This file contains site information for data in the TBL_Env_River_Discharge file.

Data Fields: The following fields are included in the Table.

Field_Name	Data_Type	Units	Description	Relationships
Obj_ID	Autonumber		Autonumber	
Site_Code	Text		Site Code, Links to Discharge Table	E1
Site_Name	Text		Locations of Discharge Measurements	
Latitude	Number	Decimal Degrees	Latitude of discharge measurements	
Longitude	Number	Decimal Degrees	Longitude of discharge measurements	
Theme	Text		Theme Name (always Environmental)	
Data_Type	Text		Type of Data recorded at location	
River	Text		River of Discharge Measurements	
Year Start	Text		Year Start	
Year End	Text		Year End	
Area	Number	km^2	upstream area	

Data Theme: Environmental
Data Type: Environmental
Data Source: R-ArcticNet, an electronic, hydrographic data network for the Arctic region at University of New Hampshire http://www.r-arcticnet.sr.unh.edu/v3.0/
Data Time Period: NA
Relevant Reports: NA
Data Location: Various Rivers
Data Quality: For reference only, not used in analysis.

Table B-21. LU_ENV_NCEP_LOCS

Data Abstract: This file contains locations to link to wind data in TBL_Env_NCEP_Daily_Winds table.

Data Fields: The following fields are included in the Table.

Field_Name	Data_Type	Units	Description	Relationships
Obj_ID	Autonumber		Autonumber	
Site_Code	Text		Site Code, links to data table	E4
Site_Name	Text		Site Name	
LonWGS84	Number		Longitude (assume WGS84)	
LatWGS84	Number		Latitude (assume WGS84)	
Theme	Text		Theme Name (always Environmental)	
Data_Type	Text		Type of Data recorded at location	

Data Theme: Weather
Data Type: Location
Data Source: NOAA-CIRES Climate Diagnostics Center, Boulder, CO NCEP/NCAR Reanalysis Project
Data Time Period: NA
Relevant Reports: NA
Data Location: 70-72.5°N, 130–160°W, 1 x 1 degree grid
Data Quality: For reference only. Regional spatial averages over several grid points were used in analyses.

Table B-22. TBL_ENV_NCEP_DAILY_WINDS

Data Abstract: This file contains model-based daily wind speeds at the surface in E-W (uwnd) and N-S (vwnd) at selected locations, gridded data on a 2.5° grid with centers of grid points at 70°N and 72.5 °N from 130–150°W.

Data Fields: The following fields are included in the Table.

Field_Name	Data_Type	Units	Description	Relationships
Obj_ID	Autonumber		Autonumber	
Year	Number		Year	
Month	Number		Month	
Day	Number		Day (based on 6-hourly estimates)	
Uwnd	Number		Wind speeds (m/s) in u-direction (positive is to the east, negative is to the west)	
Vwnd	Number		Wind speeds (m/s) in v-direction (positive is to the north, negative is to the south)	

Data Theme: Weather
Data Type: Weather
Data Source: NOAA-CIRES Climate Diagnostics Center, Boulder, CO NCEP/NCAR Reanalysis Project
Data Time Period: 1961–2005
Relevant Reports: NA
Data Location: 70-72.5 N, 130–160W, 2.5 x 2.5 degree grid
Data Quality: Modeled winds should be used with caution because of orographic effects, particularly in locations that are potentially effected by the proximity of the Brooks Range in the eastern Beaufort Sea. A detailed comparison of modeled and measured winds at Barrow and Deadhorse is included as an appendix.

Table B-23. LU_ENV_OI_LOCS

Data Abstract: This file contains location information, links to TBL_Env_OI_SST_Ice table.

Data Fields: The following fields are included in the Table.

Field_Name	Data_Type	Units	Description	Relationships
Obj_ID	Autonumber		Autonumber	
Site_Code	Text		Site Code, links to data table	E5
Site_Name	Text		Site Name	
LonWGS84	Number		Longitude (assume WGS84)	
LatWGS84	Number		Latitude (assume WGS84)	
Theme	Text		Theme Name (always Environmental)	
Data_Type	Text		Type of Data recorded at location	

Data Theme: Environmental
Data Type: Location
Data Webpage: http://www.cdc.noaa.gov/cdc/data.noaa.oisst.v2.html
Data Source: Climate Modeling Branch W/NP24, NCEP/NWS/NOAA 5200 Auth Road, Room 807 Camp Springs, MD 20746 USA More information is available at the CMB SST Web page.

Please note: If you acquire NOAA Optimum Interpolation (OI) SST V2 data products from PSD, we ask that you acknowledge us in your use of the data. This may be done by including text such as *NOAA Optimum Interpolation (OI) SST V2 data provided by the NOAA/OAR/ESRL PSD, Boulder, Colorado, USA, from their Web site at* http://www.cdc.noaa.gov in any documents or publications using these data. We would also appreciate receiving a copy of the relevant publications. This will help PSD to justify keeping the NOAA Optimum Interpolation (OI) SST V2 data set freely available online in the future.

Contact person(s): Climate Diagnostics Data Management
Climate Diagnostics branch of ESRL/PSD
325 Broadway
R/PSD1
Boulder, CO 80305-3328
cdcdata@noaa.gov

Data Time Period: NA
Relevant Reports: NA
Data Location: 69-72°N, 134–153°W, 1 x 1 degree grid
Data Quality: For reference only. Regional spatial averages over several grid points were used in analyses.

Table B-24. TBL_ENV_OI_SST_ICE

Data Abstract: This file contains monthly Optimum Interpolation (OI) version 2 sea surface temperature of Reynolds et al (2002) and monthly mean ice concentrations for various 1x1 degree regions, January 1982–July 2005.

Data Fields: The following fields are included in the Table.

Field_Name	Data_Type	Units	Description	Relationships
Obj_ID	Autonumber		Autonumber	
Site_Code	Text		Site code, links to TBL_Env_OI_Locs	E5
Year	Number		Year of Data	
Month	Number		Month	
SST	Number	C	Sea Surface Temperature (C)	
Ice	Number	Percent	Ice Concentration	

Data Theme: Environmental
Data Type: Environmental
Data Webpage: http://www.cdc.noaa.gov/cdc/data.noaa.oisst.v2.html,
Data Source: Climate Modeling Branch W/NP24, NCEP/NWS/NOAA 5200 Auth Road, Room 807 Camp Springs, MD 20746 USA More information is available at the CMB SST Web page.

Please note: If you acquire NOAA Optimum Interpolation (OI) SST V2 data products from PSD, we ask that you acknowledge us in your use of the data. This may be done by including text such as *NOAA Optimum Interpolation (OI) SST V2 data provided by the NOAA/OAR/ESRL PSD, Boulder, Colorado, USA, from their Web site at* http://www.cdc.noaa.gov/ in any documents or publications using these data. We would also appreciate receiving a copy of the relevant publications. This will help PSD to justify keeping the NOAA Optimum Interpolation (OI) SST V2 data set freely available online in the future.

Contact person(s): Climate Diagnostics Data Management
Climate Diagnostics branch of ESRL/PSD
325 Broadway
R/PSD1
Boulder, CO 80305-3328
cdcdata@noaa.gov

Data Time Period: 1982–2005
Relevant Reports: NA
Data Location: 69-72°N, 134–153°W, 1 x 1 degree grid
Data Quality: The quality of the OI SST data in Arctic regions has not been fully evaluated. There are relatively few in-situ or satellite observations (due to cloud cover) in the Beaufort Sea compared to other regions and the region is ice-covered much of the year. A detailed description of the OI analysis can be found in: Reynolds and Smith 1994. "Improved global sea surface temperature analyses". J. Climate, 7, 929-948.
A comparison of OI SST with measured near-shore SSTs in Prudhoe Bay can be found in the Task 3 report, section III.2.

Table B-25. LU_ENV_REYNOLDS_LOCS

Data Abstract: This file contains site information for data in table TBL_Env_Reynolds_SST.

Data Fields: The following fields are included in the Table.

Field_Name	Data_Type	Units	Description	Relationships
Obj_ID	Autonumber		Autonumber	
Site_Code	Text		Site code to link to TBL_Env_Reynolds_SST	E3
Site_Name	Number		Site Name	
LonWGS84	Number		Longitude (assumed WGS84)	
LatWGS84	Number		Latitude (assumed WGS84)	
Theme	Text		Theme Name (always Environmental)	
Data_Type	Text		Type of Data recorded at location	

Data Theme: Environmental
Data Type: Location
Data Source: NCDC/NESDIS/NOAA, http://www.cdc.noaa.gov/cdc/data.noaa.ersst.html

Please note: If you acquire NOAA_ERSST_V2 data products from PSD, we ask that you acknowledge us in your use of the data. This may be done by including text such as *NOAA_ERSST_V2 data provided by the NOAA/OAR/ESRL PSD, Boulder, Colorado, USA, from their Web site at* http://www.cdc.noaa.gov/ in any documents or publications using these data. We would also appreciate receiving a copy of the relevant publications. This will help PSD to justify keeping the NOAA_ERSST_V2 data set freely available online in the future.

Contact person(s): Climate Diagnostics Data Management
Climate Diagnostics branch of ESRL/PSD
325 Broadway, R/PSD1
Boulder, CO 80305-3328 *cdcdata@noaa.gov*

Data Time Period: NA
Data Location: 2.5 x 2.5 degree grid
Relevant Reports: ERSST.v1: Smith and Reynolds 2003; ERSST.v2: Smith and Reynolds 2004
Data Quality: For reference only. Regional spatial averages over several grid points were used in analyses.

Table B-26. TBL_ENV_REYNOLDS_SST

Data Abstract: This file contains the extended reconstructed sea surface temperature (ERSST) was constructed using the most recently available International Comprehensive Ocean-Atmosphere Data Set (ICOADS) SST data and improved statistical methods that allow stable reconstruction using sparse data. This monthly analysis begins January 1854, but because of sparse data the analyzed signal is heavily damped before 1880. Afterwards the strength of the signal is more consistent over time. The ERSST analysis will be updated as new data become available.

Currently, the ERSST version 2 (ERSST.v2) is available. ERSST.v2 is an improved extended reconstruction. In the reconstruction the high-frequency SST anomalies are reconstructed by fitting to a set of spatial modes. Compared to the earlier reconstruction, version 1 (v1), the improved reconstruction better resolves variations in weak-variance regions. It also uses sea-ice concentrations to improve the high-latitude SST analysis, a modified historical bias correction for the 1939-1941 periods, and it includes an improved error estimate.

Data Fields: The following fields are included in the Table.

Field_Name	Data_Type	Units	Description	Relationships
Obj_ID	Autonumber		Autonumber	
Year	Number		Year	
Month	Number		Month	
Latitude	Number		Latitude of grid centroid (no datum specified)	
Longitude	Number		Longitude of grid centroid (no datum specified)	
SST	Number	C	Sea Surface Temperature °C	

Data Theme: Environmental
Data Type: Environmental
Data Source: NCDC/NESDIS/NOAA, http://www.cdc.noaa.gov/cdc/data.noaa.ersst.html

Please note: If you acquire NOAA_ERSST_V2 data products from PSD, we ask that you acknowledge us in your use of the data. This may be done by including text such as *NOAA_ERSST_V2 data provided by the NOAA/OAR/ESRL PSD, Boulder, Colorado, USA, from their Web site at* http://www.cdc.noaa.gov/ in any documents or publications using these data. We would also appreciate receiving a copy of the relevant publications. This will help PSD to justify keeping the NOAA_ERSST_V2 data set freely available online in the future.

Contact person(s): Climate Diagnostics Data Management
Climate Diagnostics branch of ESRL/PSD
325 Broadway, R/PSD1
Boulder, CO 80305-3328 *cdcdata@noaa.gov*

Data Time Period: 1900–2003
Data Location: 2.5 x 2.5 degree grid
Relevant Reports: ERSST.v1: Smith and Reynolds 2003; ERSST.v2: Smith and Reynolds 2004
Data Quality: The quality of Reynolds SST in the Arctic has not been fully evaluated. See above references and comments under TBL_Env_OI_SST_ICE. A comparison of Reynold’s SST and OI SST shows relatively poor agreement, which may be due to the different spatial coverage (see Task 3 report, section III.2).

Table B-27. TBL_ENV_RIVER_DISCHARGE

Data Abstract: This file contains river discharge volumes for Alaskan and Yukon rivers, taken from R-Arctic Net.

Data Fields: The following fields are included in the Table.

Field_Name	Data_Type	Units	Description	Relationships
Obj_ID	Autonumber		Autonumber	
Site_Code	Text		Site code, links to lookup table	E1
Year	Number		Year	
Month	Number		Month discharge measured	
Discharge	Number	m^3/s	River discharge	
DisFlag	Text		Caveats describing instances were data were estimated.	

Data Theme: Environmental
Data Type: Environmental
Data Source: R-ArcticNet, an electronic, hydrographic data network for the Arctic region at University of New Hampshire http://www.r-arcticnet.sr.unh.edu/v3.0/; Environment Canada for Canadian data
Data Time Period: 1971–2003
Relevant Reports: NA
Data Location: Various Rivers
Data Quality: Some Norman Wells missing values estimated by regression of log(discharge) at Norman Wells on log(discharge) at Red River (R^2 = 0.974), other missing values estimated by averaging monthly discharge across years. There was one conspicuous outlier in 1997, resulting from an unusually large discharge recorded at Norman Wells in December 1996. It is not clear whether this is a data error. Monthly discharge values are likely to accurately measure discharge at the gauge stations, but it is unclear if and how discharge at these upstream locations reflects total Mackenzie discharge or if it reflects conditions in tributaries where Arctic cisco spawn.

THEME—PEEL RIVER

Table B-28. TBL_PEEL_RIVER

Data Abstract: This file contains a sampling of Peel River spawning population, differences in mesh size, sampling location, etc.

Data Fields: The following fields are included in the Table.

Field_Name	Data_Type	Units	Description	Relationships
Obj_ID	Autonumber		Autonumber	
Site_Code	Text		Site Code, links to LU_Peel_River_Locs	
Year	Number		Year of Data	
Date	Date/Time		Date	
Fecundity	Number		Fecundity (estimated number of eggs)	
S#_on_envelope	Text		Sample ID	
FL(mm)	Number	Mm	fork length in millimeters	
Fork_Class	Number		fork length in millimeters, rounded to nearest 10mm	
Species	Text		Species (always Arctic cisco)	
Final_Ages	Number		Estimated age in years	
Wt_(g)	Number	G	Weight	
Monitor	Text		Name of person monitoring net	
Sex	Text		Sex (M or F)	
GW_(g)	Number	G	Gonad weight in grams	
Net_Type	Text		Type of gillnet (E = Experimental, S = Standard)	
Mesh_Size	Number	In	Mesh Size	

Data Theme: Peel River
Data Type: Fishery
Data Source: Jennifer Walker-Larsen (enviro.biologist@grrb.nt.ca)
Data Time Period: 1998–2002
Relevant Reports: (VanGerwen-Toyne and Walker-Larsen 2004)
Data Location: Peel River, Yukon territory
Data Quality: These data were obtained opportunistically over a few years and do not provide useful time series. However, the age and length/weight data provide useful information on age composition in a spawning population, and on size-at-age and weight-at-length in older fishes.

Table B-29. LU_PEEL_RIVER_LOCS

Data Abstract: This file contains approximate sampling locations for Arctic cisco data in TBL_Peel_River file.

Data Fields: The following fields are included in the Table.

Field_Name	Data_Type	Units	Description	Relationships
Obj_ID	Autonumber		Autonumber	
Site_Code	Text		Site code to link to TBL_Peel_River	P1
Site_Name	Number		Site Name	
LonWGS84	Number		Longitude (WGS84)	
LatWGS84	Number		Latitude (WGS84)	
Theme	Text		Theme Name (always Peel River)	
Data_Type	Text		Type of Data recorded at location	

Data Theme: Peel River
Data Type: Location
Data Source: Jennifer Walker-Larsen (enviro.biologist@grrb.nt.ca)
Data Time Period: 1998–2002
Relevant Reports: (VanGerwen-Toyne and Walker-Larsen 2004)
Data Location: Peel River, Yukon territory
Data Quality: Locations denote general areas only

THEME—PRUDHOE BAY

Table B-30. TBL_PB_BODY_COMPOSITION

Data Abstract: This file contains body composition of Arctic Cisco caught at Prudhoe Bay.

Data Fields: The following fields are included in the Table.

Field_Name	Data_Type	Units	Description	Relationships
Obj_ID	Autonumber		Autonumber	
Month	Text		Month	
Year	Number		Year	
Location	Text		Location (always=Prudhoe Bay)	
Sample	Number		Sample ID	
Species	Text		Species (Always Arctic cisco)	
Group	Text		Group ID	
LengthInt	Text	mm	Length Interval	
Length	Number	mm	Length in mm	
Weight	Number	g	Weight in g	
Lipid	Number	Percent	Percent lipid	
Protein	Number	Percent	Percent protein	
H2O	Number	Percent	Average percent H_2O based on 2 replicate samples per fish	
Ash	Number	Percent	Average percent Ash based on 2 replicate samples per fish	

Data Theme: Prudhoe Bay
Data Type: Fishery
Data Source: LGL Alaska Research Associates Inc., 1101 East 76th Avenue, Suite B, Anchorage, Alaska 99518, (907) 562-3339, www.lgl.com
Data Time Period: 1990–1993
Relevant Reports: LGL 1992, 1993, 1994a, 1994b.
Data Location: Prudhoe Bay
Data Quality: These data were collected using a statistically rigorous sampling design with replicate measurements. Estimates of body composition reflect averages across replicates within size classes and have a small coefficient of variation. However, it is unclear whether the sampled fishes are representative of the Arctic cisco population as a whole. Data are available for only 4 years and are insufficient to examine changes over time.

Table B-31. TBL_PB_CATCH

Data Abstract: This file contains annual catch by species, year, and station (species totals only in 1998)

Data Fields: The following fields are included in the Table.

Field_Name	Data_Type	Units	Description	Relationships
Obj_ID	Autonumber		Autonumber	
Common_Name	Text		Species common name	L1
Year	Number		Year of catch	
Site_Code	Text		Station ID	L2
Number	Number		Number of fish	
Comments	Text		Comments	

Data Theme: Prudhoe Bay
Data Type: Fishery
Data Source: LGL Alaska Research Associates Inc., 1101 East 76th Avenue, Suite B, Anchorage, Alaska 99518, (907) 562-3339, www.lgl.com
Data Time Period: 1989–2003
Relevant Reports: Fechhelm et al. 2002, 2003, 2004; LGL 1990b,1991, 1992, 1993, 1994a, 1994b, 1995, 1996, 1997, 1999a, 1999.
Data Location: Prudhoe Bay
Data Quality: Data are limited to 1988-2004 with four missing years (1997-2000). Two stations were sampled consistently between 1989 and 2004. It is not clear whether all species are adequately sampled by the sampling gear (fyke nets).

Table B-32. TBL_PB_CPUE

Data Abstract: This file contains daily catch per unit effort by cohort (single age or age group) at Prudhoe Bay.

Data Fields: The following fields are included in the Table.

Field_Name	Data_Type	Units	Description	Relationships
Obj_ID	Autonumber		Autonumber	
Date	Date/Time		Date	
Site_Code	Text		Station ID	L4
Side	Tex		Side of net (E=East, W=West, N=North, S=South)	
NetSide	Text		Station and side combined	
CPUE_1	Number	fish/net/24 h	CPUE Age 1	
CPUE_2	Number	fish/net/24 h	CPUE Age 2	
CPUE_3	Number	fish/net/24 h	CPUE Age 3	
CPUE_4	Number	fish/net/24 h	CPUE Age 4	
CPUE_3&4	Number	fish/net/24 h	CPUE Ages 3 and 4	
CPUE_2&3	Number	fish/net/24 h	CPUE Ages 2 and 3	
CPUE_3+	Number	fish/net/24 h	CPUE Ages 3 and older	

Data Theme: Prudhoe Bay
Data Type: Fishery
Data Source: LGL Alaska Research Associates Inc., 1101 East 76th Avenue, Suite B, Anchorage, Alaska 99518, (907) 562-3339, www.lgl.com
Data Time Period: 1985–2003
Relevant Reports: Fechhelm et al. 2002; LGL 1990a (Niedoroda and Colonell 1990), 1990b,1991, 1992, 1993, 1994a, 1994b, 1995, 1996, 1997, 1999a, 1999.
Data Location: Prudhoe Bay, AK
Data Quality: These data are not raw data as they were obtained from processed reports. No data were collected or reported for 1997, 1999, and 2000. Catch-per-unit-effort was standardized to number of fish per 24 hr period, assuming that catches are proportional to the time between net checks, which is a reasonable assumption for fyke net samples (no "saturation" effect). CPUE was reported for different age cohorts, which were defined based on modes and gaps in the length-frequency distribution. Older age-classes (age 3+ or 4+) were reported as a single cohort. In some years younger age classes could not be distinguished because of the small number of specimens caught and were combined into a single cohort (e.g. ages 3&4 were combined in 1990 and 1996, and ages 1&2 were combined in 2004), complicating interannual comparisons. No unusual values or extreme outliers were found. For detailed assessments see individual reports.

Table B-33. TBL_PB_EFFORT

Data Abstract: This file contains effort (in days) used for CPUE calculations for Prudhoe Bay data.

Data Fields: The following fields are included in the Table.

Field_Name	Data_Type	Units	Description	Relationships
Obj_ID	Autonumber		Autonumber	
Date	Date/Time		Date	L5
Year	Number		Year	
Day	Number		Day Number	
NetSide	Text		Station Code	L6
Effort	Number	days	Number of Days net in water	
Comment	Text		Comments	

Data Theme: Prudhoe Bay
Data Type: Fishery
LGL Alaska Research Associates Inc., 1101 East 76th Avenue, Suite B, Anchorage, Alaska 99518, (907) 562-3339, www.lgl.com
Data Time Period: 1984–2004
Relevant Reports: Fechhelm et al. 2002, 2003, 2004, 2005; LGL 1990a (Niedoroda and Colonell 1990), 1990b,1991, 1992, 1993, 1994a, 1994b, 1995, 1996, 1997, 1999a, 1999.

Data Location: Prudhoe Bay, AK
Data Quality: These data were obtained from processed reports and reflect effort in time (number of days) between net checks. No unusual values were found.

Table B-34. LU_PB_LOCS

Data Abstract: This file contains station information for linking to other LGL data. Link by station

Data Fields: The following fields are included in the Table.

Field_Name	Data_Type	Units	Description	Relationships
Obj_ID	Autonumber		Autonumber	
Site_Code	Text		Station Number	L2, L3, L4
Site_Name	Number		adjusted LGL_Station Code	
Latitude	Number		Latitude dd83	
Longitude	Number		Longitude dd83	
Theme	Text		Theme Name (always LGL)	
Data_Type	Text		Type of Data recorded at location	
LGL_Code2	Number		LGL_Station Code	
Region	Text		Region	
Comment	Text		Comments	

Data Theme: Prudhoe Bay
Data Type: Location
Data Source: LGL Alaska Research Associates Inc., 1101 East 76th Avenue, Suite B, Anchorage, Alaska 99518, (907) 562-3339, www.lgl.com
Data Time Period: NA
Relevant Reports: Fechhelm et al. 2002, 2003, 2004, 2005, 2006; LGL 1990a (Niedoroda and Colonell 1990), 1990b,1991, 1992, 1993, 1994a, 1994b, 1995, 1996, 1997, 1999a, 1999.
Data Location: Prudhoe Bay, AK
Data Quality: For reference only. Latitude and longitude of fyke net stations

Table B-35. LU_PB_SPECIES

Data Abstract: This file contains a list of species, common names, scientific names, Inupiaq names and fish type for linking to other files (by common names)

Data Fields: The following fields are included in the Table.

Field_Name	Data_Type	Units	Description	Relationships
Obj_ID	Autonumber		Autonumber	
Common_Name	Text		Species common name	L1
Scientific_Name	Text		Species scientific name	
Inupiat_Name	Text		Species_Inupiat name	
Type	Text		Type of Fish	

Data Theme: Prudhoe Bay
Data Type: Fishery
Data Source: LGL Alaska Research Associates Inc., 1101 East 76th Avenue, Suite B, Anchorage, Alaska 99518, (907) 562-3339, www.lgl.com
Data Time Period: NA
Relevant Reports: Fechhelm et al. 2002, 2003, 2004, 2005, 2006; LGL 1990a (Niedoroda and Colonell 1990), 1990b,1991, 1992, 1993, 1994a, 1994b, 1995, 1996, 1997, 1999a, 1999.
Data Location: Prudhoe Bay, AK
Data Quality: For reference only.

Table B-36. TBL_PB_TEMP_SALINITY

Data Abstract: This file contains temperature and salinity data for Prudhoe Bay from LGL Reports.

Data Fields: The following fields are included in the Table.

Field_Name	Data_Type	Units	Description	Relationships
Obj_ID	Autonumber		Autonumber	
Date	Date/Time		Date	
Year	Number		Year	
Region	Number		Region	
Site_Code	Text		Site Code, links to Data table	L3
Type	Text		Type (onshore or offshore)	
Depth	Number	m	Depth of sample (m?)	
Temp	Number	C	Temperature	
Salinity	Number	ppt	Salinity	
Problems	Text		List of apparent problems in the dataset	

Data Theme: Prudhoe Bay
Data Type: Environmental
Data Source: LGL Alaska Research Associates Inc., 1101 East 76th Avenue, Suite B, Anchorage, Alaska 99518, (907) 562-3339, www.lgl.com
Data Time Period: 1988–2004
Relevant Reports: Fechhelm et al. 2003, 2004, 2005; LGL 1990b,1991, 1992, 1993, 1994a, 1994b, 1995, 1996, 1997, 1999a, 1999.
Data Location: Prudhoe Bay, AK
Data Quality: Data were obtained from processed reports; see reports for detailed discussion. Salinity and temperature were measured at fyke net locations in conjunction with biological sampling; hence, no measurements were available for 1997, 1999, and 2000. Not all stations were sampled consistently, and only one station (214) was sampled each year. There was relatively good agreement between stations, suggesting that average temperatures and salinities are representative of a larger area rather than reflecting small-scale, local conditions only. Some unusually high temperatures were reported (e.g. 18.8°C in 2002), which may have been a data error or may reflect local warming in very shallow water. These high temperatures had negligible influence on results and were retained.

THEME—WEATHER

Table B-37. TBL_WEATHER_BARROW_HOURLY

Data Abstract: This file contains hourly wind, temperature and precipitation data from NOAA Climatic Monitoring and Diagnostic Laboratory in Barrow, AK 1973–2004.

Data Fields: The following fields are included in the Table.

Field_Name	Data_Type	Units	Description	Relationships
Obj_ID	Autonumber		Autonumber	
Site Code	Text		Site Code, links to location table	W3
Year	Number		Year	
Month	Number		Month	
Day	Number		Day	
Hour	Number		Hours in coordinated universal time	
Winddir	Number	degrees	vector wind direction in degrees	
Wind_ms	Number	m/s	vector wind speed in meters per second	
Windsteadiness	Number	unitless	Wind Steadiness- 100 times the ratio of the vector wind speed to the average wind speed for the hour.	
Pressure	Number	millibars	Barometric Pressure hg	
Temp_C	Number	C	Air temperature in degrees Celsius	
Dewpoint_C	Number	C	dew point temperature in degrees Celsius	
Precip_mm	Number	mm	precipitation amount in millimeters	

Data Theme: Weather
Data Type: Weather
Data Source: NOAA Climatic Monitoring and Diagnostic Laboratory, 2005, ftp://140.172.192.211/met/hourlymet/brw/
Data Time Period: 1973–2004
Relevant Reports: NA
Data Location: Barrow, AK (N71.18 W156.47)
Data Quality: High quality long-term weather data. Reflect local and larger-scale weather conditions. There are some missing values.

Table B-38. TBL_WEATHER_BARROW_MONTHLY

Data Abstract: This file contains Barrow monthly mean, minimum, and maximum temperature and precipitation from Western Regional Climate Center.

Data Fields: The following fields are included in the Table.

Field_Name	Data_Type	Units	Description	Relationships
Obj_ID	Autonumber		Autonumber	
Site Code	Text		Site Code, links to location table	W5
Year	Number		Year of Measurement	
Month	Number		Month of Measurement	
Measure	Text		Measure (mean, minimum, maximum temperature, or total precipitation)	
Units	Text		Units of Measure (F=degrees Fahrenheit, IN = inches)	
Value	Number		Value of measurement	

Data Theme: Weather
Data Type: Weather
Data Source: Western Regional Climate Center, http://www.wrcc.dri.edu/summary/climsmak.html
Data Time Period: 1949–2005
Relevant Reports: NA
Data Location: Barrow, AK (N71.18 W156.47)
Data Quality: Individual Months not used for annual or monthly statistics if more than 5 days are missing.

Table B-39. TBL_WEATHER_DEADHORSE_DAILY

Data Abstract: This file contains daily weather data for Deadhorse AK 70°12'N / 148°29'W

Data Fields: The following fields are included in the Table.

Field_Name	Data_Type	Units	Description	Relationships
Obj_ID	Autonumber		Autonumber	
Site Code	Text		Site Code, links to location table	W2
Year	Number		Year	
Month	Number		Month	
Day	Number		Day of Month	
TmaxF	Number	F	Maximum Daily Temperature	
TminF	Number	F	Minimum Daily Temperature	
TavgF	Number	F	Average Daily Temperature	
DepartF	Number	F	Departure from Normal	
DewPointF	Number	F	Average Dew Point	
WetBulbF	Number	F	Average Wet Bulb Temperature	
Heat	Number		Heating Degree Days base 65F, season begins with July	
Cool	Number		Cooling Degree Days base 65F, season begins with January	
CodeSum	Text		Significant Weather Phenomena	
SnowDepthIn	Number	in	Snow/ice on ground	
PrecipTotal	Number	in	Precipitatiom	
PrecipFlag	Text		Precipitation descriptor	
StnPressure	Number	in hg	Average Station Pressure	
SeaLevel	Number	in hg	Average Sea Level Pressure	
WindSpMPH	Number	MPH	Resultant Wind Speed (THE VECTOR SUM OF WIND SPEEDS DIVIDED BY THE NUMBER OF OBSE	
WindDir	Number	tens of degrees	Resultant Direction (THE VECTOR SUM OF WIND DIRECTIONS DIVIDED BY THE NUMBER OF OBSERVATIONS)	
AvgWindMPH	Number	MPH	Average wind speed	
MaxWind5sec	Number	MPH	Maximum 5 second wind speed	
MaxDir5sec	Number	tens of degrees	5 second wind direction	
MaxWind2min	Number	MPH	Maximum 2 minute wind speed	
MaxDir2min	Number	tens of degrees	2 minute wind direction	

Data Theme: Weather
Data Type: Weather
Data Source: NOAA National Climatic Data Center, http://lwf.ncdc.noaa.gov/oa/ncdc.html
Data Time Period: 1999–2005
Relevant Reports: NA
Data Location: Deadhorse, AK (70°12'N / 148°29'W)
Data Quality: High quality weather data for recent years only. There are some missing values.

Table B-40. LU_WEATHER_LOCS

Data Abstract: This file contains locations of weather data sites.

Data Fields: The following fields are included in the Table.

Field_Name	Data_Type	Units	Description	Relationships
Obj_ID	Autonumber		Autonumber	
Site_Code	Text		Site code to link to data tables	W1-W6
Site_Name	Number		Site Name	
LonWGS84	Number		Longitude (WGS84)	
LatWGS84	Number		Latitude (WGS84)	
Theme	Text		Theme Name (always Weather)	
Data_Type	Text		Type of Data recorded at location	

Data Theme: Weather
Data Type: Location
Data Source: Various
Data Time Period: NA
Relevant Reports: NA
Data Location: Various
Data Quality: For reference only.

Table B-41. TBL_WEATHER_MACKENZIE

Data Abstract: This file contains monthly weather summaries for two sites along the Mackenzie River from Environment Canada

Data Fields: The following fields are included in the Table.

Field_Name	Data_Type	Units	Description	Relationships
Obj_ID	Autonumber		Autonumber	
Site Code	Text		Site Code, links to location table	W4
Year	Number		Year	
Month	Text		Month	
MeanMaxTemp	Number	C	Mean of daily maxima by month (°C)	
MeanTemp	Number	C	Mean of daily means by month (°C)	
MeanMinTemp	Number	C	Mean of daily minima by month (°C)	
ExtrMaxTemp	Number	C	Maximum of daily maxima (°C)	
ExtrMinTemp	Number	C	Minimum of daily minima (°C)	
TotalRain	Number	mm	Total amount of all liquid precipitation during month (mm)	
TotalSnow	Number	cm	Total amount of all frozen precipitation during month (cm)	
TotalPrecip	Number	mm	Total rainfall + water equivalent of total snowfall (mm)	
SnowGrnd LastDay	Number	cm	Depth of snow on the final day of the month (cm)	
DirMaxGust	Number	10's deg	True direction (geographic) of maximum gust (10's Deg)	
SpdMaxGust	Number	kmh	Speed of the maximum wind gust (km/h)	
Flag	Text		Comments on data	

Data Theme: Weather
Data Type: Weather
Data Source: Environment Canada, http://climate.weatheroffice.ec.gc.ca/climateData/canada_e.html
Data Time Period: 1957–2004
Relevant Reports: NA
Data Location: Mackenzie River: Tuktoyaktuk 69° 25' N, 133° 1' W, Elevation 4.6 m; Inuvik 68° 18' N, 133° 28' W, Elevation 68.30 m (125 km from coast)
Data Quality: High quality long-term weather data. There are several missing periods (e.g. no data at Tuktoyuktuk for 1994-1999) and other missing values. The most complete record is available for Inuvik (Mar 1957 – Jun 1995 and Jan 1997 – Oct 2004). Reflect local and larger-scale weather conditions.

Table B-42. TBL_WEATHER_NUIQSUT_DAILY

Data Abstract: This file contains unedited daily weather data from unmanned NOAA weather station in Nuiqsut, AK

Data Fields: The following fields are included in the Table.

Field_Name	Data_Type	Units	Description	Relationships
Obj_ID	Autonumber		Autonumber	
Site Code	Text		Site Code, links to location table	W6
Year	Number		Year	
Month	Number		Month	
Day	Number		Day of Month	
TmaxF	Number	F	Maximum Daily Temperature	
TminF	Number	F	Minimum Daily Temperature	
TavgF	Number	F	Average Daily Temperature	
DepartF	Number	F	Departure from Normal	
DewPointF	Number	F	Average Dew Point	
WetBulbF	Number	F	Average Wet Bulb Temperature	
Heat	Number		Heating Degree Days base 65F, season begins with July	
Cool	Number		Cooling Degree Days base 65F, season begins with January	
CodeSum	Text		Significant Weather Phenomena	
SnowDepthIn	Number	in	Snow/ice on ground	
Water1	Number	in	Water Equivalent in inches (1200 LST)	
Snowfall	Number	in	Snowfall in inches 2400 LST	
PrecipTotal	Number	in	Precipitation	
PrecipFlag	Text		Precipitation descriptor	
StnPressure	Number	in hg	Average Station Pressure	
SeaLevel	Number	in hg	Average Sea Level Pressure	
WindSpMPH	Number	MPH	Resultant Wind Speed (THE VECTOR SUM OF WIND SPEEDS DIVIDED BY THE NUMBER OF OBSE	
WindDir	Number	tens of degrees	Resultant Direction (THE VECTOR SUM OF WIND DIRECTIONS DIVIDED BY THE NUMBER OF OBSERVATIONS)	
AvgWindMPH	Number	MPH	Average wind speed	
MaxWind5sec	Number	MPH	Maximum 5 second wind speed	
MaxDir5sec	Number	tens of degrees	5 second wind direction	
MaxWind2min	Number	MPH	Maximum 2 minute wind speed	
MaxDir2min	Number	tens of degrees	2 minute wind direction	

Data Theme: Weather
Data Type: Weather
Data Source: NOAA National Climatic Data Center, http://lwf.ncdc.noaa.gov/oa/ncdc.html
Data Time Period: 1998–2005
Relevant Reports: NA
Data Location: Nuiqsut, AK (lat:, 70.217 lon:, -151.000)
Data Quality: Unknown quality. Relatively short time series from unmanned weather station. Some missing values.

Table B-43. TBL_WEATHER_NUIQSUT_HOURLY

Data Abstract: This file contains unedited hourly weather data from unmanned NOAA weather station in Nuiqsut, AK

Data Fields: The following fields are included in the Table.

Field_Name	Data_Type	Units	Description	Relationships
Obj_ID	Autonumber		Autonumber	
Site Code	Text		Site Code, links to location table	W1
Year	Number		Year of measurements	
Month	Number		Month of measurements	
Day	Number		Day of measurements	
Time	Number		Time of measurements	
StationType	Text		A02=unattended, A02A=Attended (Observer Present)	
MaintenanceInd	Text		ASOS Maintenance Indicator, indicates ASOS EQuipment is experiencing maintenance as a result of internal quality assurance checks.	
SkyCond	Text		Sky Conditions below 12,000 ft agl.	
Vis	Text		Visibility in statute miles and through 10+	
WeatherType	Text		Weather Types	
Tdrybulb	Number	F	Dry Bulb Temperature (Degrees Fahrenheit)	
DewPt	Number	F	Dew Pt Temperature (Degrees Fahrenheit)	
Twetbulb	Number	F	Wet Bulb Temperature (Degrees Fahrenheit)	
Rel_Hum	Number	Percent	Relative Humidity (Percent)	
Windknots	Number	knots	Wind Speed (knots)	
Dir	Number	10s of Deg.	Wind direction (Tens of Degrees from True North)	
Sin	Number	radians	Sin of wind direction in radians.	
Cos	Number	radians	Cos of wind direction in radians	
DirFlag	Text		VRB=Variable wind	
WindChGusts	Text	knots	Wind Characteristic Gusts (knots)	
ValWindCharGusts	Number		Value for wind Character (whole units)	
StationPressure	Number	100s of in	Station Pressure (inches in hundreds)	
PressureTendency	Number		Pressure Tendency	
SealevelPressure	Number	10s of millibars	Sea level pressure, tenth of hectopascals (millibars) shown as last three digits (eg. 013=1001.3 MB)	
ReportType	Text		AA- Metar (Aviation routine weather report-hourly), SP-Aviation special report	
TotalPrecip	Number	in	Hourly total Precipitation in inches and hundredths for ReportType=AA, cumulative since last hourly report for ReportType=SP.	
PrecFlag	Text		T= trace amount of precipitation	

Data Theme: Weather
Data Type: Weather
Data Source: NOAA National Climatic Data Center, http://lwf.ncdc.noaa.gov/oa/ncdc.html
Data Time Period: 1998–2004
Relevant Reports: NA
Data Location: Nuiqsut, AK (lat:, 70.217 lon:, -151.000)
Data Quality: Unknown quality. Relatively short time series from unmanned weather station. There are some missing values.

RELATIONSHIPS

Figure B-1. ANWR Relationships

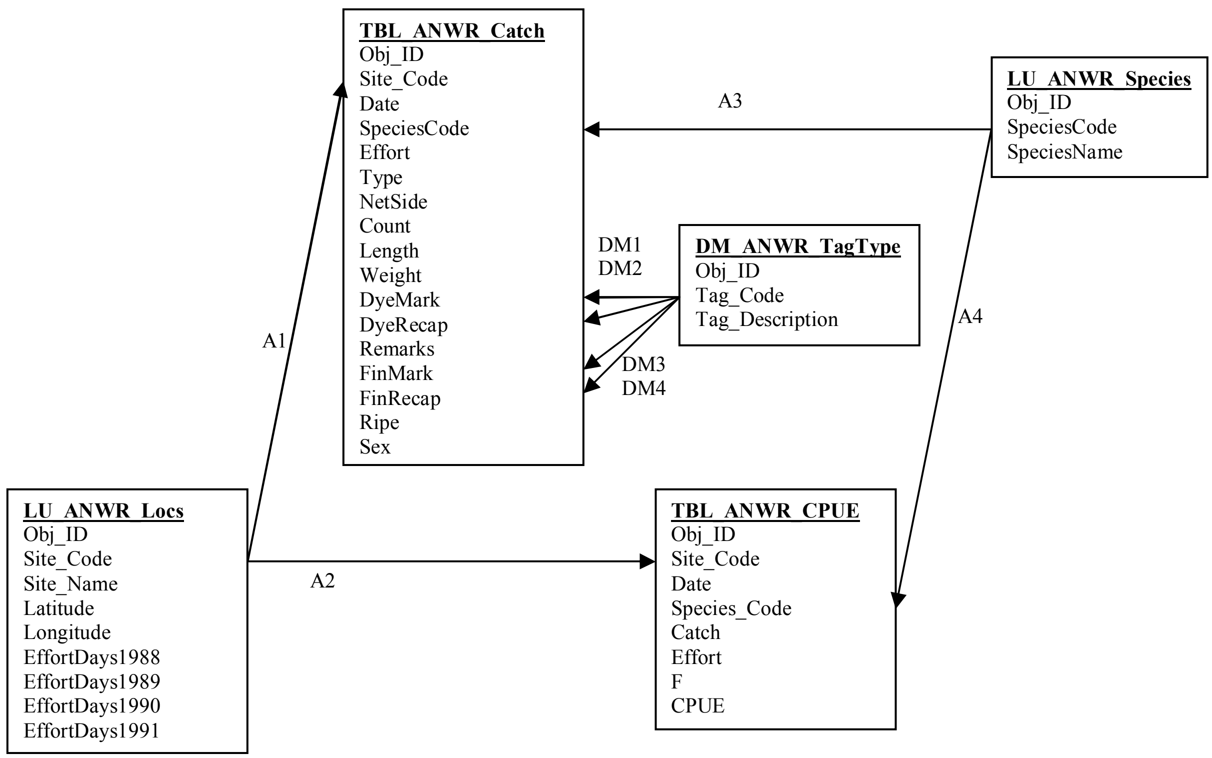

Figure B-2. Colville Relationships

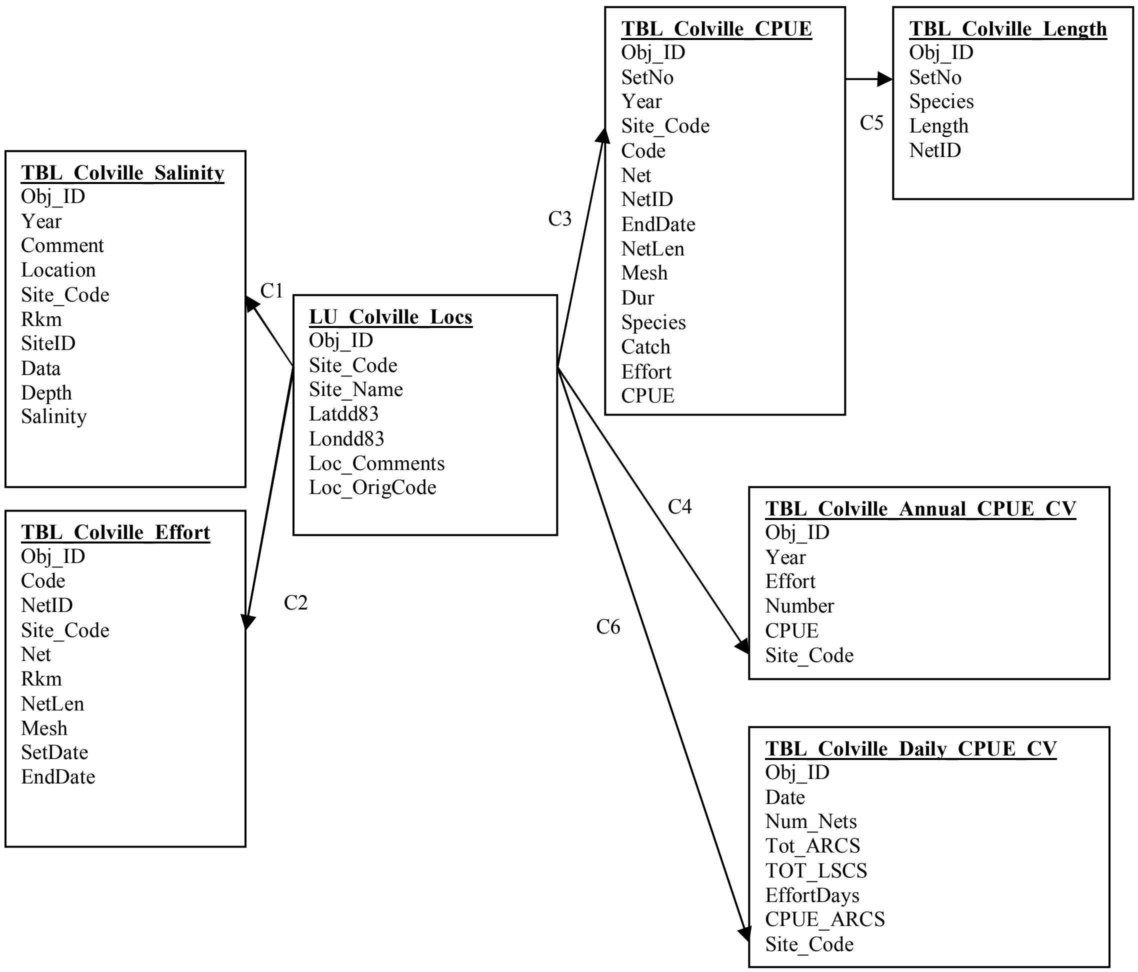

Figure B-3. Development Relationships

TBL_Dev_Beaufort
Obj_ID
Year
Coastal Section
Season
Sea Surface State
Activity Start Date
Activity End Date
Broad Location
Location
Well name / fine location
Structure
Activity
Activity sub-category
Duration
Seismic/acoustic lines
5 km blocks seismic
OCS blocks seismic
Disturbance potential ranking

Figure B-4. Environmental Relationships

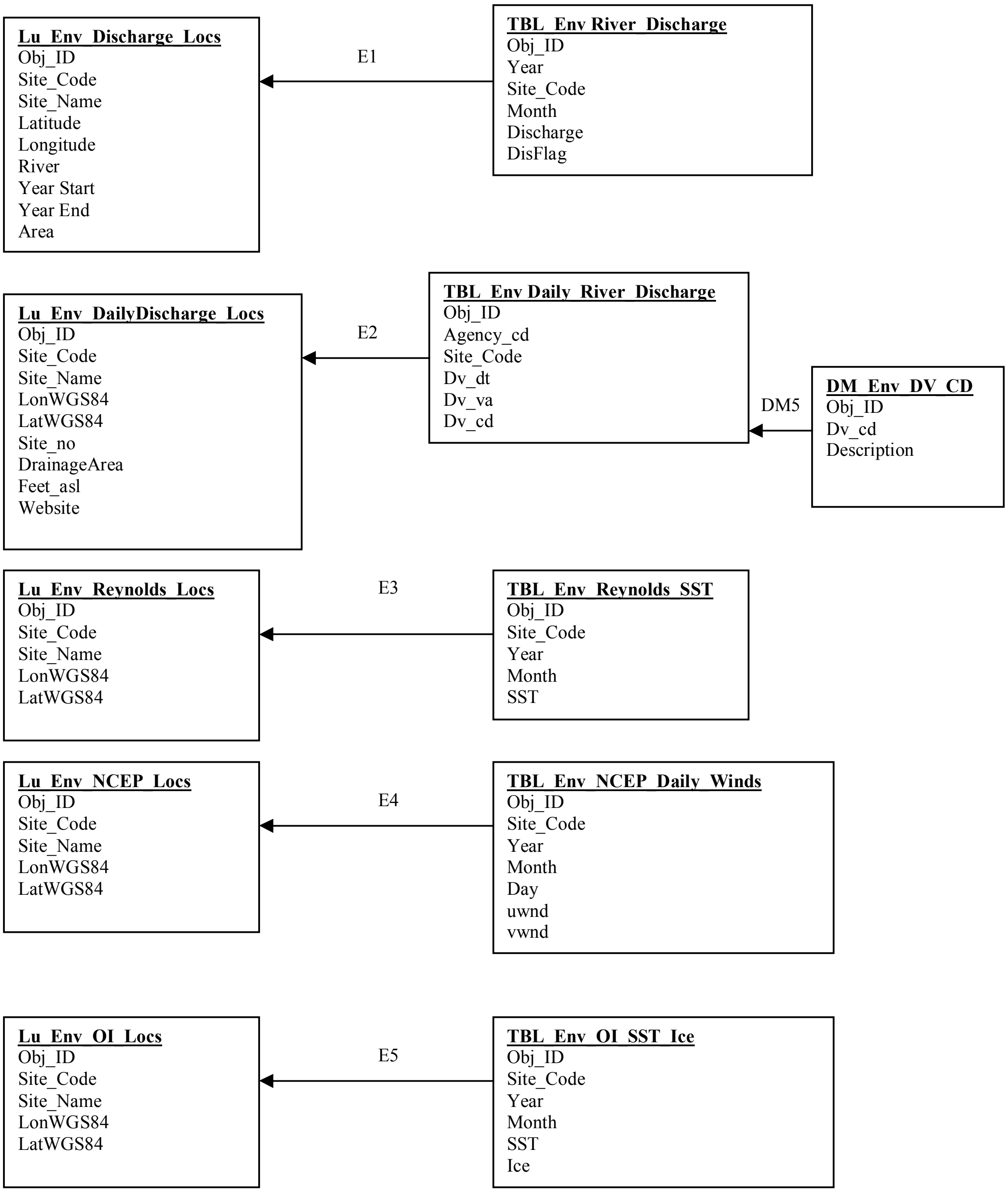

Figure B-5. Prudhoe Bay Relationships

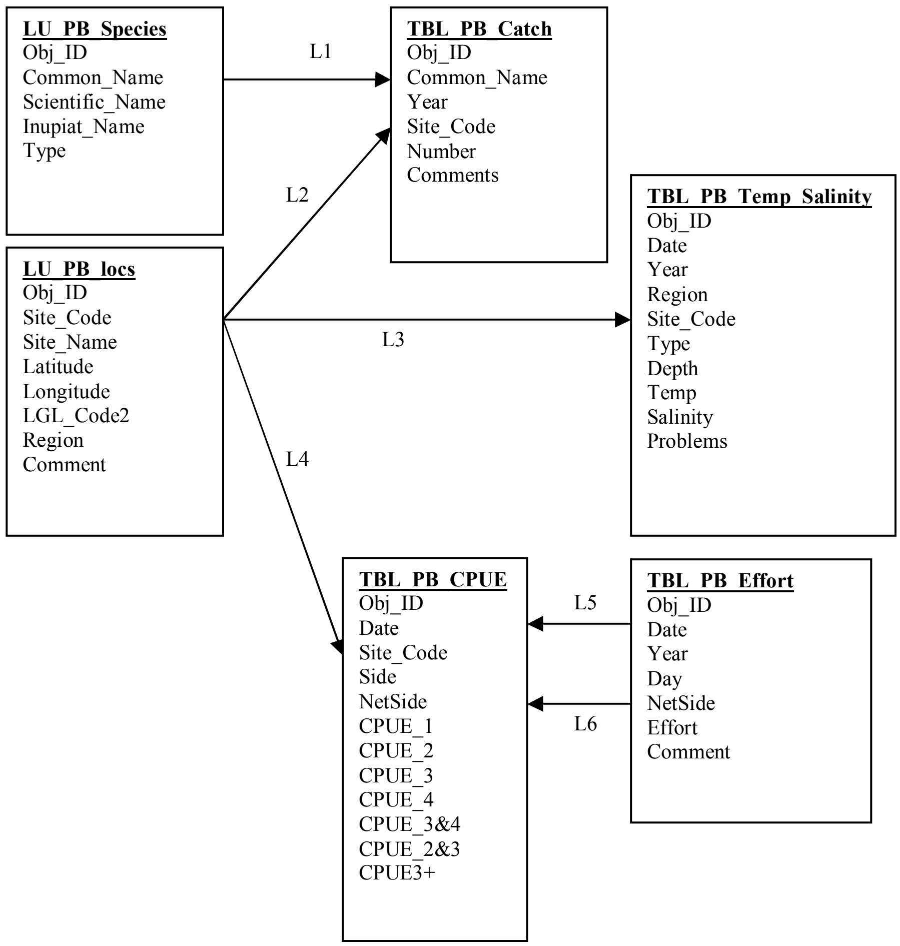

Figure B-6. Peel River Relationships

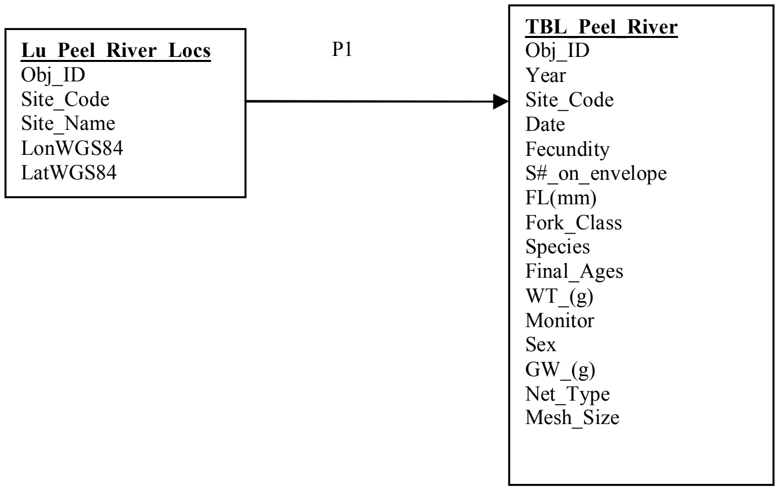

Figure B-7. Weather Relationships

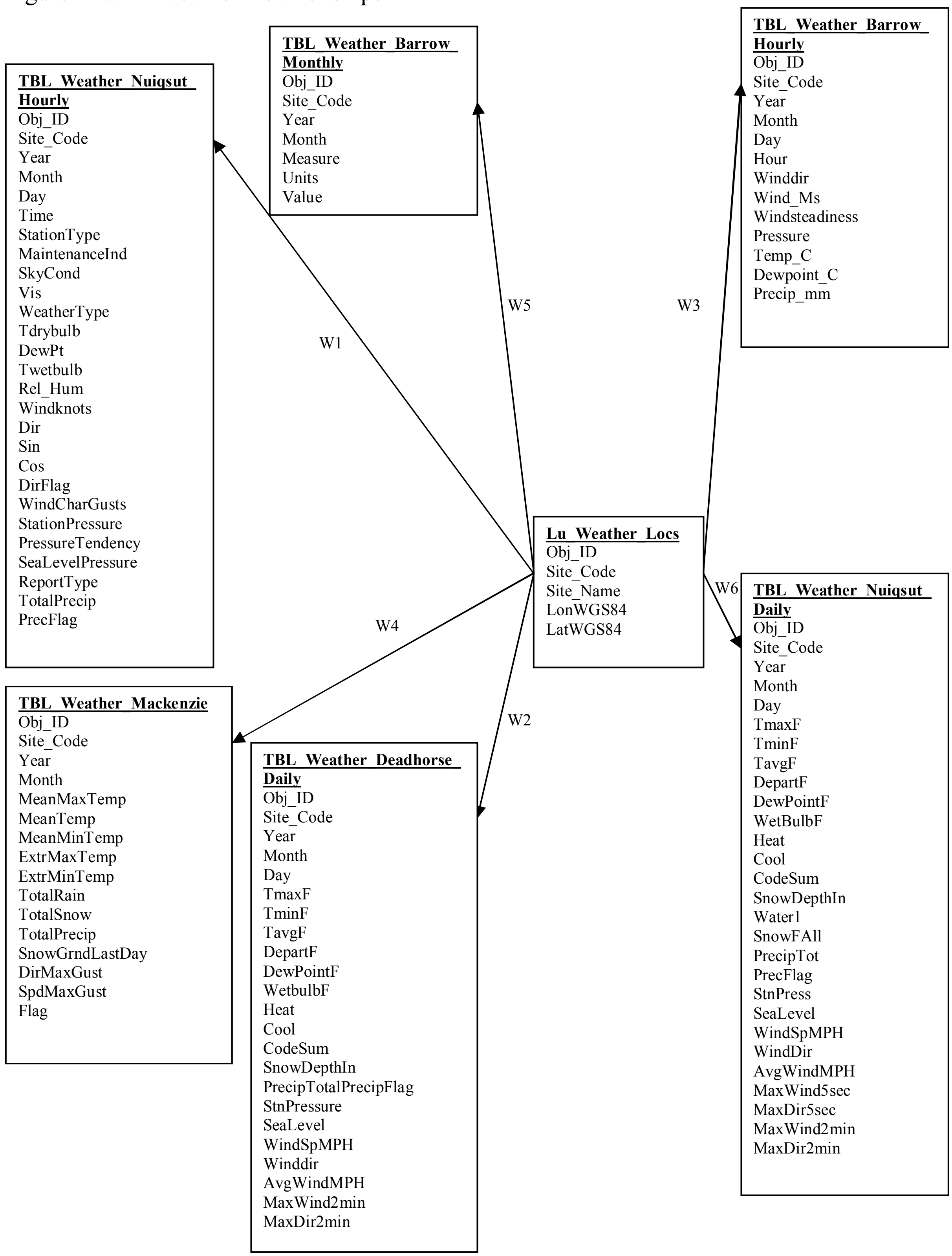

Table B-44. Relationships

Relation ID	Theme	Table 1	Field 1	Table 2	Field 2	Type	Description
A1	ANWR	LU_ANWR_Locs	Site_Code	TBL_ANWR_Catch	Site_Code	One-to-many	One station description from LU_ANWR_Locs for multiple rows of TBL_ANWR_Catch
A2	ANWR	LU_ANWR_Locs	Site_Code	TBL_ANWR_CPUE	Site_Code	One-to-many	One station description from LU_ANWR_Locs for multiple rows of TBL_ANWR_CPUE
A3	ANWR	LU_ANWR_Species	SpeciesCode	TBL_ANWR_Catch	SpeciesCode	One-to-many	One species description from LU_ANWR_Species for each row of TBL_ANWR_Catch
A4	ANWR	LU_ANWR_Species	SpeciesCode	TBL_ANWR_CPUE	SpeciesCode	One-to-many	One species description from LU_ANWR_Species for multiple rows of TBL_ANWR_CPUE
C1	Colville	LU_Colville_Locs	Site_Code	TBL_Colville_Salinity	Site_Code	One-to-many	One location description from LU_Colville_locs for multiple rows of TBL_Colville_Salinity
C2	Colville	LU_Colville_Locs	Site_Code	TBL_Colville_Effort	Site_Code	One-to-many	One location description from LU_Colville_locs for each row of TBL_Colville_Effort
C3	Colville	LU_Colville_Locs	Site_Code	TBL_Colville_CPUE	Site_Code	One-to-many	One location description from LU_Colville_locs for multiple rows of TBL_Colville_CPUE
C4	Colville	LU_Colville_Locs	Site_Code	TBL_Colville_Annual_CPUE_CV	Site_Code	One-to-many	One location description from LU_Colville_locs for multiple rows of TBL_Colville_Annual_CPUE_CV
C5	Colville	LU_Colville_CPUE	SetNo	TBL_Colville_Length	SetNo	One-to-many	One CPUE description from LU_Colville_CPUE for multiple rows of TBL_Colville_Length
C6	Colville	LU_Colville_Locs	Loc_Code	TBL_Colville_Daily_CPUE_CV	Loc_Code	One-to-many	One location description from LU_Colville_locs for multiple rows of TBL_Colville_Daily_CPUE_CV
E1	Environmental	LU_Env_Discharge_Locs	Site_Code	TBL_Env_River_Discharge	Site_Code	One-to-many	One location description from LU_Env_Discharge_Locs for multiple rows of TBL_Env_River_Discharge
E2	Environmental	LU_Env_DailyDischarge_Locs	Site_Code	TBL_Env_Daily_River_Discharge	Site_Code	One-to-many	One location description from LU_Env_DailyDischarge_Locs for multiple rows of TBL_Env_Daily_River_Discharge
E3	Environmental	LU_Env_Reynolds_Locs	Site_Code	TBL_Env_Reynolds_SST	Site_Code	One-to-many	One location description from LU_Env_Reynolds_Locs for multiple rows of TBL_Env_Reynolds_SST
E4	Environmental	LU_Env_NCEP_Locs	Site_Code	TBL_Env_NCEP_Daily_Winds	Site_Code	One-to-many	One location description from LU_Env_NCEP_Locs for multiple rows of TBL_Env_NCEP_Daily_Winds
E5	Environmental	LU_Env_OI_Locs	Site_Code	TBL_Env_OI_SST_Ice	Site_Code	One-to-many	One location description from LU_Env_OI_Locs for multiple rows of TBL_Env_OI_SST_Ice
L1	Prudhoe Bay	LU_PB_Species	Common_Name	TBL_PB_Catch	Common_Name	One-to-many	One species description from LU_PB_Species for multiple rows of TBL_PB_Catch
L2	Prudhoe Bay	LU_PB_Locs	Site_Code	TBL_PB_Catch	Site_Code	One-to-many	One station description from LU_PB_Locs for multiple rows of TBL_PB_Catch
L3	Prudhoe Bay	LU_PB_Locs	Site_Code	TBL_PB_Temp_Salinity	Site_Code	One-to-many	One station description from LU_PB_Locs for multiple rows of TBL_PB_Temp_Salinity
L4	Prudhoe Bay	LU_PB_Locs	Site_Code	TBL_PB_CPUE	Site_Code	One-to-many	One station description from LU_PB_Locs for multiple rows of TBL_PB_CPUE
L5	Prudhoe Bay	TBL_PB_CPUE	Date	TBL_PB_Effort	Date	One-to-many	L5 and L6 define one effort level from LU_PB_Efforts for multiple rows of TBL_PB_CPUE

Table B-44. Continued.

Relation ID	Theme	Table 1	Field 1	Table 2	Field 2	Type	Description
L6	Prudhoe Bay	TBL_PB_CPUE	NetSide	TBL_PB_Effort	NetSide	One-to-many	L5 and L6 define one effort level from LU_PB_Efforts for multiple rows of TBL_PB_CPUE
P1	Peel River	TBL_Peel_River_Locs	Site_Code	TBL_Peel_River	Site_Code	One-to-many	One location description from TBL_Peel_River_Locs for multiple rows of TBL_Peel_River
W1	Weather	LU_Weather_Locs	Site_Code	TBL_Weather_Nuiqsut_Hourly	Site_Code	One-to-many	One location description from LU_Weather_Locs for multiple rows of TBL_Weather_Nuiqsut_Hourly
W2	Weather	LU_Weather_Locs	Site_Code	TBL_Weather_Nuiqsut_Hourly	Site_Code	One-to-many	One location description from LU_Weather_Locs for multiple rows of TBL_Weather_Deadhorse_Daily
W3	Weather	LU_Weather_Locs	Site_Code	TBL_Weather_Nuiqsut_Hourly	Site_Code	One-to-many	One location description from LU_Weather_Locs for multiple rows of TBL_Weather_Barrow_Hourly
W4	Weather	LU_Weather_Locs	Site_Code	TBL_Weather_Nuiqsut_Hourly	Site_Code	One-to-many	One location description from LU_Weather_Locs for multiple rows of TBL_Weather_Mackenzie
W5	Weather	LU_Weather_Locs	Site_Code	TBL_Weather_Nuiqsut_Hourly	Site_Code	One-to-many	One location description from LU_Weather_Locs for multiple rows of TBL_Weather_Barrow_Monthly
W6	Weather	LU_Weather_Locs	Site_Code	TBL_Weather_Nuiqsut_Hourly	Site_Code	One-to-many	One location description from LU_Weather_Locs for multiple rows of TBL_Weather_Nuiqsut_Daily

DATA DICTIONARY

Table B-45. Data Dictionary

Table Name	Field Name	Data Type	Units	Description	Relationships
TBL_ANWR_Catch	Obj_ID	Autonumber		Autonumber	
	Site_Code	Text		Station Code	A1
	Date	Date/Time		Date	
	SpeciesCode	Text		Species Code	A4
	Effort	Number	hours	Effort in hours	
	Type	Text		S=Standard fyke net, P=Experimental (portable) fyke net	
	NetSide	Text		L=Left, R=Right	
	Count	Number			
	Length	Number	mm		
	Weight	Number	g		
	DyeMark	Text		RP=right pelvic, LP=left pelvic, CP=caudal peduncle, BLUELP= blue dye, left pelvic	DM1
	DyeRecap	Text		RP=right pelvic, LP=left pelvic, CP=caudal peduncle, AD=adipose fin, C=fin clip, BLUELP=blue dye, left pelvic, BLACKRD=?, BLACKLD=?	DM2
	TagNum	Text			
	TagRecap	Text			
	Remarks	Text			
	FinMark	Text		RP=right pelvic, LP=left pelvic, AD=adipose fin	DM3
	FinRecap	Text		RP=right pelvic, LP=left pelvic, AD=adipose fin, C=fin clip	DM4
	Ripe	Text		X=Yes	
	Sex	Text		I=Immature, X=?, F=Female, M=Male	
TBL_ANWR_CPUE	Obj_ID	Autonumber		Autonumber	
	Site_Code	Text		Station Code	A2
	Date	Date/Time		Date	
	Species_Code	Text		Species Code	A5
	Catch	Number		Number Caught	
	Effort	Number	hours	Effort	
	F	Number		Effort/24	
	CPUE	Number	Fish/d	Catch Per Unit Effort Adjusted to 24 hour period	

Table B-45. Continued.

Table Name	Field Name	Data Type	Units	Description	Relationships
LU_ANWR_Species	Obj_ID	Autonumber		Autonumber	
	Species_Code	Text		Species ID Code	A4, A5
	Species_Name	Text		Species Common Names	
LU_ANWR_Locs	Obj_ID	Autonumber		Autonumber	
	Site_Code	Text		Station Code	A1, A2, A3
	Site_Name	Text		Area Name	
	Latitude	Number	dd	Latitude (no datum specified)	
	Longitude	Number	dd	Longitude (no datum specified)	
	EffortDays1988	Number	days	Number of days of effort in 1988	
	EffortDays1989	Number	days	Number of days of effort in 1989	
	EffortDays1990	Number	days	Number of days of effort in 1990	
	EffortDays1991	Number	days	Number of days of effort in 1991	
TBL_Colville_Age	Obj_ID	Autonumber		Autonumber	
	Year	Number		Year data collected	
	Age3	Number	Percent	Percent of sample in age 3 category	
	Age4	Number	Percent	Percent of sample in age 4 category	
	Age5	Number	Percent	Percent of sample in age 5 category	
	Age6	Number	Percent	Percent of sample in age 6 category	
	Age7	Number	Percent	Percent of sample in age 7 category	
	Age8	Number	Percent	Percent of sample in age 8 category	
	Age9	Number	Percent	Percent of sample in age 9 category	
	Age10	Number	Percent	Percent of sample in age 10 category	
	Age11	Number	Percent	Percent of sample in age 11 category	
	Count	Number		Sample size for each year	
	Comment	Text		Comments	
TBL_Colville_Annual_CPUE_CV	Obj_ID	Autonumber		Autonumber	
	Year	Number		Year	
	Effort	Number	net-days	effort in net-days of 46 m net	
	Number	Number		Number of Arctic cisco per year	
	CPUE	Number	Fish/net-day	Number of Arctic cisco caught per net-day	
	Site_Code	Text		Location Code, link to Location table	C4

Table B-45. Continued.

Table Name	Field Name	Data Type	Units	Description	Relationships
TBL_Colville_CPUE	Obj_ID	Autonumber		Autonumber	
	SetNo	Text		Set number – a number assigned to each net check, used to relate information from different files.	C5
	Year	Number		year of measurement	
	Site_Code	Text		Location Code	C3
	Code	Number		Numeric code of fisherman ID, consistent across years	
	Net	Text		alphabetic code to identify each net used by a fisherman during a season	
	NetID	Text		combination of year, fisherman code and net code used to identify a unique location where fishing occurred	
	Enddate	Date/Time		Date the net was checked	
	Netlen	Number	m	length of net in meters	
	Mesh	Number	mm	gill net mesh size in millimeters	
	Dur	Number	hours	duration of set in hours	
	Species	Text		species of fish caught (all Arctic cisco in this file)	
	Catch	Number		number of fish caught	
	Effort	Number	net-days	effort in net-days per 18 meters of net	
	CPUE	Number	net-days	fish per net-day per 18 meters of net	
TBL_Colville_Daily_CPUE_CV	Obj_ID	Autonumber		Autonumber	
	Date	Date/Time		Date nets were checked	
	Num_Nets	Number		number of 3” (76mm) mesh nets fished	
	Tot_ARCS	Number		Total catch of arctic cisco (ARCS) for 3” mesh for that day	
	Tot_LSCS	Number		Total catch of least cisco (LSCS) for 3” mesh for that day	
	EffortDays	Number	days	Number of days net fished	
	CPUE_ARCS	Number	Fish/net-day	CPUE of Arctic cisco per net day	
	Site_Code	Text		Location Code	C6
TBL_Colville_Effort	Obj_ID	Autonumber		Autonumber	
	Code	Number		Numeric code of fisherman ID, consistent across years	
	NetID	Text		combination of year, fisherman code and net code used to identify a unique location where fishing occurred	
	Site_Code	Text		Location Code	C2
	Net	Text		alphabetic code to identify each net used by a fisherman during a season	
	RKm	Number	km	river kilometer on the Niġliq Channel where the net was set (nets not on the Niġliq Channel are left blank)	
	NetLen	Number	m	length of net in meters	

Table B-45. Continued.

Table Name	Field Name	Data Type	Units	Description	Relationships
	Mesh	Number	mm	gill net mesh size in millimeters	
	SetDate	Date/Time		Date net was set	
	EndDate	Date/Time		Date the net was pulled	
TBL_Colville_Length	Obj_ID	Autonumber		Autonumber	
	SetNo	Text		Set number – a number assigned to each net check, used to relate information from different files.	C5
	Species	Text		species of fish measured (all Arctic cisco in this file)	
	Length	Number	mm	fork length in millimeters	
	NetID	Text		Net_ID	
LU_Colville_Locs	Obj_ID	Autonumber		Autonumber	
	Site_Code	Text		ABR code unique location identifier	C1,C2,C3,C4,C6
	Site_Name	Text		Name from original file	
	Latdd83	Number		Latitude NAD 1983 of center of area	
	Londd83	Number		Longitude NAD 1983 of center of area	
	Loc_Comments	Text		Comments	
	Loc_OrigCode	Text		Location code of original data	
TBL_Colville_rkm	Obj_ID	Autonumber		Autonumber	
	RKM_Code	Number		Kilometer markers along the Niġliq channel of the Colville River Delta	
	LAT_DD83	Number		Latitude NAD 1983	
	LON_DD83	Number		Longitude NAD 1983	
	RKM_Comments	Text		Comments	
TBL_Colville_Salinity	Obj_ID	Autonumber		Autonumber	
	Year	Number		Year of Data	
	Comment	Text		Comments	
	Site_Code	Text		Area Code, links to Location Table	C1
	Rkm	Number		River Kilometer, as measured from the mouth of Niġliq Channel	
	SiteID	Text		Site ID, not listed most years	
	Date	Date/Time		Date of data collection	
	Depth	Number	m	Depth in meters from the upper surface of ice	
	Salinity	Number	ppt	Salinity	

Table B-45. Continued.

Table Name	Field Name	Data Type	Units	Description	Relationships
TBL_Dev_Beaufort	Obj_ID	Autonumber		Autonumber	
	Year	Number		Year	
	Coastal section	Text		Location along coast, 3 broad areas	
	Season	Text		Season	
	Sea surface state	Text		(Open=Open Water, Frozen=Ice)	
	Activity start date	Text		Start Date	
	Activity end Date	Text		End Date	
	Broad location	Text		General location description	
	Location	Text		Location	
	Well name / fine scale location	Text		Location Name	
	Structure	Text		Structure	
	Activity	Text		Activity	
	Activity sub-category	Text		activity sub-category	
	Duration	Number	hours	Duration of activity	
	Seismic/acoustic lines	Number	km	Length of seismic or acoustic lines	
	5 km blocks seismic	Number		Number of 5 km blocks	
	OCS blocks seismic	Number		Number of OCS blocks	
	Disturbance potential ranking	Text		ABR ranking of potential disturbance	
TBL_Env_Arctic_Oscillation	Obj_ID	Autonumber		Autonumber	
	Year	Number		Year	
	Month	Number		Month	
	AO	Number	Unitless	Arctic Oscillation	
TBL_Env_Bering_Transport	Obj_ID	Autonumber		Autonumber	
	Year	Number		Year	
	Transport	Number	Sv	Estimated water transport through Bering Strait in Sverdrups (106 m³ s-1)	
TBL_Env_Colville_River_Breakup	Obj_ID	Autonumber		Autonumber	
	Year	Number		Year	
	Date_FirstFlow	Date/Time		Approximate Date of First Flowing Water	
	Peak_Elevation	Number	ft	Peak Water Surface Elevation (ft)	
	Date_Peak_Elev	Date/Time		Date of Peak Water Surface Elevation	
	Est_Peak_Discharge	Number	cfs	Estimated Peak Breakup Discharge (cfs)	
	Notes1	Memo		Notes on data 1	

Table B-45. Continued.

Table Name	Field Name	Data Type	Units	Description	Relationships
	Notes2	Memo		Notes on data 2	
	Notes3	Memo		Notes on data 3	
	Notes4	Memo		Notes on data 4	
	Notes5	Memo		Notes on data 5	
LU_Env_DailyDischarge_Locs	Obj_ID	Autonumber		Autonumber	
	Site_Code	Text		Site code links to daily discharge table	E2
	Site_Name	Text		Descriptive site name	
	LonWGS84	Number		Longitude of site WGS84	
	LatWGS84	Number		Latitude of site WGS84	
	Site_no	Number		USGS site number	
	Drainage Area	Number	Sq. miles	Area of upstream drainage	
	Feet_asl	Number	ft	Elevation of sea level	
	Website	Text		Website of site information	
TBL_Env_Daily_River_Discharge	Obj_ID	Autonumber		Autonumber	
	Agency_cd	Text		Agency code	
	Site_Code	Text		Station code	E2
	Dv_dt	Date/Time		date of daily mean streamflow	
	Dv_va	Number	cfs	daily mean streamflow value, in cubic-feet per-second	
	Dv_cd	Text		daily mean streamflow value qualification code see http://waterdata.usgs.gov/nwis/help?codes_help#dv_cd	DM5
LU_Env_Discharge_Locs	Obj_ID	Autonumber		Autonumber	
	Site_Code	Text		Site Code, Links to Discharge Table	E1
	Site_Name	Text		Locations of Discharge Measurements	
	Latitude	Number	Decimal Degrees	Latitude of discharge measurements	
	Longitude	Number	Decimal Degrees	Longitude of discharge measurements	
	River	Text		River of Discharge Measurements	
	Year Start	Text		Year Start	
	Year End	Text		Year End	
	Area	Number	km^2	upstream area	
TBL_Env_NCEP_Daily_Winds	Obj_ID	Autonumber		Autonumber	
	Year	Number		Year	
	Month	Number		Month	

Table B-45. Continued.

Table Name	Field Name	Data Type	Units	Description	Relationships
	Day	Number		Day (based on 6-hourly estimates)	
	uwnd	Number		Wind speeds (m/s) in u-direction (positive is to the east, negative is to the west)	
	vwnd	Number		Wind speeds (m/s) in v-direction (positive is to the north, negative is to the south)	
LU_Env_NCEP_Locs	Obj_ID	Autonumber		Autonumber	
	Site_Code	Text		Site Code, links to data table	E4
	Site_Name	Text		Site Name	
	LonWGS84	Number		Longitude (assume WGS84)	
	LatWGS84	Number		Latitude (assume WGS84)	
TBL_Env_OI_Locs	Obj_ID	Autonumber		Autonumber	
	Site_Code	Text		Site Code, links to data table	E5
	Site_Name	Text		Site Name	
	LonWGS84	Number		Longitude (assume WGS84)	
	LatWGS84	Number		Latitude (assume WGS84)	
TBL_Env_OI_SST_ICE	Obj_ID	Autonumber		Autonumber	
	Site_Code	Text		Site code, links to TBL_Env_OI_Locs	E5
	Year	Number		Year of Data	
	Month	Number		Month	
	SST	Number	C	Sea Surface Temperature ©	
	Ice	Number	Percent	Ice Concentration	
LU_Env_Reynolds_Locs	Obj_ID	Autonumber		Autonumber	
	Site_Code	Text		Site code to link to TBL_Env_Reynolds_SST	E3
	Site_Name	Number		Site Name	
	LonWGS84	Number		Longitude (assumed WGS84)	
	LatWGS84	Number		Latitude (assumed WGS84)	
TBL_Env_Reynolds_SST	Obj_ID	Autonumber		Autonumber	
	Year	Number		Year	
	Month	Number		Month	
	Latitude	Number		Latitude of grid centroid (no datum specified)	
	Longitude	Number		Longitude of grid centroid (no datum specified)	
	SST	Number	C	Sea Surface Temperature °C	

Table B-45. Continued.

Table Name	Field Name	Data Type	Units	Description	Relationships
TBL_Env_River_Discharge	Obj_ID	Autonumber		Autonumber	
	Site_Code	Text		Site code, links to lookup table	E1
	Year	Number		Year	
	Month	Number		Month discharge measured	
	Discharge	Number	m^3/s	River discharge	
	DisFlag	Text		Caveats describing instances were data were estimated.	
TBL_PB_Body_Composition	Obj_ID	Autonumber		Autonumber	
	Month	Text		Month	
	Year	Number		Year	
	Location	Text		Location (always=Prudhoe Bay)	
	Sample	Number		Sample ID	
	Species	Text		Species (Always Arctic cisco)	
	Group	Text		Group ID	
	LengthInt	Text	mm	Length Interval	
	Length	Number	mm	Length in mm	
	Weight	Number	g	Weight in g	
	Lipid	Number	Percent	Percent lipid	
	Protein	Number	Percent	Percent protein	
	H2O	Number	Percent	Average percent H_2O based on 2 replicate samples per fish	
	Ash	Number	Percent	Average percent Ash based on 2 replicate samples per fish	
TBL_PB_Catch	Obj_ID	Autonumber		Autonumber	
	Common_Name	Text		Species common name	L1
	Year	Number		Year of catch	
	Site_Code	Text		Station ID	L2
	Number	Number		Number of fish	
	Comments	Text		Comments	
TBL_PB_CPUE	Obj_ID	Autonumber		Autonumber	
	Date	Date/Time		Date	
	Site_Code	Text		Station ID	L4
	Side	Text		Side of net (E=East, W=West, N=North, S=South)	
	NetSide	Text		Station and side combined	
	CPUE_1	Number	fish/net/24 h	CPUE Age 1	
	CPUE_2	Number	fish/net/24 h	CPUE Age 2	

Table B-45. Continued.

Table Name	Field Name	Data Type	Units	Description	Relationships
	CPUE_3	Number	fish/net/24 h	CPUE Age 3	
	CPUE_4	Number	fish/net/24 h	CPUE Age 4	
	CPUE_3&4	Number	fish/net/24 h	CPUE Ages 3 and 4	
	CPUE_2&3	Number	fish/net/24 h	CPUE Ages 2 and 3	
	CPUE_3+	Number	fish/net/24 h	CPUE Ages 3 and older	
TBL_PB_Effort	Obj_ID	Autonumber		Autonumber	
	Date	Date/Time		Date	L5
	Year	Number		Year	
	Day	Number		Day Number	
	NetSide	Text		Station Code	L6
	Effort	Number	days	Number of Days net in water	
	Comment	Text		Comments	
LU_PB_Species	Obj_ID	Autonumber		Autonumber	
	Common_Name	Text		Species common name	L1
	Scientific_Name	Text		Species scientific name	
	Inupiat_Name	Text		Species_Inupiat name	
	Type	Text		Type of Fish	
LU_PB_Locs	Obj_ID	Autonumber		Autonumber	
	Site_Code	Text		Station Number	L2, L3, L4
	Site_Name	Number		adjusted LGL_Station Code	
	Latitude	Number		Latitude dd83	
	Longitude	Number		Longitude dd83	
	LGL_Code2	Number		LGL_Station Code	
	Region	Text		Region	
	Comment	Text		Comments	
TBL_PB_Temp_Salinity	Obj_ID	Autonumber		Autonumber	
	Date	Date/Time		Date	
	Year	Number		Year	
	Region	Number		Region	
	Site_Code	Text		Site Code, links to Data table	L3
	Type	Text		Type (onshore or offshore)	
	Depth	Number	m	Depth of sample (m?)	

Table B-45. Continued.

Table Name	Field Name	Data Type	Units	Description	Relationships
	Temp	Number	C	Temperature	
	Salinity	Number	ppt	Salinity	
	Problems	Text		List of apparent problems in the dataset	
TBL_Peel_River	Obj_ID	Autonumber		Autonumber	
	Site_Code	Text		Site Code, links to LU_Peel_River_Locs	
	Year	Number		Year of Data	
	Date	Date/Time		Date	
	Fecundity	Number		Fecundity (estimated number of eggs)	
	S#_on_envelope	Text		Sample ID	
	FL(mm)	Number	mm	fork length in millimeters	
	Fork_Class	Number		fork length in millimeters, rounded to nearest 10mm	
	Species	Text		Species (always Arctic cisco)	
	Final_Ages	Number		Estimated age in years	
	Wt_(g)	Number	g	Weight	
	Monitor	Text		Name of person monitoring net	
	Sex	Text		Sex (M or F)	
	GW_(g)	Number	g	Gonad weight in grams	
	Net_Type	Text		Type of gillnet used (E = Experimental, S = Standard)	
	Mesh_Size	Number	in	Mesh Size	
LU_Peel_River_Locs	Obj_ID	Autonumber		Autonumber	
	Site_Code	Text		Site code to link to TBL_Peel_River	P1
	Site_Name	Number		Site Name	
	LonWGS84	Number		Longitude (WGS84)	
	LatWGS84	Number		Latitude (WGS84)	
TBL_Weather_Barrow_Hourly	Obj_ID	Autonumber		Autonumber	
	Site Code	Text		Site Code, links to location table	W3
	Year	Number		Year	
	Month	Number		Month	
	Day	Number		Day	
	Hour	Number		Hours in coordinated universal time	
	Winddir	Number	degrees	vector wind direction in degrees	

Table B-45. Continued.

Table Name	Field Name	Data Type	Units	Description	Relationships
	Wind_ms	Number	m/s	vector wind speed in meters per second	
	Windsteadiness	Number	unitless	Wind Steadiness- 100 times the ratio of the vector wind speed to the average wind speed for the hour.	
	Pressure	Number	millibars	Barometric Pressure hg	
	Temp_C	Number	C	Air temperature in degrees Celsius	
	Dewpoint_C	Number	C	dew point temperature in degrees Celsius	
	Precip_mm	Number	mm	precipitation amount in millimeters	
TBL_Weather_Barrow_Monthly	Obj_ID	Autonumber		Autonumber	
	Site Code	Text		Site Code, links to location table	W5
	Year	Number		Year of Measurement	
	Month	Number		Month of Measurement	
	Measure	Text		Measure (mean, minimum, maximum temperature, or total precipitation)	
	Units	Text		Units of Measure (F=degrees Fahrenheit, IN = inches)	
	Value	Number		Value of measurement	
TBL_Weather_Deadhorse_Daily	Obj_ID	Autonumber		Autonumber	
	Site Code	Text		Site Code, links to location table	W2
	Year	Number		Year	
	Month	Number		Month	
	Day	Number		Day of Month	
	TmaxF	Number	F	Maximum Daily Temperature	
	TminF	Number	F	Minimum Daily Temperature	
	TavgF	Number	F	Average Daily Temperature	
	DepartF	Number	F	Departure from Normal	
	DewPointF	Number	F	Average Dew Point	
	WetBulbF	Number	F	Average Wet Bulb Temperature	
	Heat	Number		Heating Degree Days base 65F, season begins with July	
	Cool	Number		Cooling Degree Days base 65F, season begins with January	
	CodeSum	Text		Significant Weather Phenomena	
	SnowDepthIn	Number	in	Snow/ice on ground	
	PrecipTotal	Number	in	Precipitatiom	
	PrecipFlag	Text		Precipitation descriptor	
	StnPressure	Number	in hg	Average Station Pressure	

Table B-45. Continued.

Table Name	Field Name	Data Type	Units	Description	Relationships
	SeaLevel	Number	in hg	Average Sea Level Pressure	
	WindSpMPH	Number	MPH	Resultant Wind Speed (THE VECTOR SUM OF WIND SPEEDS DIVIDED BY THE NUMBER OF OBSE	
	WindDir	Number	tens of degrees	Resultant Direction (THE VECTOR SUM OF WIND DIRECTIONS DIVIDED BY THE NUMBER OF OBSERVATIONS)	
	AvgWindMPH	Number	MPH	Average wind speed	
	MaxWind5sec	Number	MPH	Maximum 5 second wind speed	
	MaxDir5sec	Number	tens of degrees	5 second wind direction	
	MaxWind2min	Number	MPH	Maximum 2 minute wind speed	
	MaxDir2min	Number	tens of degrees	2 minute wind direction	
LU_Weather_Locs	Obj_ID	Autonumber		Autonumber	
	Site_Code	Text		Site code to link to data tables	W1-W6
	Site_Name	Number		Site Name	
	LonWGS84	Number		Longitude (WGS84)	
	LatWGS84	Number		Latitude (WGS84)	
TBL_Weather_Mackenzie	Obj_ID	Autonumber		Autonumber	
	Site Code	Text		Site Code, links to location table	W4
	Year	Number		Year	
	Month	Text		Month	
	MeanMaxTemp	Number	C	Mean of daily maxima by month (°C)	
	MeanTemp	Number	C	Mean of daily means by month (°C)	
	MeanMinTemp	Number	C	Mean of daily minima by month (°C)	
	ExtrMaxTemp	Number	C	Maximum of daily maxima (°C)	
	ExtrMinTemp	Number	C	Minimum of daily minima (°C)	
	TotalRain	Number	mm	Total amount of all liquid precipitation during month (mm)	
	TotalSnow	Number	cm	Total amount of all frozen precipitation during month (cm)	
	TotalPrecip	Number	mm	Total rainfall + water equivalent of total snowfall (mm)	
	SnowGrnd LastDay	Number	cm	Depth of snow on the final day of the month (cm)	
	DirMaxGust	Number	10's deg	True direction (geographic) of maximum gust (10's Deg)	
	SpdMaxGust	Number	kmh	Speed of the maximum wind gust (km/h)	
	Flag	Text		Comments on data	

Table B-45. Continued.

Table Name	Field Name	Data Type	Units	Description	Relationships
TBL_Weather_Nuiqsut_Daily	Obj_ID	Autonumber		Autonumber	
	Site Code	Text		Site Code, links to location table	W6
	Year	Number		Year	
	Month	Number		Month	
	Day	Number		Day of Month	
	TmaxF	Number	F	Maximum Daily Temperature	
	TminF	Number	F	Minimum Daily Temperature	
	TavgF	Number	F	Average Daily Temperature	
	DepartF	Number	F	Departure from Normal	
	DewPointF	Number	F	Average Dew Point	
	WetBulbF	Number	F	Average Wet Bulb Temperature	
	Heat	Number		Heating Degree Days base 65F, season begins with July	
	Cool	Number		Cooling Degree Days base 65F, season begins with January	
	CodeSum	Text		Significant Weather Phenomena	
	SnowDepthIn	Number	in	Snow/ice on ground	
	Water1	Number	in	Water Equivalent in inches (1200 LST)	
	Snowfall	Number	in	Snowfall in inches 2400 LST	
	PrecipTotal	Number	in	Precipitatiom	
	PrecipFlag	Text		Precipitation descriptor	
	StnPressure	Number	in hg	Average Station Pressure	
	SeaLevel	Number	in hg	Average Sea Level Pressure	
	WindSpMPH	Number	MPH	Resultant Wind Speed (THE VECTOR SUM OF WIND SPEEDS DIVIDED BY THE NUMBER OF OBSE	
	WindDir	Number	tens of degrees	Resultant Direction (THE VECTOR SUM OF WIND DIRECTIONS DIVIDED BY THE NUMBER OF OBSERVATIONS)	
	AvgWindMPH	Number	MPH	Average wind speed	
	MaxWind5sec	Number	MPH	Maximum 5 second wind speed	
	MaxDir5sec	Number	tens of degrees	5 second wind direction	
	MaxWind2min	Number	MPH	Maximum 2 minute wind speed	
	MaxDir2min	Number	tens of degrees	2 minute wind direction	

Table B-45. Continued.

Table Name	Field Name	Data Type	Units	Description	Relationships
TBL_Weather_Nuiqsut_Hourly	Obj_ID	Autonumber		Autonumber	
	Site Code	Text		Site Code, links to location table	W1
	Year	Number		Year of measurements	
	Month	Number		Month of measurements	
	Day	Number		Day of measurements	
	Time	Number		Time of measurements	
	StationType	Text		A02=unattended, A02A=Attended (Observer Present)	
	MaintenanceInd	Text		ASOS Maintenance Indicator, indicates ASOS EQuipment is experiencing maintenance as a result of internal quality assurance checks.	
	SkyCond	Text		Sky Conditions below 12,000 ft agl.	
	Vis	Text		Visibility in statute miles and through 10+	
	WeatherType	Text		Weather Types	
	Tdrybulb	Number	F	Dry Bulb Temperature (Degrees Fahrenheit)	
	DewPt	Number	F	Dew Pt Temperature (Degrees Fahrenheit)	
	Twetbulb	Number	F	Wet Bulb Temperature (Degrees Fahrenheit)	
	Rel_Hum	Number	Percent	Relative Humidity (Percent)	
	Windknots	Number	knots	Wind Speed (knots)	
	Dir	Number	10s of degrees	Wind direction (Tens of Degrees from True North)	
	Sin	Number	radians	Sin of wind direction in radians.	
	Cos	Number	radians	Cos of wind direction in radians	
	DirFlag	Text		VRB=Variable wind	
	WindChGusts	Text	knots	Wind Characteristic Gusts (knots)	
	ValWindCharGusts	Number		Value for wind Character (whole units)	
	StationPressure	Number	100s of in	Station Pressure (inches in hundreds)	
	PressureTendency	Number		Pressure Tendency	
	SealevelPressure	Number	10s of millibars	Sea level pressure, tenth of hectopascals (millibars) shown as last three digits (eg. 013=1001.3 MB)	
	ReportType	Text		AA- Metar (Aviation routine weather report-hourly), SP-Aviation special report	
	TotalPrecip	Number	in	Hourly total Precipitation in inches and hundredths for ReportType=AA, cumulative since last hourly report for ReportType=SP.	
	PrecFlag	Text		T= trace amount of precipitation	

DOMAIN DESCRIPTIONS

Table B-46. Domain Descriptions.

Theme	Domain Table Name	Field	Description	Data Table	Relationships
ANWR	DM_ANWR_TagType	Tag_Code	Tag_Description	TBL_ANWR_Catch	D1-D4
Environmental	DM_ENV_DV_CD	Dv_cd	Description	TBL_Env_Daily_River_Discharge	D5

Appendix C.
Panel of Local Experts' Meeting Minutes

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APPENDIX C: PANEL OF LOCAL EXPERTS' MEETING MINUTES

ARCTIC CISCO MEETING MINUTES FROM JUNE 27 & 28, 2005

Meeting was called to order at 3:30 PM. MMS is the study for the interior state. The objective of the meeting is for more traditional knowledge from local fishermen and analysis of the pattern in the existing data on the Colville River of the Arctic cisco, a subsistence resource of Nuiqsut residents.

Background: Why are we here? To discuss the abundance of Arctic cisco in the 1990's through the years of poor harvest. MMS is the leaser for off-shore development.

Larry Moulton gave us existing data and studies from years back—20 years of scientific data to evaluate with what subsistence residents know of *qaaqtaq* over the years.

The life history of the Arctic cisco is influenced by the wind direction, a major factor for the fish. In June and July, the fish need easterly winds to get into the Colville River delta, and for fishermen to have a good fishing season.

DNA studies taken from the McKenzie River shows that this is where the Arctic cisco spawning area is. A very few fish travel from the McKenzie River to the Colville River and they spend the fist year in the Colville River. In Larry Moulton's 1985 study: fish that traveled from the McKenzie River, DNA showed that the growth pattern of the Arctic cisco grew bigger as they traveled, that over wintering takes place in the Colville River, and that they make their way to the Kuukpik from the McKenzie River. East winds play a major roll in their travel to the Colville.

Joeb Woods Sr. said if the east wind was the factor for the size of the fish and where they traveled then that is what we would catch years before the fish were fat and healthy before the causeways were built.

Panel Discussions: Robert Lampe asked if contaminants in fish are studied. He also said that in 1999 or 2000 when he opened his fish hole there was a sheen of oil in the water. We hardly got fish that year, he said.

Marjorie said in September all kinds of fish come into the Nechelik channel and Colville in abundance. They use to catch all kinds of fish and Arctic cisco was among the fish they would catch. They would have one boat and people on shore holding the net and they drag the net left and right depending on which way the current was pulling the fish to the shore.

Annie Lampe lived in Nuiqsut since 1970 and she fished for years for Arctic cisco. During that time, they were healthy and very silver and fat. Now these days the fish that we catch taste like freezer burn.

Life history and habitat of the Arctic cisco, the *qaaktak* has traveled to the Colville River from the McKenzie River during their first year of life. Once they reach the Colville, they stay about five years before the return to the spawn in the McKenzie River. Study show that the only area they spawn is in the McKenzie. There was no data recorded in 1999 due to funding recourse. Study shows that fishers' catch has two good years and then the catch dropped. Has the coastal climate changed or is the wind direction changed or dropped? In 1998, drilling mud was lost and in 1999 was the lowest catch of fish in Nuiqsut. We had an average of one to two fish a day. Studies also show that the first five years catch with a fyle net at Prudhoe Bay was good, but after five years, there was a drop to where there was no fish caught at all. In 1993–1996 there was no fish caught.

Factors potentially impacting the Arctic cisco:

1. Over fishing or over catching could be the factor

2. Environmental Factors, productivity in the McKenzie River, Changes in the Beaufort Sea, changes in the Colville River

3. Human Factors, cause waves, construction of under sea pipe line, ice bridge and ice roads, introduction of contaminants of drilling mud, and commutation effects of on shore and off shore development

Ranking by #1

1. Effect of development and human activity

2. Renew previously collected data and including elders' info

3. Arctic cisco life history

4. Migration of the Arctic cisco

5. Water quality or contamination

6. Genetic source of stock

7. Ice road and bridges

8. Seismic noise

9. Climate change

Social and economics: What happens when residents do not catch *qaaqtaq*? Does this affect our way of life?

Renew previously collected data including elder's information. Put Canada and Alaska's information together and compare. Local fishers review total of nets and fish caught and net locations. Find out where the *qaaqtaq* is in the Colville River in the fall time. Gather traditional knowledge on paper and compare it to scientific knowledge. Spotted seals use to be seen in the upper ridges of the Colville River as they followed the *qaaqtaq* and other fish. Seals are now hardly seen in the river as they use to a lone time ago.

Compare McKenzie and Colville River data by names. To what extent the fish size has decreased with time and what is the cause of it. What are the reasons for *qaaqtaq* changes in abundance? What causes the decrease in the *qaaqtaq*?

ARCTIC CISCO MEETING MINUTES FROM NOVEMBER 8 & 9, 2005

The meeting was held at the KSOPI office on November 8 & 9 2005. Present were Gordon Mautmeak, Robert Lampe Sr., Marjorie Ahunpknana, Samuel Tukle, Gordon Brown, Leonard Lampe Sr., Archie Ahkiviana. The panel wanted to know how they were put together. We told them that the KSOPI Board picked them.

The panel wanted to know why there is a drop in the Arctic cisco. There was data from Deadhorse, the McKenzie, and the Colville River. They have been also taking data from the Beaufort Sea for about 20 years now. The Panel's question was: What could we do to help? MMS and ABR looked at the most important questions that the panel had. We went through all the data and we know that the Arctic cisco spawn in the McKenzie. In the ocean in the summer the winds blow them over to the Colville River. When the Arctic cisco are about 7 or 8 years old, they go back to the McKenzie River to spawn. Most of the fish that Nuiqsut catches are about 5 and 6 years old. The Peel River catch the fish that are 9 years or older. There was a slide of wing speeds that were collected from 1976 to 2004. From 1951 to 2002, the wing was blowing from west to east.

Questions:

What is over catch?

How much is too much?

How many fish are coming in?

Are there any young fish coming in?

Is the wind the biggest factor?

Why in 2002 and 2003 there was no young fish showing up?

Why are the Arctic cisco numbers going up and down?

Is there no fish because of the causeways?

Do we need to look at human factors?

Are there hardly any fish because of the ice bridges being built on the rivers and creeks?

In 1990's, there was a drop in the fish. However, it is not all because of the winds. From 1993 six years later there was a big drop in the *qaaktaq*. From the finds in Deadhorse from 1990's, there is a lower catch in recent years. In hypothesis, eight said why the size change has in the fish.

ARCTIC CISCO MEETING MINUTES FROM OCTOBER 19 & 20, 2006

(not submitted)

ARCTIC CISCO MEETING MINUTES FROM FEBRUARY 2007

(not submitted)

Appendix D.

Technical Summary Prepared for the Panel of Experts

[Original was printed in color]

ANALYSIS OF VARIATION IN ABUNDANCE OF ARCTIC CISCO IN THE COLVILLE RIVER: ANALYSIS OF PATTERNS IN EXISTING DATA

(MMS Contract 1435-01-04-34979)

SUMMARY REPORT OF TECHNICAL FINDINGS

Prepared for

The Nuiqsut Panel of Experts
and
The Kuukpik Subsistence Oversight Panel, Inc.

Prepared by

ABR, Inc.—Environmental Research & Services
Stephen R. Braund & Associates
Sigma Plus, Statistical Services
and
MJM Research

January 2007

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PURPOSE AND NEED FOR THE STUDY

The purpose of this study was to evaluate existing scientific data and traditional knowledge in order to increase the understanding of the variability in abundance of *qaaktaq* (Arctic cisco) in the Colville River. An improved understanding of the causes of this observed variability is needed by the Minerals Management Service (MMS) to support environmental risk assessments, Environmental Impact Statements for potential oil and gas leasing, and for other decision documents in the Beaufort Sea Planning Area.

QAAKTAQ IN THE COLVILLE RIVER

Qaaktaq are important to the culture of the Iñupiat on the North Slope, and the subsistence fishery on the Colville delta provides a major food source for the people of Nuiqsut. Subsistence catches in the Colville River vary yearly from an estimated low of 3,935 fishes in 2001 to a high of 46,944 fishes in 1993. This study was begun, in part, by concerns over very poor catches in 2001 and 2002, which were among the lowest on record.

The current understanding of the life history of this fish suggests that most or all *qaaktaq* in the Beaufort Sea originate from adults spawning in the Mackenzie River (Fig. D-1). In the spring, juvenile (i.e., young-of-the-year) *qaaktaq* are carried downriver into ice-free waters of the coastal Beaufort Sea and then are transported westward towards Alaska by currents. If easterly winds prevail during the summer, juvenile *qaaktaq* can be carried as far west as Prudhoe Bay and the Colville River region, where they take up winter residence. While juveniles may overwinter in the Sagavanirktok Delta, most juveniles and adults (age 2 and older) are believed to overwinter in the brackish waters of the Colville delta, which is the only river in Alaska known to support significant numbers of overwintering *qaaktaq*. In summer, subadult *qaaktaq* swim into Beaufort Sea coastal waters to feed. They remain in the Colville River region until the beginning of sexual maturity at about age seven. At this age they migrate east to the Mackenzie River for fall spawning. *Qaaktaq* will remain in the Mackenzie region for the rest of their lives after spawning and continue spawn every other year or so (*qaaktaq* live up to 19 years or more).

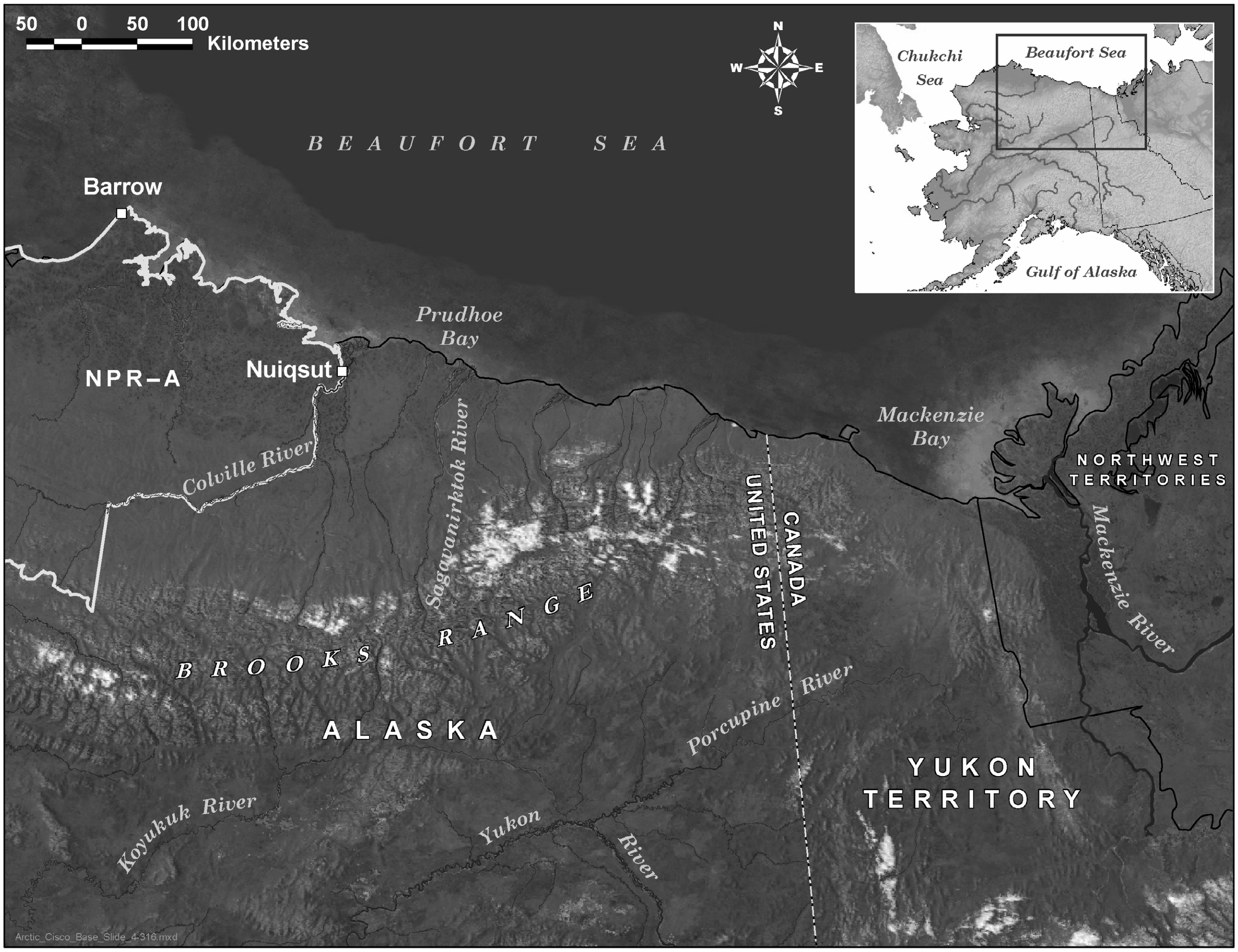

Figure D-1. Map of the North Slope and coastal Beaufort Sea showing the spawning (Mackenzie River system), summer feeding (nearshore waters of the central Beaufort Sea), and overwintering areas (Colville River delta) for *qaaktaq*.

Qaaktaq do not return to the Colville region after returning to Canada. We know this because few fish older than seven years are ever caught in the Colville River. Also, few fish younger than seven are caught in the McKenzie River system (Fig. D-2).

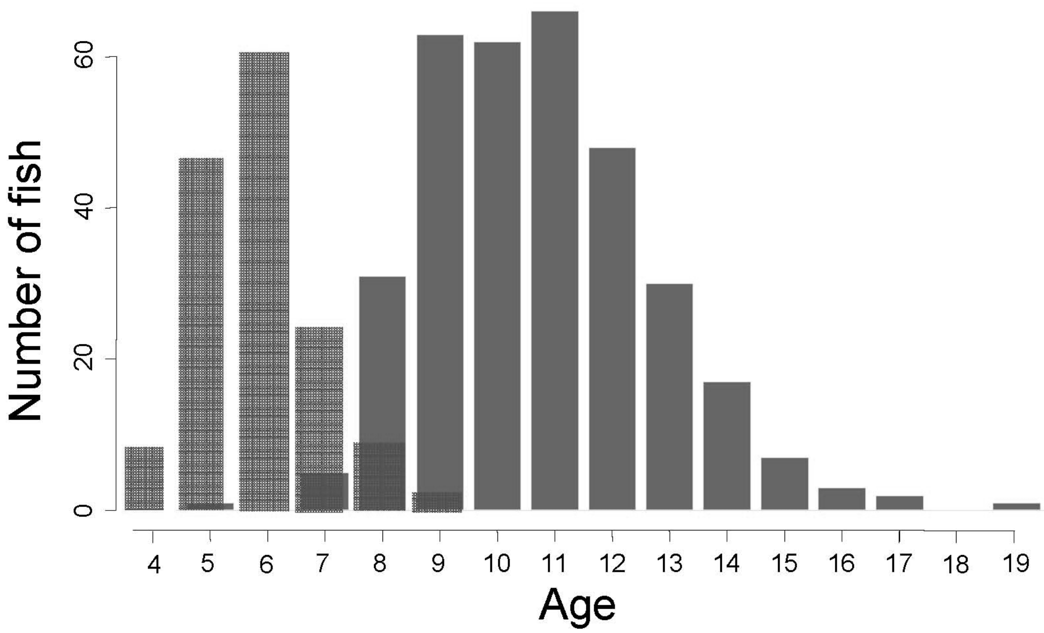

Figure D-2. Average age composition of *qaaktaq* caught in the Colville River (checked bars) and in the Mackenzie River system in the Yukon territory (solid bars).

DATA SOURCES AND ANALYSIS

In order to examine the potential effects of environmental changes and oil and gas development on *qaaktaq*, we assembled databases which included:

- Subsistence and commercial fishing data for the Colville delta including catch totals, fishing effort, and the size and age of fish.
- Catch-per-unit-effort of various age-groups of *qaaktaq* and other species in the Prudhoe Bay region (from nearshore Beaufort Sea fish monitoring project reports).
- Salinity and temperature measurements (from nearshore Beaufort Sea fish monitoring project reports).
- Salinity measurements for the Colville River (from harvest reports).
- Sea-surface temperature and ice concentrations for the coastal Beaufort Sea (from the NOAA-CIRES Climate Diagnostics Center).
- Air temperature and precipitation for Inuvik and Tuktoyaktuk, Yukon Territory (from Environment Canada).

- Air temperature, precipitation, and wind speeds for Barrow, Nuiqsut, and Deadhorse, Alaska (from NOAA).
- Wind speed data for coastal Beaufort Sea (from the NOAA-CIRES Climate Diagnostics Center).
- River discharge rates for the Mackenzie, Kuparuk, Sagavanirktok, and Colville Rivers (from Environment Canada and the US Geological Survey).
- Information on oil and gas related activities (from Alaska Department of Natural Resources and Minerals Management Service).

In order to examine the potential influence of environmental and human factors on *qaaktaq*, we first developed a set of indicator variables. These indicators attempt to simplify the biological, environmental, and human disturbance data. The main biological variables are:

- The number of *qaaktaq* arriving in the Prudhoe Bay region.
- Survival rates from the time of arrival in the Colville region to the time they are caught in the fishery.
- Catch rates (standardized by effort) in the fishery.
- Indicators of size or health.

PANEL OF EXPERTS

It was important to include the community of Nuiqsut in the project from beginning to end. With help from Kuukpik Subsistence Oversight Panel, Inc. (KSOPI), the study team searched for Nuiqsut residents who were:

- experienced and knowledgeable about *qaaktaq*,
- were willing to work with scientists to explore the reasons for variability in *qaaktaq* abundance, and
- were able to attend workshops and meetings with visiting scientists.

Ten residents were selected to be on a Panel of Local Experts after a screening process in which the study team explained the project and participant roles in the study to Nuiqsut residents:

- Joeb Woods Sr.
- Dora Nukapigak
- Gordon Matumeak

- Gordon Brown
- Robert Lampe Sr.
- Bernice Kaigelak
- Sam Tukle
- Archie Ahkiviana
- Marjorie Ahnupkana
- Frank Oyagak Jr.

The primary roles of the Panel as outlined by MMS were to evaluate the findings of the scientific team and to identify other sources of information, including traditional knowledge, that would help the scientific team understand the observed annual changes in *qaaktaq* abundance. To accomplish these goals, a series of meetings were held in Nuiqsut:

- <u>Public Meeting and Panel Selection (March 2005)</u>—introduction of project and the scientific team to the community. Selection of the Panel of Experts.
- <u>Panel Meeting No. 1 (June 2005)</u>—review scientific community's current knowledge of *qaaktaq*. Ask panel for input on changes in *qaaktaq* abundance.
- <u>Panel Meeting No. 2 (November 2005)</u>—presentation of results of analyses addressing the effects of natural factors on changes in *qaaktaq* abundance.
- <u>Panel meeting No. 3 (October 2006)</u>— presentation of results of analyses addressing the effects of human factors on changes in *qaaktaq* abundance
- <u>Panel Meeting No. 4 (January 2007)</u>—review technical results and conclusions (this document) and address any questions the Panel or KSOPI has regarding their reporting responsibilities.

The Panel of Experts identified these *qaaktaq* issues:

- Fewer fish available to subsistence fishery
- Reduced size and/or weight of fish
- Changes in distribution of fish in the Colville River
- Changes in quality of fish (taste, texture, color)
- Deformed fish
- Food chain effects (changes in prey availability and prey types)
- Energetic stress (cost of navigating obstructions)

Also during the first two panel meetings, the Panel of Experts identified potential human-related causes for changes in *qaaktaq* abundance:

- Obstructions
- Noise
- Vibration
- Contaminants
- Upstream gravel extraction
- Over harvest by fishing
- Siltation in nearshore waters

MAIN FINDINGS

Arctic cisco catches in the Colville River fishery (Fig. D-3) vary because of annual differences in the actual number of adult Arctic cisco in the region during the fall fishery and because of

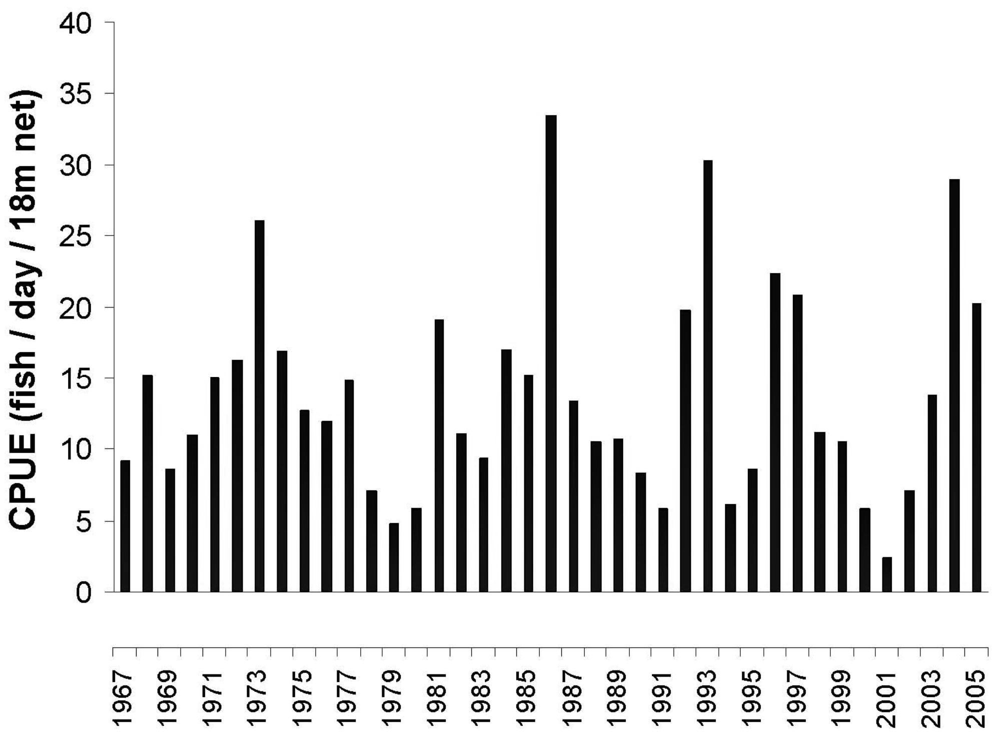

Figure D-3. Catch rates of *qaaktaq* on the Colville delta from 1967 through 2005 as estimated from the commercial fishery (1967–1984 and 1999), a combination of commercial and subsistence fishery indices (1985–2002, except 1999), or from the subsistence fishery alone (2003–2005).

changes in their availability to the fishery. The actual number, or abundance, of Arctic cisco in the Colville region may depend on:

- the number of juvenile Arctic cisco that are hatched in the Mackenzie River in preceding years and
- the number of young Arctic cisco that survive to the time they are large enough to be caught in the fishery.

The availability of Arctic cisco to the fishery may vary with:

- the spatial distribution (horizontally and vertically) of fish in the Colville River system,
- the location of the fishery,
- the type of fishing gear used (mesh size), and
- other factors.

In this report, we summarize the effects of environmental variability and of human activities on Arctic cisco for various life stages from the time of spawning in the Mackenzie River to the time they are caught in the Colville River fishery.

1. WESTWARD TRANSPORT OF AGE-0 JUVENILES

After juvenile *qaaktaq* enter the coastal Beaufort Sea from the Mackenzie River, they need to migrate or be transported by currents westward if they are to reach Prudhoe Bay and the Colville River. Previous research has shown that the number of young *qaaktaq* arriving at Prudhoe Bay is mainly a function of wind direction and speed. We updated this previous research by examining the relationships between the numbers of *qaaktaq* arriving at Prudhoe Bay and environmental variables like coastal water temperature, ice conditions, and offshore drilling and seismic activity.

Our results confirm that many of the yearly differences in numbers of *Qaaktaq* arriving in Prudhoe Bay (Fig. D-4) are a result of the strength of easterly winds (Fig. D-5). If winds are weak from the east or if they tend to be westerly on average, then not many young q*aaktaq* will arrive in Prudhoe Bay that year. Wind speed does not explain everything to do with variation in recruitment, however. The variation not explained by wind, referred to as an anomalies, could be caused by other environmental factors (e.g., water temperature) or by human

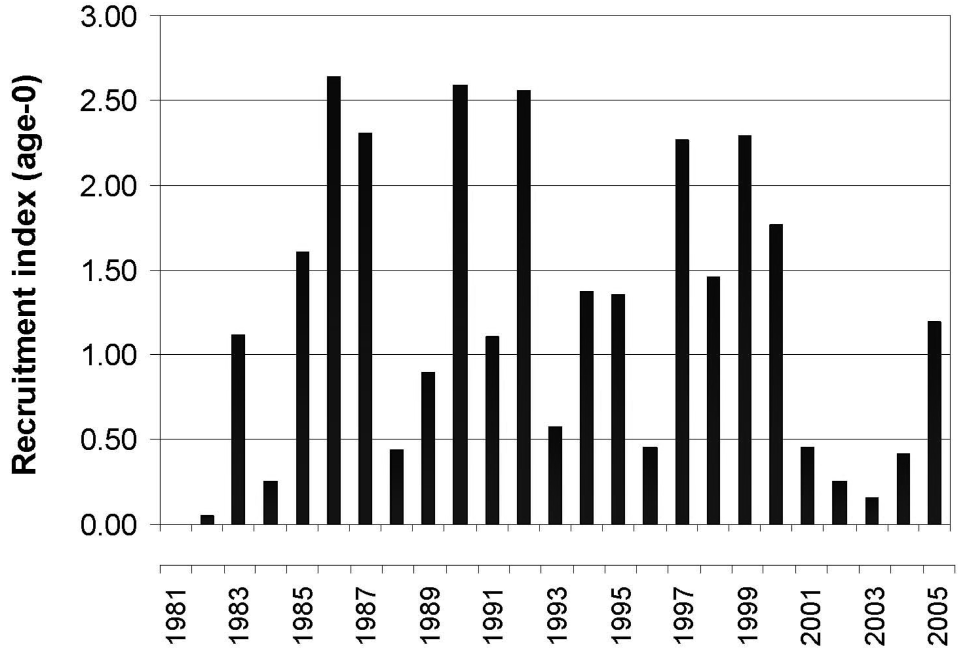

Figure D-4. Index reflecting the number of young-of-the-year *qaaktaq* arriving in Prudhoe Bay, 1981–2005.

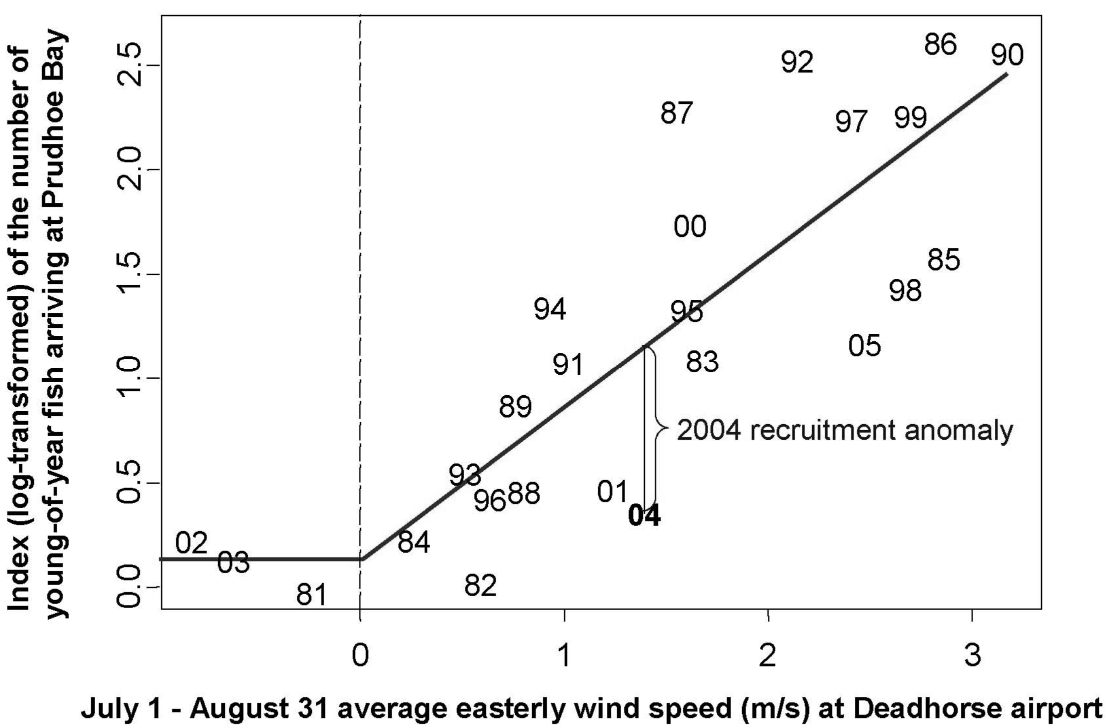

Figure D-5. Predicted effects of easterly winds on the number of age-0 *qaaktaq* recruiting to Prudhoe Bay, as estimated from a linear model with threshold. Numbers denote the last two digits of the corresponding year. The 2004 recruitment anomaly is highlighted.

disturbance. Recruitment anomalies were low in the early 1980s, increased in the mid-1980s, and have shown a significant declining trend since then with below-average recruitment in recent years (Fig. D-6). **We found no significant effects of temperature or ice conditions during early ocean life on recruitment anomalies of *qaaktaq*. There was weak evidence that recruitment anomalies in Prudhoe Bay were higher during years with above-normal discharge in the Sagavanirktok River. There was no evidence that the amount of seismic activity or the number of drilling operations during a given year in the eastern Beaufort Sea (east of the Sag River) were related to recruitment success in the same year. Therefore, the observed variability and the recent declining trend in recruitment anomalies must be due to other, unobserved changes in the Mackenzie River or during early ocean life.**

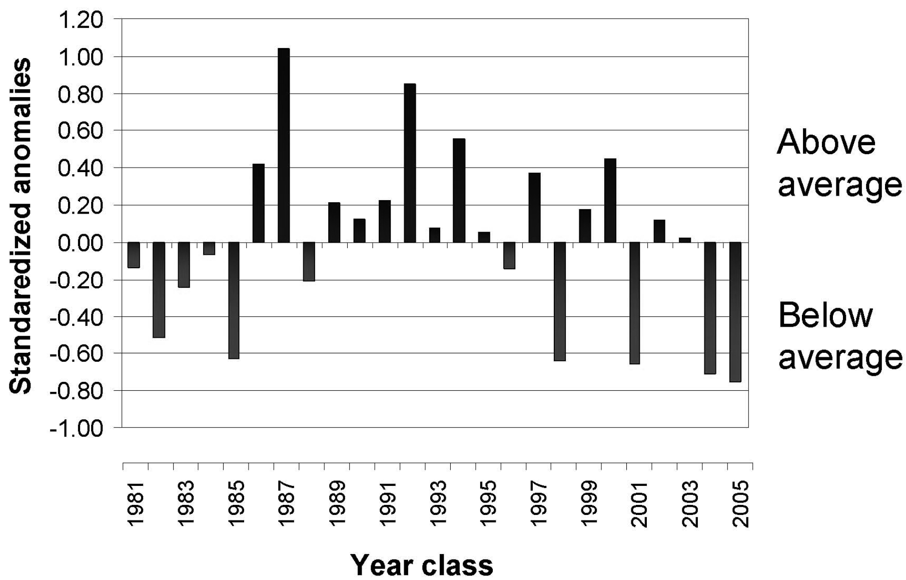

Figure D-6. Unexplained variability in recruitment (recruitment anomalies) computed as the difference between observed and predicted recruitment based on wind effects (see Fig. D-5)

2. SURVIVAL FROM AGE-0 TO AGE-5

After young *qaaktaq* arrive in the Prudhoe Bay region, they may spend their first winter(s) in the Sagavanirktok delta. However, to contribute to the Colville fishery, they must be able to migrate between summer feeding grounds in the Beaufort Sea and overwintering areas in the

Colville River. *Qaaktaq* are first caught in the fishery at about 5-years of age. A 5-year old fish caught in the Colville River today would have arrived in Prudhoe Bay as an age-0 fish 5 years ago. There is a relatively good relationship between the catch rate of age-5 fish today and the arrival of age-0 fish at Prudhoe Bay five years earlier (Fig. D-7).

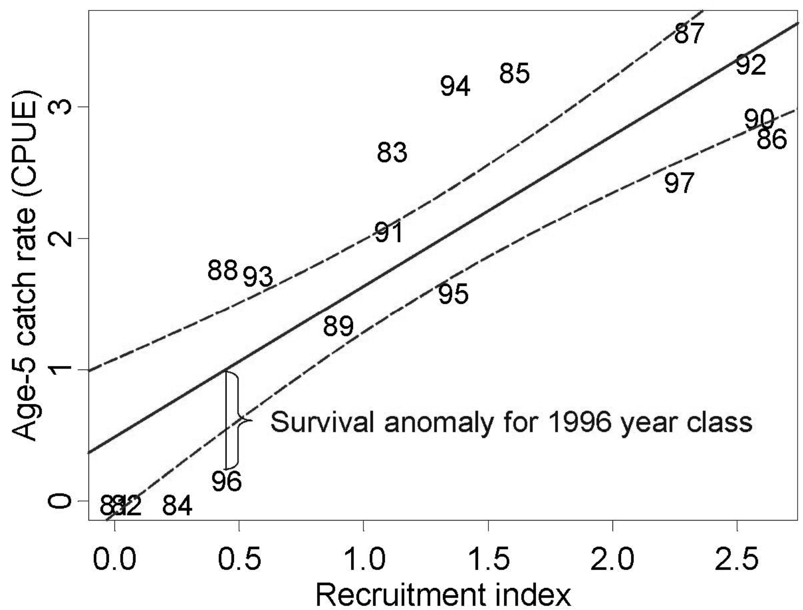

Figure D-7. Relationship between Age-5 catch rate in the commercial fishery and index of recruitment of *qaaktaq* to Prudhoe Bay with regression line and 95% confidence interval. Numbers denote the last two digits of the corresponding year class (year when fish were hatched and first entered the ocean). Solid line shows predicted catch rate assuming a linear relationship between catch rate at age-5 and age-0 recruitment. Survival anomaly for the 1996 year class over the period from 1996 to 2001 is indicated.

Differences between the observed catch rate of 5-year olds and the predicted catch rate from the number of age-0 recruits (caught 5 years earlier) occur because of both estimation errors and because of true differences in survival (Fig. D-7) between different year classes. We examined relationships between survival and environmental variables or human activities in the region. Because effects on the survival of *qaaktaq* may occur at any time between the age of recruitment (age-0) and age-5, we examined relationships at multiple time lags corresponding to environmental conditions experienced at age-0, age-1, etc., through age-5. In addition, we tested for significant relationships between age-0 to age-5 survival anomalies and environmental conditions averaged over the previous 6 years.

We found no significant relationships between any of the environmental variables examined and age-0 to age-5 survival anomalies. Similarly, we found no significant relationships between any of the indicators of human activity and age-0 to age-5 survival anomalies, at any age. In particular, we found no evidence that survival anomalies differed significantly before and after the construction and breaching of the Endicott causeway. Although average survival anomalies decreased after the construction of the Endicott causeway and decreased again after breaching, the differences were not statistically significant in light of the large variability among years (Fig. D-8). Furthermore, a decrease in survival anomalies after breaching is counterintuitive because breaching should facilitate feeding migrations along the

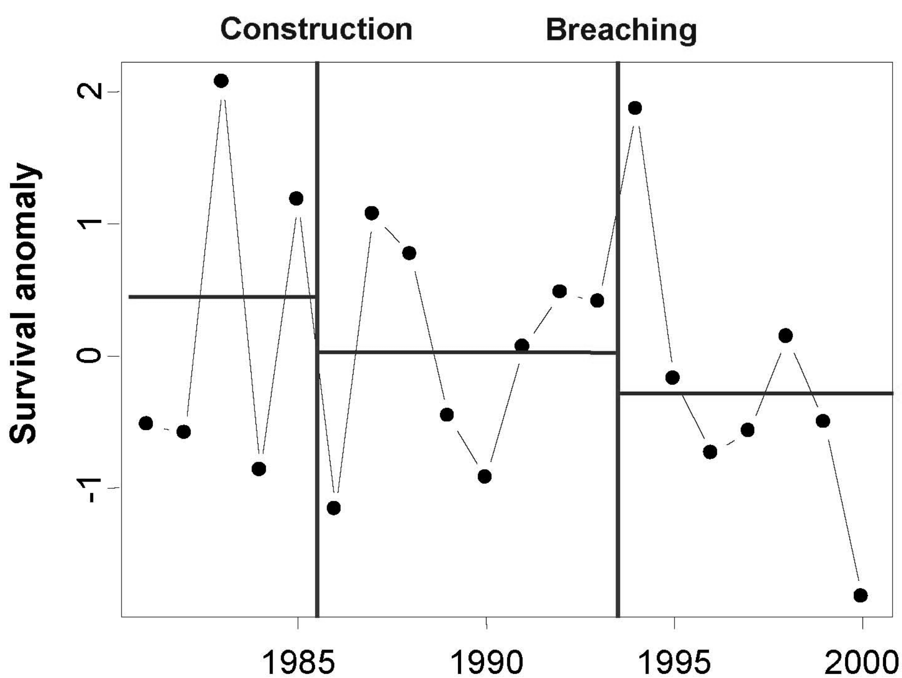

Figure D-8. Age-0 to age-5 survival anomalies by year class relative to the construction and breaching of the Endicott causeway (vertical lines). Horizontal bars denote means by period.

coast. The survival anomaly index does not extend back far enough to compare survival before and after construction of West Dock, but does span the breaching of West Dock in 1995–1996. **Survival anomalies after breaching of West Dock were somewhat lower than before breaching**, but the difference was only marginally significant ($p = 0.081$, implying an 8% probability that the difference is due to chance). The decrease was again counterintuitive, unless breaching changed the hydrographic conditions in the vicinity of West Dock to the detriment of *qaaktaq* that feed in the region or migrate along the coast.

3. SURVIVAL FROM AGE-5 TO AGE-7

Qaaktaq caught in both the commercial and subsistence fisheries range from 5 to 8 years of age. Few older fish are present because they leave the region to return to the Mackenzie River to spawn. Ages 6 and 7 are the most common age classes of *qaaktaq* in the fall fishery. Their abundances depend on the strength of the incoming year-classes and their survival from year-to-year. We estimated survival anomalies that measure the difference between observed and expected catch rates of these age groups. Survival anomalies were related to environmental or development indicators that could have affected these age classes during the preceding year in either the summer feeding or overwintering areas.

We found a significant relationship between our summer climate index (reflecting temperature, ice conditions, and discharge) for the central Beaufort Sea shelf and the survival of subadults from age 5(6) to age 6(7). The relationship was negative (Fig. D-9), suggesting that survival is apparently reduced during summers with above-average temperatures and discharge rates and below average ice concentrations. This result contrasted with our hypotheses that growth and survival are enhanced during warm years. However, the relationship is strongly influenced by a single year with an unusually high survival anomaly (1985, see Fig. D-9).

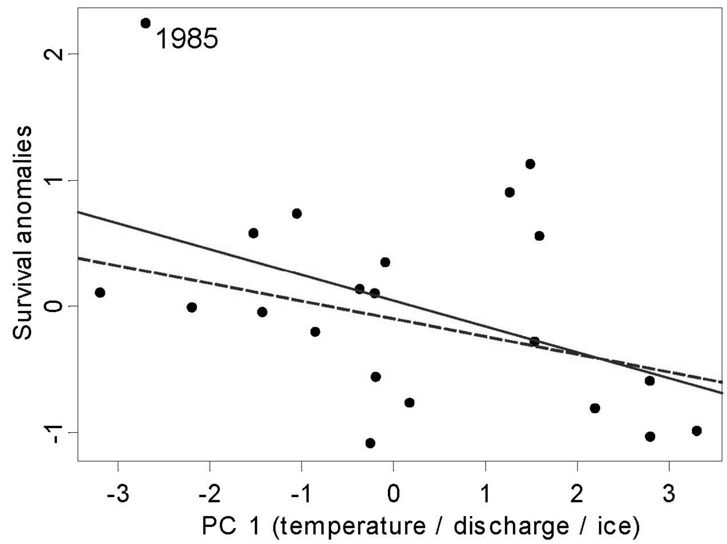

Figure D-9. Relationship between age 5(6) to age-6(7) survival anomalies and an index of environmental conditions in central Beaufort Sea (PC 1, higher values denote higher temperature and discharge, reduced ice).

We found that a period of low survival of adult *qaaktaq* from 1997 to 2001 coincided with the period of development activity in the Colville delta and the larger Colville region (Fig. D-10). However, the relationship was not statistically significant and was strongly affected by the large 1985 recruitment anomaly.

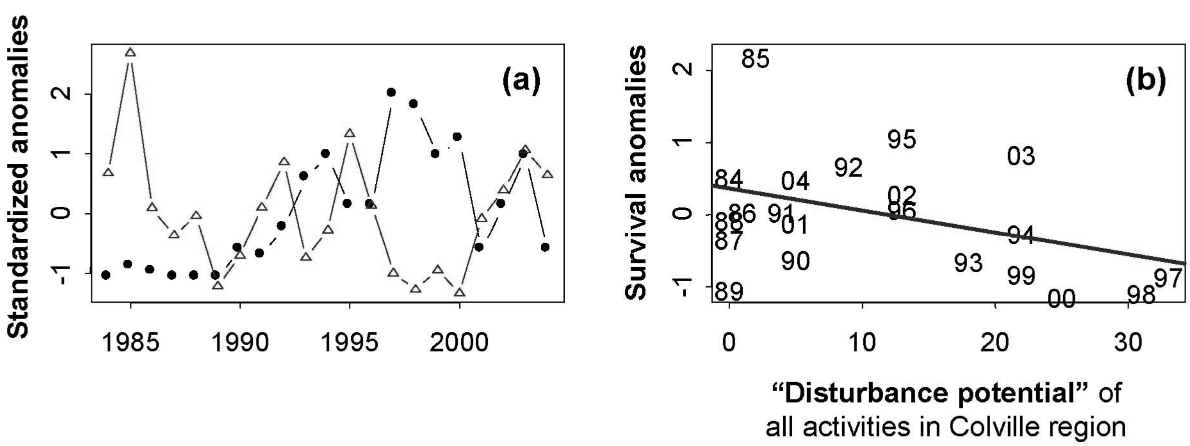

Figure D-10. (a) Time series of the “disturbance potential” of all development activities in the Colville region (solid black circles/line) and of age-5(6) to age-6(7) survival anomalies (open triangles/line), 1984–2004, and (b) scatterplot of survival anomalies against disturbance potential.

4. COLVILLE RIVER: CATCH RATES IN THE FISHERY

There was good agreement between catch rates in the commercial fishery and the subsistence fishery, as well as between catch rates from different locations within the Nigliq channel. Thus, we estimated average annual catch total by combining catch rate estimates from the commercial and subsistence fishery (Fig. D-3). Because of their unique life history, any environmental or development changes affecting juvenile and subadult stages can affect catch rates in the fishery. Catch rates also may vary as a result of local conditions that affect where *qaaktaq* are relative to the fishery, and also due to differences in fishing gear. Since gear can differ by mesh size and length, we used catch rates for the most frequently used mesh (3 inch) and standardized catches to a unit of fishing effort (# of fish per 18-meter net per day). We examined relationships between catch rates in a given year and environmental or development changes for the same year as well as the previous 8 years.

As expected, catch rates were related to average easterly wind speeds in the Beaufort Sea 5–8 years earlier (for example age-6, Fig. D-11). We modeled catch rates as a function of average wind speeds 5–8 years earlier and computed the difference between the observed and predicted catch rates as an index of catch rate anomalies (Fig. D-12). The anomalies reflect unexplained variability in catch rate that is not related to wind. The most notable feature of these anomalies is the unusually large negative catch rate anomaly in 2001 (Fig. D-12). **We did not identify any particular event (such as an oil spill or other disturbance event) or any unique combination of environmental or development indicators that could account for the unusually low catch rate in 2001.**

Local catch rates in the Colville River, based on individual sets, varied substantially with the salt content in the river (at 3–4 m depth) measured at a nearby location. Average catch rates increased substantially with increasing salt content to a maximum catch rate at salinities of around 24 parts per thousand (Fig. D-13) and decreased at higher salinities. These

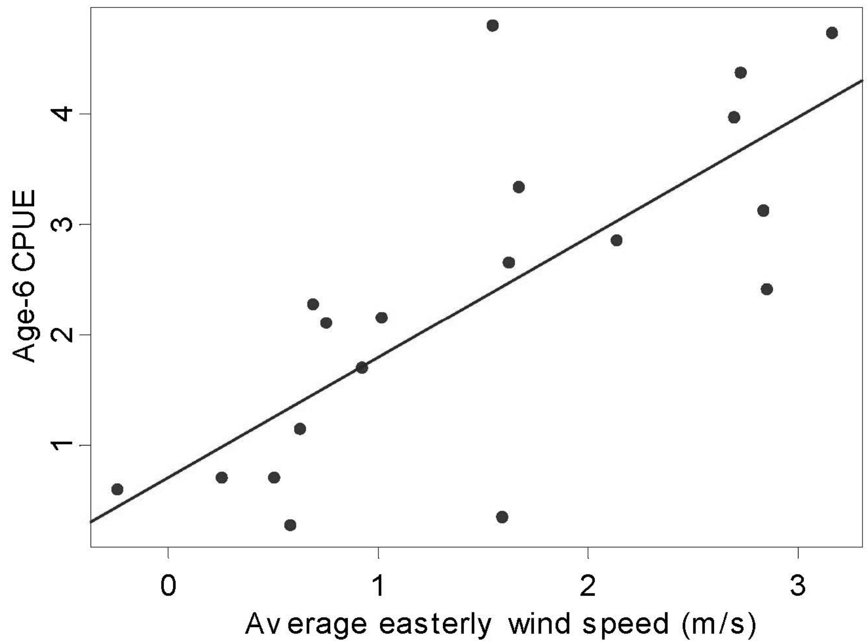

Figure D-11. Catch rate (CPUE) of age-6 *qaaktaq* in the commercial fishery against the average easterly wind speed (July 1 – August 31) at Deadhorse airport 6 years earlier.

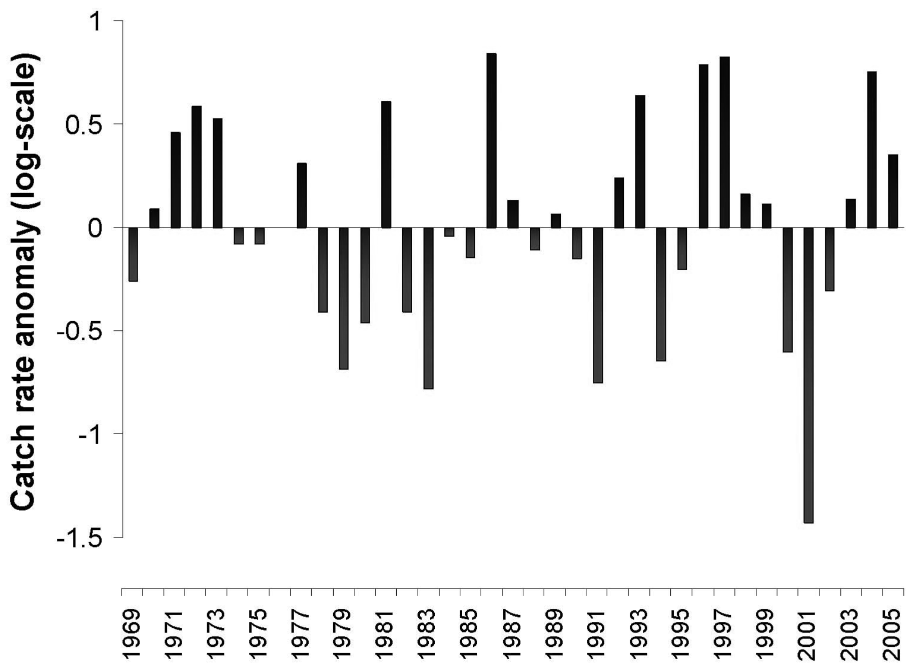

Figure D-12. Catch rate anomalies of *qaaktaq* in the Colville River fishery. Anomalies reflect the difference between observed catch rates and predicted catch rates based on the relationship between average summer wind speeds 5–8 years earlier and catch rates in the fishery.

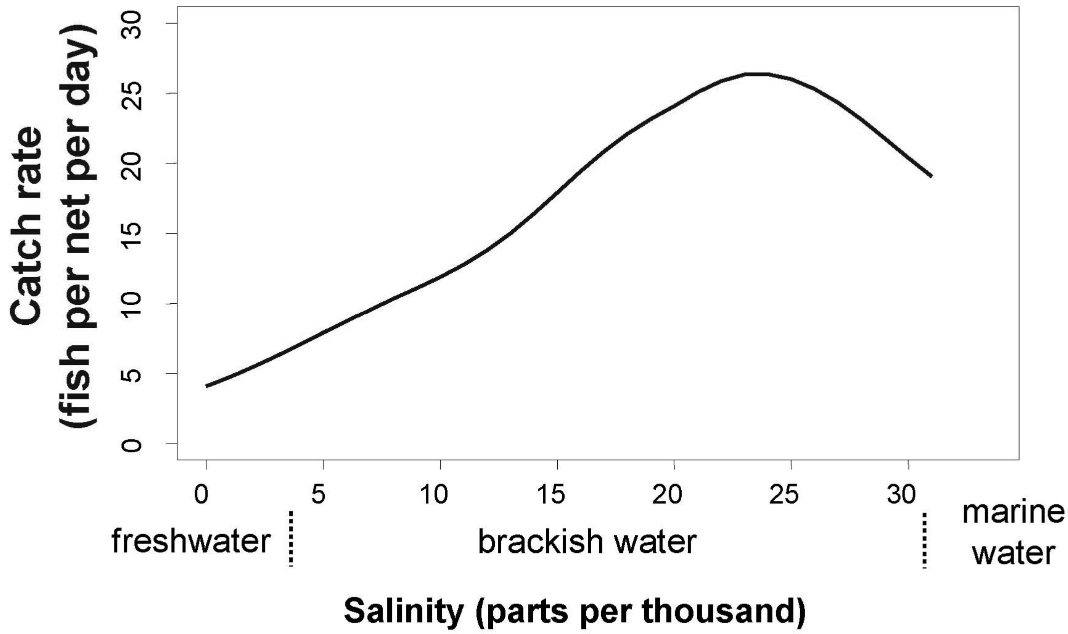

Figure D-13. Estimated average catch rate of *qaaktaq* in the Colville River fishery at different levels of salinity.

results suggest that *qaaktaq* prefer brackish waters with relatively high salt content. In addition, average catch rates decreased over the course of the fishing season from mid-October to mid-November (Fig. D-14). This decrease can likely be attributed to "local depletion," a common effect attributed to the effect of reducing the number of fish in an area and therefore reducing catch rates.

We found a significant increase in the annual average catch rate anomalies (adjusted for wind effects) with increasing average salinity in the river (Fig. D-15). This effect is likely to result from annual changes in spatial distribution of *qaaktaq* relative to the fishery rather than true abundance in the Colville region. This may explain why catch rates in 2001 were lower than average (Fig. D-15). Catch rates also were significantly higher after warm summers with low ice concentrations in the spring (not shown). It is unclear whether there may be a causal relationship between coastal temperature in summer and catch rates in the following fall.

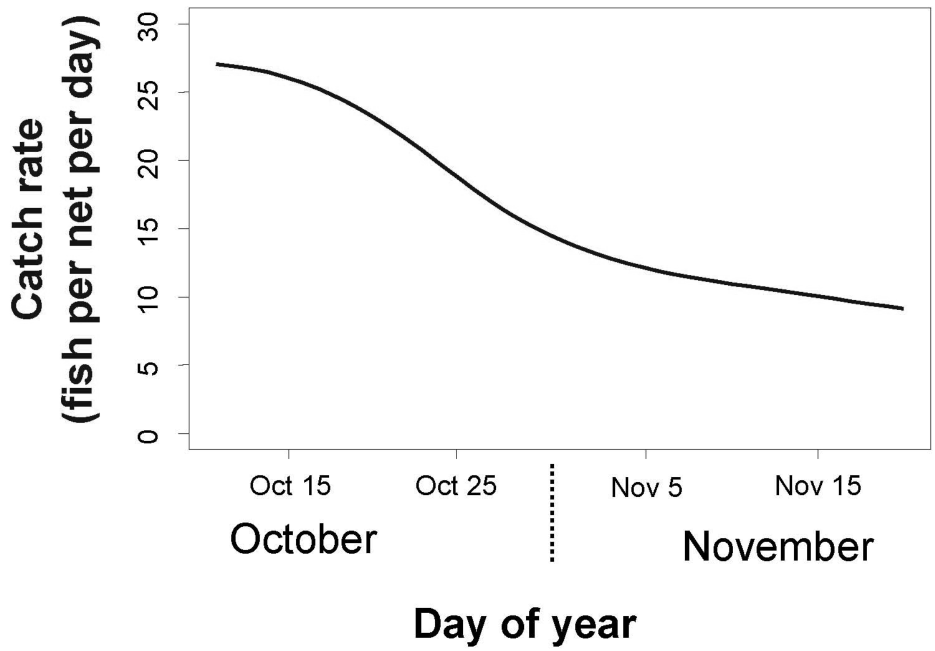

Figure D-14. Estimated average catch rate of *qaaktaq* in the Colville River fishery by day of year over the course of an average fishing season (same scale on the y-axis as in Fig. D-11 for comparison)

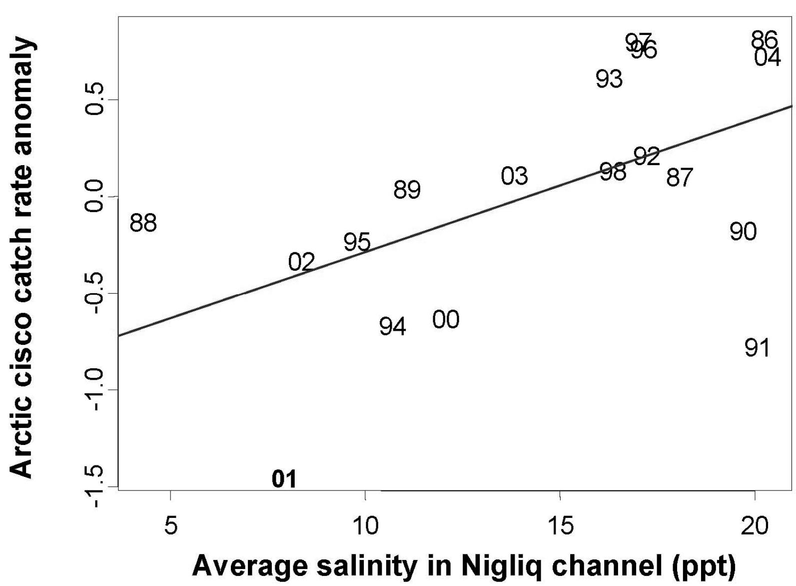

Figure D-15. Relationship between average salinity in the Niġliq channel during fall and average annual catch rate of *qaaktaq* in the fall fishery with linear regression line. Numbers denote years.

Catch rates of *qaaktaq* in the Colville fishery did not change significantly after the construction of causeways (West Dock or Endicott) or after breaching (Fig. D-16). There was no evidence that either the construction or the breaching of causeways had any effect on the catch rate of *qaaktaq* 6 years later (or at any other time lag). While catch rates decreased slightly after West Dock construction and increased slightly after Endicott construction, none of the differences were statistically significant. Interestingly, abundance of humpback whitefish in the Prudhoe Bay region, increased dramatically after breaching of the West Dock causeway in 1995/96.

We found some evidence that average catch rates were reduced following several years with relatively intense development activity in the Colville Delta (including drilling, construction, and ice roads). Specifically, catch rate anomalies were significantly lower if development activities exceeded a certain threshold (Fig. D-17).

We found no evidence that other activities in the central and western Beaufort Sea, or in the offshore areas (including drilling and seismic activity) were related to catch rates in the Colville fishery.

5. SIZE AND GROWTH OF *QAAKTAQ*

Though we lack a distinct measure of condition from the fishery, the poor appearance of *qaaktaq* ("skinny fish") was evident in their greatly reduced size-at-age for most age classes in the Prudhoe Bay region during the summers of 2002 and 2003 (Fig. D-18). By 2004, most age classes had largely recovered from the "lost" growth of the previous 2 years. Therefore, the relative size-at-age index (Fig. D-18) appears to reflect recent growth conditions.

Based on patterns in size-at-age and summer winds, we hypothesize that the small size of *qaaktaq* in 2002 and 2003 was caused by reduced prey availability resulting from a lack of upwelling of deep, nutrient-rich waters onto the shelf due to unusual westerly winds in 2002 and 2003. The two years with "skinny fish" coincided with the only two summers since 1981 when the wind blew predominantly from the west (Fig. D-17). Westerly winds imply that onshore transport of the surface layer raised sea levels along the coast. This prevented deeper, nutrient-rich waters from penetrating onto the shallow shelf and mixing with nutrient-poor shelf

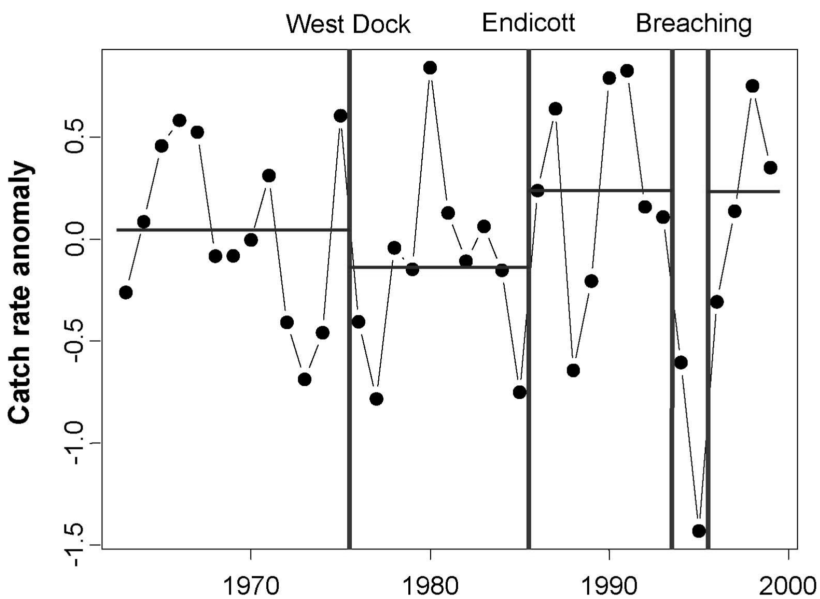

Figure D-16. Catch rate by year class relative to the construction and breaching of the Endicott causeway (vertical lines). Horizontal bars denote means by period.

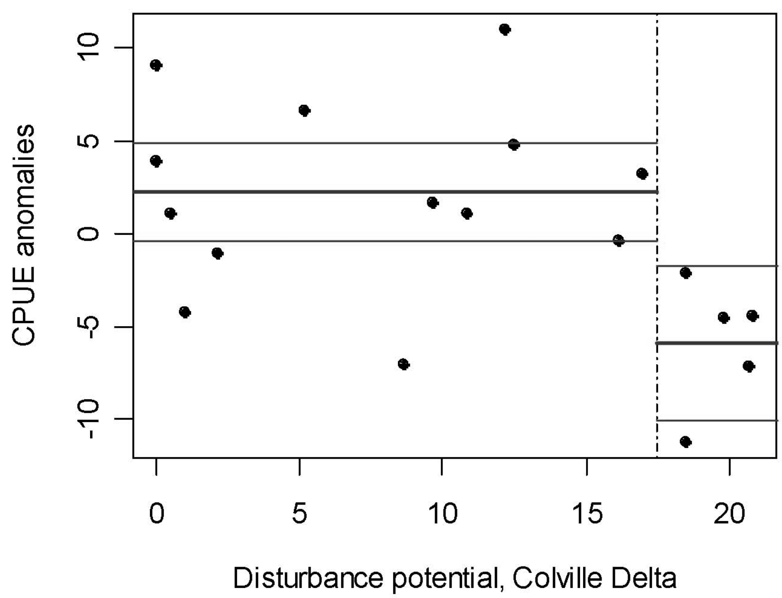

Figure D-17. Scatterplot of catch rates (CPUE) anomalies of *qaaktaq* in the Colville River against "disturbance potential" of all winter development activities in the Colville Delta averaged over previous 6 years.

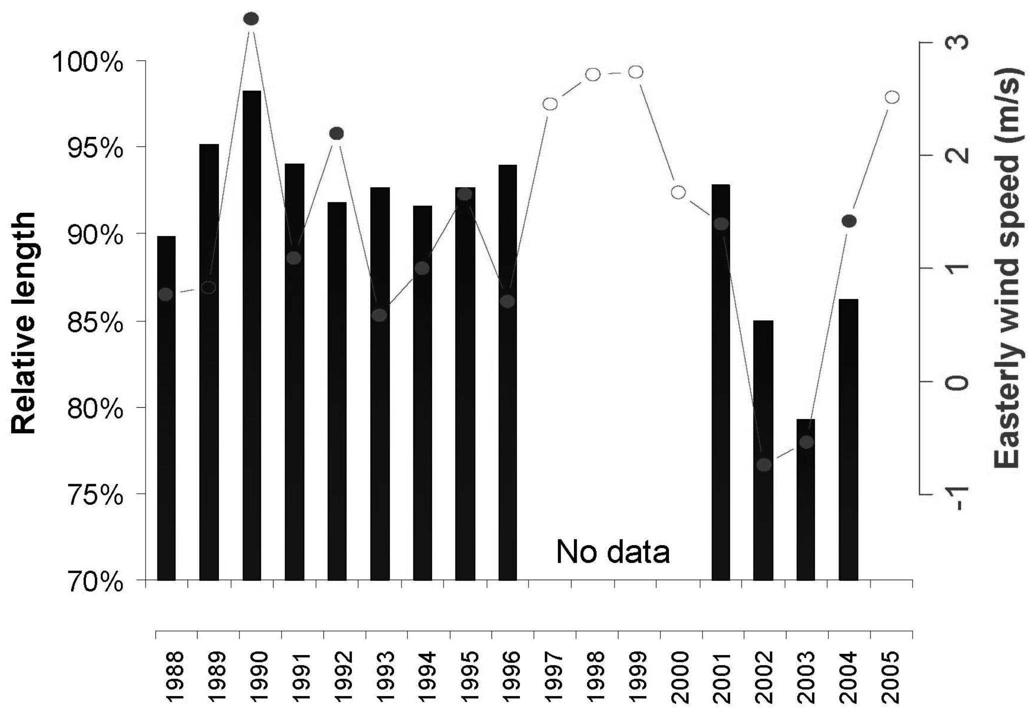

Figure D-18. Length of *qaaktaq* relative to maximum length by year, averaged across age-classes 2-6 within a given year (black bars) and average easterly wind speeds at Deadhorse during summer (July 1 – August 31).

waters. Although no measures of nutrient availability or plankton productivity are available, this reduced upwelling would likely reduce productivity and prey availability for *qaaktaq* and other fishes.

6. OTHER FISH SPECIES

Besides *qaaktaq*, a number of other fishes occur in the coastal waters of the Beaufort Sea and in the Colville River. These fishes may compete with *qaaktaq* for food and habitat or may even feed on young *qaaktaq*. The abundance of most routinely monitored species in the Prudhoe Bay region increased from the early 1980s to present. However, it is not clear whether this reflects actual changes in abundance or just changes in where the fish are living. In some cases, such as least cisco and humpback whitefish, abundances in the Prudhoe Bay region increased after the breaching of the West Dock causeway. There also was a big shift in species composition between 1989 and 1990 (Fig. D-19). *Qaaktaq*, least cisco, broad whitefish, rainbow smelt, Arctic flounder, and Dolly Varden increased in number, while fourhorn sculpin and Arctic

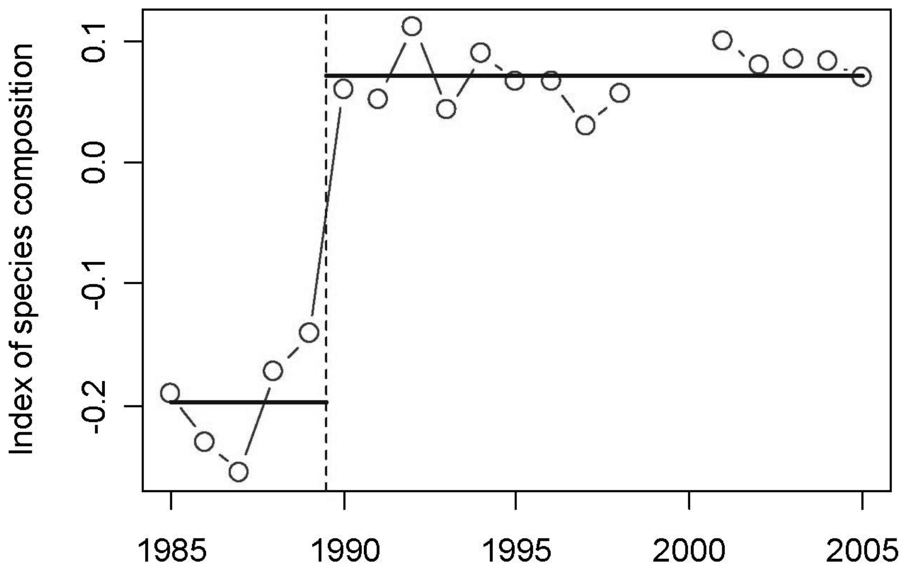

Figure D-19. Index of species composition based on catch rates of eight species collected by fyke net in Prudhoe Bay, 1985–2005 (1999/2000 missing).

cod decreased, on average, after the shift. The shift followed the well-known climate regime shift that caused the Arctic Oscillation to change sign between 1988 and 1989.

7. FISHING

Qaaktaq in the Colville Delta are harvested in both the commercial and subsistence fisheries. Catches in both fisheries have fluctuated substantially, but the subsistence fishery has only been monitored since 1985 (Fig. D-20). Commercial catches were highest in the 1970s, intermediate in the 1980s and early 1990s and have been very low in recent years. Subsistence catches have been up and down with relatively high catches occurring approximately every 5–6 years. There has been some concern that high total catches in the Colville Delta may have reduced the spawning population to unsustainable levels. If catches are too high then effects of over fishing should become apparent approximately 5 years later. This is because the fishery

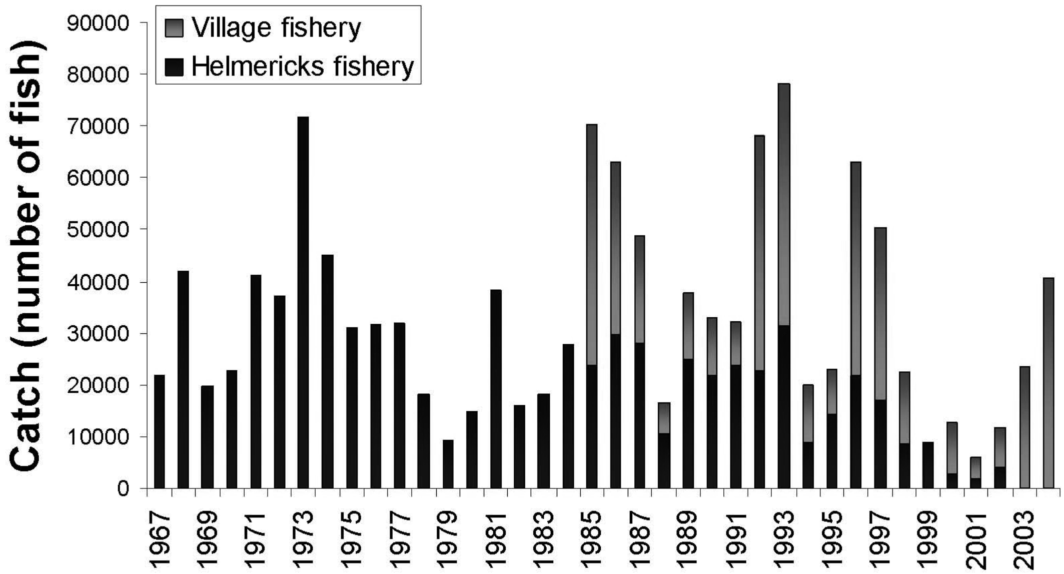

Figure D-20. Total eestimated catches of *qaaktaq* in the Colville River in commercial fishery (Helmericks) and subsistence fishery (Village). Catches in commercial fishery were estimated 1967–2002, catches in subsistence fishery were estimated for 1985–2004 (except 1999).

catches primarily 5–8 year old fish, which make up the bulk of the spawning population four years later when they are 9–12 years old (Fig. D-2). So if an 8 year old fish leaves the Colville to spawn this year, its young could be caught in 5 years. If an 8-year-old is caught this year then it will not reproduce.

We found no evidence that high catches or high rates of fishing effort tended to be followed by reduced recruitment (or recruitment anomalies). Therefore, harvest rates experienced by *qaaktaq* over the last 20 years do not seem to have negatively impacted the number of new recruits to the western Beaufort Sea.

CONCLUSIONS AND RECOMMENDATIONS

Our analyses confirmed that much of the variability in *qaaktaq* recruitment to Prudhoe Bay and subsequent catch rates in the Colville River appear to be driven by variability in wind-driven transport of juvenile fish along the Beaufort Sea coast. We found little evidence that any of the other regional or large-scale environmental variables were related to the recruitment or survival of *qaaktaq*. However, local salinity conditions in the Colville River were strongly related to catch rates in individual sets. Sub-surface salinities appear to affect the distribution of *qaaktaq* within the Colville River and, hence, the number of *qaaktaq* available to the fishery, regardless of any changes in abundance. This implies that fishers in the Nigliq channel can maintain higher catch rates by fishing near the mouth of the channel where salinities (and catch rates) generally are higher (but also more variable).

Based on our analyses of interannual variability in *qaaktaq* in relation to development activities, we found little evidence that recruitment, survival, or average catch rates were lower than "normal" during or after years when many development-related activities were occurring in coastal areas or on the Colville delta. A possible exception is the period of below average survival of *qaaktaq* from 1997–2000. This period of low year-to-year survival coincided with a period of development (drilling, construction, and ice bridges) in the Colville delta and was followed by a time of below average catches. However, the relationship was only marginally significant, and cause and effect can not be inferred from these limited data.

The lack of significant relationships between population-level trends in recruitment and abundance suggests that development activities have not had a noticeable detrimental effect on the overall population of *qaaktaq* in the Colville River. However, local effects on *qaaktaq* in areas like the Nigliq channel can only be resolved by detailed studies in conjunction with specific activities that may impact catch rates. We recommend that such studies be undertaken where the potential for disturbance exists.

For assessing the *qaaktaq* population, it is critical to monitor trends in spawner abundance, in recruitment, and in overall abundance or biomass. Unfortunately, there is virtually no information available on spawner abundances in the Mackenzie River. Establishing a monitoring program for spawners should therefore be a high priority from a fisheries biology perspective.

Recruitment trends have been monitored since 1981 and are strongly related to easterly winds (Fig. D-5). The decreasing trend in recruitment anomalies since 1987 (Fig. D-6) is a potential concern, but recent anomalies (1998, 2001, 2004, 2005) are not unprecedented and were similar to anomalies of the early 1980s (Fig. D-6). The declining trend did not correlate with any of our measures of development activities in the eastern and central Beaufort Sea. This suggests that the actual number of *qaaktaq* entering the Beaufort Sea has declined, resulting in fewer young *qaaktaq* arriving in Prudhoe Bay. Recruitment of young-of-year fish should continue to be monitored.

Catch rates in the fishery have been highly variable from year-to-year, but the low catch rate in 2001 was highly unusual in the context of the entire 1967–2005 time series (Fig. D-12). Several years of below average survival and low in-river salinities in 2001 undoubtedly contributed to the low catch rate. Catch rates increased in 2003–2005 because of strong age-0 recruitment in 1997–2000. However, recruitment failures in 2002–2003 resulting from westerly winds (Fig. D-5) combined with low recruitment in 2001, 2004 and 2005 (Fig. D-6) are expected to reduce catch rates in 2007–2010 (Figure D-21).

Our analysis suggests that the *qaaktaq* population does not appear to be very sensitive to oil and gas development activities that have occurred to date, but may be very sensitive to climate change, particularly if such changes affect the direction of alongshore winds in the Beaufort Sea. Two recent years (2002 and 2003) were characterized by highly unusual westerly winds during the summer (1981 is the only other year since 1976 with westerly winds on average). Westerly winds led to complete recruitment failures and may have contributed to the exceptionally poor growth and reduced size of subadult *qaaktaq* during the same two years. The population may be sensitive to fishing, but the effects cannot be determined because we were unable to estimate fishing mortality rates due to the unknown status of the spawning population. This again emphasizes the importance of better information on the spawning population of *qaaktaq* in the Mackenzie River

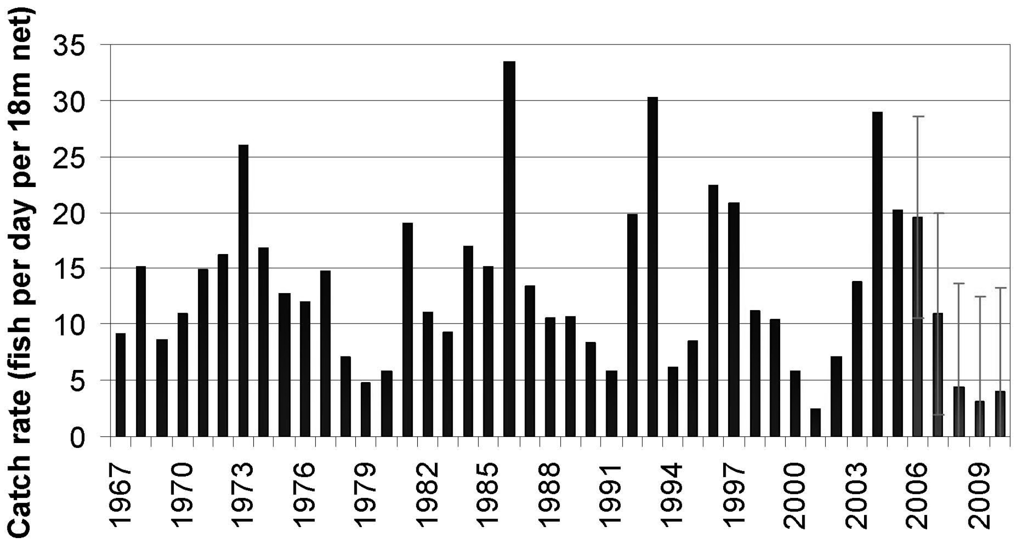

Figure D-21. Reconstructed catch rates for 1967–2005 (as in Figure D-3) and predicted catch rates for 2006–2010 based on estimated recruitment to Prudhoe Bay from 2000–2005. Bars indicate 80% confidence intervals.

QAAKTAQ RESULTS SUMMARY & QUESTIONNAIRE

PANEL MEMBER:_________________________

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1. WESTWARD TRANSPORT OF AGE-0 JUVENILES

1.1 Much of the variability in recruitment of Arctic cisco to Prudhoe Bay is determined by the strength of easterly winds.

Does this make sense? *yes or no*
Do you think this is correct? *yes or no*
Comments:

1.2 No evidence that the amount of seismic activity or the number of drilling operations during a given year in the eastern Beaufort Sea (east of the Sag River) was related to recruitment success in the same year.

Does this make sense? *yes or no*
Do you think this is correct? *yes or no*
Comments:

2. SURVIVAL FROM AGE-0 TO AGE-5

2.1 No significant relationships between any of the environmental variables examined and survival of age-0 to age-5.

Does this make sense? *yes or no*
Do you think this is correct? *yes or no*
Comments:

2.2 No significant relationships between any of the indicators of human activity, including the Endicott Causeway, and survival of age-0 to age-5 fish.

Does this make sense? *yes or no*
Do you think this is correct? *yes or no*
Comments:

3. SURVIVAL FROM AGE-5 TO AGE-7

3.1 Significant negative relationship between our summer climate index (reflecting temperature, ice conditions, and discharge) for the central Beaufort Sea shelf and the survival of subadults. This result suggests that survival is reduced during summers with above-average temperatures and discharge rates and below average ice concentrations.

Does this make sense? *yes or no*
Do you think this is correct? *yes or no*
Comments:

3.2 The period of low survival of adult Arctic cisco from 1997 to 2001 coincided with the period of most intense development activities in the Colville delta and the larger Colville region, but the relationship was not statistically significant and was strongly affected by the large 1985 recruitment anomaly.

Does this make sense? *yes or no*
Do you think this is correct? *yes or no*
Comments:

4. COLVILLE RIVER: CATCH RATES IN THE FISHERY

4.1 Catch rates were related to average easterly wind speeds in the Beaufort Sea 5-8 years earlier because of the effects of wind on recruitment and on the abundance of the resulting year classes when they enter the fishery.

Does this make sense? *yes or no*
Do you think this is correct? *yes or no*
Comments:

4.2 The unusually low catch rate in 2001 could not be accounted for by specific events (such as oil spills or other short-term development activities) or any unique combination of environmental or development indicators.

Does this make sense? *yes or no*
Do you think this is correct? *yes or no*
Comments:

4.3 Local catch rates in the Colville River varied substantially with the salt content in the river.

Does this make sense? yes or no
Do you think this is correct? yes or no
Comments:

4.4 Significant increase in the annual average catch rate were associated with increasing average salinity in the river.

Does this make sense? yes or no
Do you think this is correct? yes or no
Comments:

4.5 Average catch rates of Arctic cisco in the Colville fishery did not change significantly after the construction of causeways (West Dock or Endicott) or after breaching.

Does this make sense? yes or no
Do you think this is correct? yes or no
Comments:

4.6 Average catch rates of Arctic cisco in the Colville fishery were reduced following several years with relatively intense development activity in the Colville Delta (drilling, construction, and ice roads).

Does this make sense? yes or no
Do you think this is correct? yes or no
Comments:

5. SIZE AND GROWTH OF QAAKTAQ

5.1 Based on patterns in size-at-age and summer winds and on our knowledge of coastal oceanography, it appears that the small size of Arctic cisco in 2002/03 was caused by reduced prey availability resulting from a lack of upwelling of deep, nutrient-rich waters onto the shelf due to unusual westerly winds in 2002 and 2003.

Does this make sense? yes or no
Do you think this is correct? yes or no
Comments:

6. FISHING

6.1 We found no evidence that high catches or high rates of fishing effort tended to be followed by reduced recruitment of young fish. Therefore, harvest rates experienced by Arctic cisco over the last 20 years do not seem to have negatively impacted the number of new recruits to the western Beaufort Sea.

Does this make sense? yes or no
Do you think this is correct? yes or no
Comments:

PLEASE PROVIDE ADDITIONAL COMMENTS ON THE FOLLOWING QUESTIONS:

1. DO YOU THINK ESTABLISHING A PANEL OF EXPERTS WAS AN EFFECTIVE WAY TO WORK WITH THE SCIENTISTS?

2. DO YOU THINK THE PROCESS OF HOLDING MEETINGS IN THE COMMUNITY WITH THE SCIENTISTS WAS AN EFFECTIVE WAY TO DISCUSS YOUR VIEWS AND THEORIES AND TO REVIEW THE WORK OF THE SCIENTISTS?

3. WOULD YOU RECOMMEND THAT RESOURCE ISSUES OF IMPORTANCE TO THE COMMUNITY BE HANDLED IN A SIMILAR WAY?

Appendix E.

Panel of Experts' Report

PANEL OF EXPERTS' REPORT

Prepared for

Minerals Management Service
United States Department of the Interior

Prepared by

Leonard Lampe, Sr.
Kuukpik Subsistence Oversight Panel, Inc.
and
The Panel of Experts
Nuiqsut, AK

April 2007

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INTRODUCTION

The purpose of this study was to evaluate existing scientific data and traditional knowledge in order to increase the understanding of the variability in abundance of *qaaktaq* (Arctic cisco) in the Colville River.

KSOPI, represented by Leonard Lampe, Sr., and 10 residents from Nuiqsut (see below), who were selected to be on a Panel of Experts, worked directly with the scientific team to provide local and traditional knowledge and to review the findings of the scientists. Panel members included:

- Joeb Woods Sr.
- Dora Nukapigak
- Gordon Matumeak
- Gordon Brown
- Robert Lampe Sr.
- Bernice Kaigelak
- Sam Tukle
- Archie Ahkiviana
- Marjorie Ahnupkana
- Frank Oyagak Jr.

The primary roles of the panel were to evaluate the findings of the scientific team and to identify other sources of information, including traditional knowledge, that would help the scientific team understand the observed annual changes in *qaaktaq* abundance. This report was prepared for MMS to provide an assessment of how KSOPI and the panel viewed this process and whether we think the study's objectives were met.

Five meetings were held in Nuiqsut:

- <u>Public Meeting and Panel Selection (March 2005)</u>—introduction of project and the scientific team to the community. Selection of the Panel of Experts.

- Panel Meeting No. 1 (June 2005)—review scientific community's current knowledge of *qaaktaq*. Ask panel for input on changes in *qaaktaq* abundance.
- Panel Meeting No. 2 (November 2005)—presentation of results of analyses addressing the effects of natural factors on changes in *qaaktaq* abundance.
- Panel meeting No. 3 (October 2006)— presentation of results of analyses addressing the effects of human factors on changes in *qaaktaq* abundance
- Panel Meeting No. 4 (January 2007)—review technical results and conclusions and address any questions the Panel or KSOPI has regarding their reporting responsibilities.

EFFECTIVENESS OF HAVING SCIENTISTS COLLABORATE DIRECTLY WITH PANEL MEMBERS

CONFIRMATION OF TRADITIONAL KNOWLEDGE BY WESTERN SCIENCE

Panel members viewed the process of collaborating directly with the scientists as a positive and effective experience. In many cases, the scientific findings confirmed what panel members already knew through personal observations and traditional knowledge. For example, the effect of currents and winds on *qaaktaq* migration was an important factor identified by panel members that was corroborated by the scientists' research. Other observations that were confirmed through scientists' research included the effect of salinity and industrial activity on local *qaaktak* abundance.

CONTRIBUTION OF WESTERN SCIENCE TO PANEL MEMBERS' UNDERSTANDING OF *QAAKTAQ*

The scientific findings also confirmed panel members' knowledge and allowed them to have a greater understanding of other factors that affect *qaaktak*, such as sedimentation and global warming. Local fishermen have noticed a change in the timing of the *qaaktak* harvest as well as the timing of freeze-up each fall. *Qaaktak* are arriving earlier, but the ice is not freezing adequately until later in the season; thus, local fishermen are now arriving at their fishing spots at the peak of the *qaaktak* run, instead of before the peak. Panel members found the discussion of the role of global warming on *qaaktak* migration to increase their understanding of this trend.

MEETING ORGANIZATION

Having multiple meetings was beneficial as it helped panel members absorb the information from each meeting and comment appropriately. One meeting would not have been enough for panel members to adequately comment on the information and to provide adequate traditional knowledge. Panel members also found the summarization of previous findings and discussions, as well as plans for future meetings, to be helpful in maintaining continuity between meetings. The panel members appreciated having follow-up meetings the next day after each initial meeting, rather than just one meeting per trip. This served to allow panel members time to absorb the first day's information and think about items and questions to address the next day.

The four meetings with panel members took place over a span of 1.5 years. Some panel members indicated that the length of time between meetings allowed them to fully absorb the information presented at each previous meeting. Others believed that the time span was too long and would have liked to have seen report materials and findings earlier in the process.

Providing questionnaires to panel members to complete independently allowed them to fully express what they thought about the process and the findings. They were able to apply both their own traditional knowledge and the scientific data that they had learned during the meetings when they completed the questionnaires.

PANEL MEMBER COMPENSATION

Compensating the panel members was appropriate, as their providing traditional knowledge is akin to acting as consultants to the scientists. Locals' amount of knowledge varies depending on their experience and the resources that they harvest; in the future, compensation could vary depending on the individual providing the information.

RECOMMENDATIONS ON IMPROVING THE PROCESS

IMPLEMENTATION OF RESEARCH TO ANSWER PANEL MEMBERS' QUESTIONS ABOUT *QAAKTAQ*

Some of the scientific findings would have benefited from research rather than relying only on existing data. For example, scientists found that *qaaktaq* catch rates decreased after several years of relatively intense industrial activity on the Colville delta. It is clear to the panel members, through their own observations, that industrial activity affects *qaaktak* abundance. For example, panel members strongly believe that the loss of drilling mud in the Colville River due to horizontal drilling had a direct effect on *qaaktaq* abundance. Comparing a calendar of activities during those years of intense industrial activity to *qaaktaq* harvest amounts would have allowed for further analysis of the effects of development on *qaaktaq* numbers.

INCREASING COMMUNICATION BETWEEN MEETINGS

Panel members also recommend increased communication among the scientists, panel members, and local agencies between meetings. This could be made possible by providing email accounts to panel members and including them in all communications so that they do not rely solely on local organizations for information. More planning could take place through email communications regarding what type of information panel members could gather in preparation for future meetings, as well as what topics panel members and scientists would like to address at future meetings. Including panel members in inter-meeting communications would also increase organizations' accountability and panel members' support of staff.

INDIVIDUAL MEETINGS WITH PANEL MEMBERS

Sitting down one on one with individual panel members would have been helpful in ensuring that their input be documented thoroughly. It would have been especially helpful to go through each members' final questionnaire individually so that their answers and thoughts were clear to everyone involved.

PUBLIC EDUCATION

Educating the public about the project and including their input is another recommendation of the independent panel. Education of local residents could occur by holding public meetings and developing fliers and pamphlets outlining the purpose of the project and the role of the panel members in providing important local knowledge to the scientists. Meetings should be scheduled in advance and at times when most residents will be in town. The City of Nuiqsut and the Native Village of Nuiqsut both have calendars showing when village members are most active (during subsistence seasons, after quarterly dividends, and on holidays).

WRITTEN AGREEMENT

The panel also recommends that a written agreement be in place outlining the scientists', agencies', and panel members' responsibilities and expectations.

EFFECTIVENESS OF THE PROCESS IN TAKING ADVANTAGE OF LOCAL KNOWLEDGE

PROVIDE EXISTING TRADITIONAL KNOWLEDGE REPORTS TO PANEL MEMBERS

Although the process was effective, the incorporation of existing reports which contain relevant data and documentation of traditional knowledge would have helped to prompt panel members' memories of past events and topics of importance. For example, old records exist that outline *qaaktak* harvests over time on Nechelik Channel; these data may have helped remind panel members of significant harvest years. Other valuable data include the MJM Research Colville River fall fishery reports and North Slope Borough Department of Wildlife Management subsistence reports.

The independent panel's recommendation is to provide panel members with hard copies of these existing reports to assist them in preparing for future meetings. The presence of elders on the panel helped remind younger panel members about past trends and key traditional knowledge. Having existing data and sources of traditional knowledge in addition to the valuable memories of elders could help give panel members a basis for comparison between past and present.

INCREASED COMMUNICATION

As discussed above, communicating with panel members between meetings helps keep them involved in the process and thinking about future topics for discussion. Assigning positions (such as chairman) and responsibilities to panel members may also encourage their ongoing involvement.

USE OF PANEL MEMBERS' TRADITIONAL KNOWLEDGE BY SCIENTISTS

Not only do the panel members believe that the scientists used their knowledge effectively, but they were pleased that the scientists used this information to confirm existing traditional knowledge. In addition, panel members were educated about the scientific findings and this helped provide them with a greater understanding of the environment.

TRADITIONAL KNOWLEDGE NOT USED DUE TO LACK OF EXISTING DATA

In some cases, panel members desired additional studies applying their knowledge; scientists were not able to answer all of the panel members' questions or use all of the traditional knowledge available because adequate data did not exist to conduct such studies.

One example, as discussed above, was the relationship between years of intense industrial activities and low catch rates. Scientists were able to gather enough information from industry to identify a link between intense industrial activities and *qaaktaq* harvests. However, panel members would have liked further analysis of the calendar of activities during those years and a comparison of these specific activities to *qaaktaq* harvest numbers.

Panel members also observed that nearshore waters west of the causeways had become shallower, presumably due to changes in sediment deposits, and that shallower and more turbid water has changed the distribution of seals and perhaps *qaaktaq* in that area. However, scientists were unable to conduct research addressing this observation because there were no existing data from previous studies.

Another observation discussed by panel members but not addressed by scientists was the existence of underground channels connecting lakes and rivers, and the potential contamination of the Colville River by connected lakes that are closer to development activities.

IMPLEMENTATION OF FUTURE RESEARCH TO ADDRESS PANEL MEMBERS' QUESTIONS

Overall, panel members believe that much of the research conducted resulted in more questions than answers. As a result, the process helped panel members identify what future studies are necessary to further identify the causes of change in *qaaktaq* availability and the effects of industrial activities on the local environment. The recommended studies include the following:

- Effects of ice bridges on *qaaktaq* health and abundance
- Effects of saltwater treatment plants on *qaaktaq* distribution and abundance
- Obtain specific data about the dates of drilling and seismic activities by oil companies, and compare this data with catch rates

- Gather data on *qaaktaq* in the Mackenzie River delta, involving Canadian scientists and Natives
- Changes in the *qaaktaq* food chain

SUMMARY OF RESPONSES: RESULTS & QUESTIONNAIRE

At the end of the fourth and final panel meeting, each panel member in attendance was given a summary of the scientists' results and a questionnaire regarding panel members' views of the results. Five panel members were present and completed the questionnaire. The following is a summary of those panel members' responses and comments.

WESTWARD TRANSPORT OF AGE-0 JUVENILES

Scientific Finding #1: Much of the variability in recruitment of Arctic cisco to Prudhoe Bay is determined by the strength of easterly winds.

	Yes	No	No Answer
Does this make sense?	4	1	0
Do you think this is correct?	3	2	0

Panel Comments regarding Scientific Finding #1:

We need more scientific study of the years that were poor years (anomalies). What was the industry doing during the years when the wind had no factor in the migration of qaaktaq?

What if the sedimentation from the Colville was a factor?

Scientific Finding #2: No evidence that the amount of seismic activity or the number of drilling operations during a give year in the eastern Beaufort Sea (east of the Sag River) was related to recruitment success in the same year.

	Yes	No	No Answer
Does this make sense?	1	3	1
Do you think this is correct?	1	3	1

Panel Comments regarding Scientific Finding #2:

[There is an] unknown factor of how many were in the migration route before they reached the offshore industry seismic activity. There was no assessment from Canada of how good the fishing catches were [there] and how much actually made it to Colville through this seismic activity. During seismic, the whales migrated further due to noise levels of activity. Does noise affect qaaktaq migration?

Activities from oil companies always affect fish and mammals.

SURVIVAL FROM AGE-0 TO AGE-5

Scientific Finding #1: No significant relationships between any of the environmental variables examined and survival of age-0 to age-5.

	Yes	No	No Answer
Does this make sense?	4	1	0
Do you think this is correct?	2	2	1

Panel Comments regarding Scientific Finding #1:

Now we know [that] five to seven year old fish, we catch, but the older ones leave to Canada and never come back.

Scientific Finding #2: No significant relationships between any of the indicators of human activity, including the Endicott Causeway, and survival of age-0 to age-5 fish.

	Yes	No	No Answer
Does this make sense?	3	2	0
Do you think this is correct?	1	4	0

Panel Comments regarding Scientific Finding #2:

The elders seem to think that the qaaktaq had contaminants after the causeway at Endicott and the saltwater treatment plant at Oliktok Point. They saw a change of catch and health after the causeways and saltwater treatment plants and seismic activity: skinnier fish, deformities.

Causeways affect the fish whether we know it or not.

SURVIVAL FROM AGE-5 TO AGE-7

Scientific Finding #1: Significant negative relationship between our summer climate index (reflecting temperature, ice conditions, and discharge) for the central Beaufort Sea shelf and the survival of subadults. This result suggests that survival is reduced during summers with above-average temperatures and discharge rates and below average ice concentrations.

	Yes	No	No Answer
Does this make sense?	1	4	0
Do you think this is correct?	0	2	3

Panel Comments regarding Scientific Finding #1:

We need [more] discharge measurements or studies.

Scientific Finding #2: The period of low survival of adult Arctic cisco from 1997 to 2001 coincided with the period of most intense development activities in the Colville delta and the larger Colville region, but the relationship was not statistically significant and was strongly affected by the large 1985 recruitment anomaly.

	Yes	No	No Answer
Does this make sense?	5	0	0
Do you think this is correct?	5	0	0

Panel Comments regarding Scientific Finding #2:

Alpine construction, horizontal drilling, and the loss of drilling mud in the Colville River had a significant [effect] on the catch of qaaktaq. Very low catch rate was seen after the fact. That drilling mud was disposed in the Colville River. Vibration from CD-2 [drilling well] also had an [effect]- in the construction phase- on catch rate.

COLVILLE RIVER: CATCH RATES IN THE FISHERY

Scientific Finding #1: Catch rates were related to average easterly wind speeds in the Beaufort Sea 5-8 years earlier because of the effects of wind on recruitment and on the abundance of the resulting year classes when they enter the fishery.

	Yes	No	No Answer
Does this make sense?	5	0	0
Do you think this is correct?	4	0	1

Panel Comments regarding Scientific Finding #1:

Wind is the factor? What about no complaints previous to development? I never heard anyone complaints of catch rates in the 1980s and prior to development. Elders speak of the health of fish and they thought that was due to the saltwater treatment plant at Endicott ; fish were skinnier, they no longer saw the good food chain.

Scientific Finding #2: The unusually low catch rate in 2001 could not be accounted for by specific events (such as oil spills or other short-term development activities) or any unique combination of environmental or development indicators.

	Yes	No	No Answer
Does this make sense?	0	3	2
Do you think this is correct?	0	3	2

Panel Comments regarding Scientific Finding #2:

There was something bad happening in 2001 [with the] oil companies.

Scientific Finding #3: Local catch rates in the Colville River varied substantially with the salt content in the river.

	Yes	No	No Answer
Does this make sense?	5	0	0
Do you think this is correct?	4	0	1

Panel Comments regarding Scientific Finding #3:

Qaaktaq is always caught in Nuiqsut. How much salinity is in Nuiqsut banks, just outside of town?

Scientific Finding #4: Significant increase in the annual average catch rate were associated with increasing average salinity in the river.

	Yes	No	No Answer
Does this make sense?	5	0	0
Do you think this is correct?	4	1	0

Panel Comments regarding Scientific Finding #4:

Yes, along with winds and other natural calendar activities.

Nuiqsut puts out nets right at freeze up just near town at the boat docks. No salinity levels were taken or studied right at freeze up when there is a few nets near town. Fish was caught – qaaktaq - six miles inside Itkillik River in July. [There is] fresh water in Itkillik.

I believe that the salinity is a factor.

Scientific Finding #5: Average catch rates of Arctic cisco in the Colville fishery did not change significantly after the construction of causeways (West Dock or Endicott) or after breaching.

	Yes	No	No Answer
Does this make sense?	1	4	0
Do you think this is correct?	0	5	0

Panel Comments regarding Scientific Finding #5:

How can you determine the effect of rates when the fishery is here two to three weeks of our season. When we start fishing right at freeze up and still have nets out…we [still] have nets out when the data collectors leave early.

[We] need more data.

Scientific Finding #6: Average catch rates of Arctic cisco in the Colville fishery were reduced following several years with relatively intense development activity in the Colville Delta (drilling, construction, and ice roads).

	Yes	No	No Answer
Does this make sense?	5	0	0
Do you think this is correct?	5	0	0

Panel Comments regarding Scientific Finding #6:

The Colville delta is being affected.

With any development comes effects in the health of fish and the food chain is no longer seen as seen before. The texture of the fish is different since the causeway and the saltwater treatment plants were developed. Discharge at saltwater treatment plants may have affected the food chain.

Lots of activity from the oil companies was bad for us Eskimos.

SIZE AND GROWTH OF QAAKTAQ

Scientific Finding #1: Based on patterns in size-at-age and summer winds and on our knowledge of coastal oceanography, it appears that the small size of Arctic cisco in 2002/03 was caused by reduced prey availability resulting from a lack of upwelling of deep nutrient-rich waters onto the shelf due to unusual westerly winds in 2002 and 2003.

	Yes	No	No Answer
Does this make sense?	2	2	1
Do you think this is correct?	3	1	1

Panel Comments regarding Scientific Finding #1:

We have seen that causeways and saltwater treatment plants have affected the food chain. Back in the early years, before development, the elders stressed to us the health of our fish was richer, fatter, and the food chain was healthy. Winds have had no affect on how healthy our fish were before development. Our elders have told us and stressed to us that before development, fish and game were healthy, rich, catch rates were great."

I believe this to be true.

FISHING

Scientific Finding #1: We found no evidence that high catches or high rates of fishing effort tended to be followed by reduced recruitment of young fish. Therefore, harvest rates experienced by Arctic cisco, over the last 20 years do not seem to have negatively impacted the number of new recruits to the western Beaufort Sea.

	Yes	**No**	**No Answer**
Does this make sense?	5	0	0
Do you think this is correct?	5	0	0

Panel Comments regarding Scientific Finding #1:

In the 1960s, the Woods caught over 20 sacks in the few months they fished. Helmericks fished a lot too, and still the population is still healthy. The catch rate that [has been] depleted has to do with development over time.

We have the highs and lows. It is only natural that this is happening. We are not the factor of the lows.

Appendix F.

Contractor's Report on Panel Process

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APPENDIX F: CONTRACTOR'S REPORT ON PANEL PROCESS

This project was designed to be a collaboration between the scientific team and a Panel of Experts selected from the subsistence users residing in Nuiqsut. The role of the panel was to "validate" the conclusions and recommendations of the scientific team and provide local knowledge about Arctic cisco and factors that influence the distribution, abundance, and, ultimately, the harvest of this important subsistence resource. To facilitate this process, the ABR-lead study team asked the Kuukpik Subsistence Oversight Panel, Inc. (KSOPI) if they would be interested in subcontracting on this project to help with (1) meeting logistics, (2) panel member selection, and (3) reporting requirements, which included panel meeting minutes and the "Panel of Experts' Report" (Appendix E). Leonard Lampe, Sr., former Director of KSOPI, agreed to be part of the team and provide those functions.

SUMMARY OF ACTIVITIES

Five meeting were held in Nuiqsut between March 2005 and February 2007. Each meeting had a distinct purpose as summarized below:

- Public Meeting and Panel Selection (March 2005)—introduction of project and the scientific team to the community. Selection of the Panel of Experts.
- Panel Meeting No. 1 (June 2005)—review scientific community's current knowledge of *qaaktaq*. Ask panel for input on changes in *qaaktaq* abundance.
- Panel Meeting No. 2 (November 2005)—presentation of results of analyses addressing the effects of natural factors on changes in *qaaktaq* abundance.
- Panel meeting No. 3 (October 2006)— presentation of results of analyses addressing the effects of human factors on changes in *qaaktaq* abundance
- Panel Meeting No. 4 (February 2007)—review technical results and conclusions and address any questions the Panel or KSOPI has regarding their reporting responsibilities.

Three meetings with Leonard Lampe, Sr. (KSOPI) were held in Anchorage in May 2007 to complete work on the Panel of Experts (Appendix E).

VALUABLE PANEL INPUT

The Panel of Experts provided valuable input to the scientific team, including 1) Arctic cisco life history information; 2) among-year changes in the size, weight, texture, color, and taste of the fish; 3) among-year changes in the distribution and abundance of fish available for harvest;

4) anthropogenic and natural factors thought to either positively or negatively affect the quality, distribution, and abundance of the fish; and 5) critical reviews of the results and conclusions of the scientific findings.

A good example of how this collaborative effort produced results that would not have been realized without Panel input was the case of "skinny fish." Several panel members commented that during 2002 and 2003 when the quantity of fish being harvested was depressed, the quality of fish also was abnormal. Comments included reduced weighs, mushy texture, unusual color of flesh, poor taste, and abnormal stomach contents (e.g., no shrimp [copepods?]). Because this reduction in fish quantity and quality coincided with development of the Alpine Oilfield on the Colville delta, most panel members thought these were development-related impacts. Although we were not able to reject the hypothesis that development affected the quantity of fish available in those years (see Chapter 5; Winter Development Activities in the Colville Delta and Arctic Cisco Catch Rates), we were able to associate the changes in fish quality to environmental factors (see Chapter 5; Environmental Effects and Effects of Other Species on Arctic Cisco Size-at-Age). We tested three hypotheses related to the effects of environmental factors on size-at-age:

1) Size-at-age of Arctic cisco is higher in warm years,
2) Size-at-age of Arctic cisco is reduced during years with westerly winds, and
3) Size-at-age of Arctic cisco is inversely related to the abundance of other species, in particular other coregonids that may feed on similar prey.

These analyses indicated that size-at-age during the years in question may be related to environmental factors. We concluded that "the 2 years with the smallest size-at-age (2002 and 2003) coincided with the only 2 years in the last two decades that had predominantly westerly winds during summer. This is consistent with our hypothesis that prey availability and, therefore, growth and size are reduced during years without consistent upwelling in the coastal Beaufort Sea. This conclusion is based on only 2 years of westerly winds but provides a compelling argument for the importance of upwelling (easterly) winds to the productivity of the coastal Beaufort Sea. The reduced growth of Arctic cisco was readily apparent in size-at-age across numerous age classes and their sizes recovered quickly after a single summer of 'normal' easterly winds."

These analyses would never have been conducted if the panel had not identified these issues pertaining to fish quality, because the study originally was designed to focus on the quantity of fish. Further, the panel's notion that these changes in fish quality were development related were dispelled to some degree because of the analysis of environmental factors. So, in this case, both the scientists and the susbsitence community learned something new from one another, and this outcome could be realized only through this type of collanborative problem solving.

STRENGTHS AND WEAKNESSES OF THE PROCESS

The strengths of the collaboration between the scientists and the local experts were that we were able to build a relationship of trust, which in turn facilitated effective information transfer. Because the community is concerned about being exploited by outsiders, they are not always willing to open up and share their opinions with people they don't know or trust. Multiple meeting and honest dialogue were central to building trust. We also were fortunate to have benign project objectives that did not include, for example, trying to acquire permits for a new development. Usually when the Nuiqsut residents are asked to review scientific documents, they were written for a scientific audience and are applied studies associated with advancing development interests. We think that the panel was more receptive to working with our team because we did not represent developers and because they were told from the onset that their knowledge and opinions were valued and central to the objectives of the study. We also had the advantage of having Larry Moulton on our team, who has built up trust and strong relations with Nuiqsut residents for over two decades.

The following list summarizes the strengths of the collaboration between the scientific team and the Panel of Experts:

- Having a local community organization be a member of the study team was instrumental in gaining acceptance into the community to conduct this project.
- Visiting the community multiple times during the project and developing an ongoing relationship with the panel members was a positive experience for both the western

scientists and panel members and added to the quality of the information exchange by all participants.

- Working with community residents on a continuing basis provided the community with a sense that the scientists were committed to the project.
- Listening to community residents/panel members and having them see the results of their comments incorporated into the project at the following community meeting added to the productive dialogue and trust among participants.
- Incorporating community suggestions into the study plan gave the panel members the sense that the scientists were listening to panel members and taking their comments seriously.
- Working on a subsistence resource and issue that is important to the community added meaning and satisfaction to panel members.
- Providing comprehensive information at multiple meetings to panel members systematically presenting scientific information about a resource that has keen local interest provided a learning experience for panel members of the value of western science. Panel members learned things about Arctic cisco that they did not know, and they appeared to appreciate learning it.
- Paying panel members for their participation provided project acknowledgement of the valuable information that local residents can provide to scientific enquiry.
- Paying KSOPI for their participation added credibility to the study team's commitment to include a local organization in the project.
- Conducting meetings and maintaining an ongoing dialogue between scientists and local knowledgeable subsistence harvesters resulted in growing trust from panel members that the scientists were sincere in working with the community.
- Reviewing study findings with community panel participants over time allowed panel members time think about results between meetings and ask questions about things they did not accept or understand at a subsequent meeting.

- Providing questionnaires to panel members at the final meeting asking them to comment on each of the study findings showed promise as a method to refine in the future.
- A capable, prepared, and committed project leader continually conveyed to panel members their role and responsibility on the project.

Weaknesses of the process were associated with trying to schedule two-day meeting with up to 17 people. Once the scientists got their schedules aligned, we then had to get 12 people (2 KSOPI representatives and the 10 panel members) scheduled to meet with us. Communication was through KSOPI, and they were not always to locate all of the panel members. Fortunately, we anticipated this problem to some degree and populated the panel with 10 members rather than the minimum of 5, which was specified by MMS. Although we always had a quorum for our meetings, we did not always have good continuity among meetings. Because our meetings and presentations built upon what was presented at the previous meeting, it was somewhat problematic to have inconsistent attendance. We dealt with this by providing a lot of review at the onset of the meetings, but this was not particularly efficient.

We also discovered that tasking the panel (e.g., Independent Panel Report) and KSOPI (e.g., meeting minutes) with assignments that required writing was difficult for some of the participants. In our experience, people were more comfortable communicating verbally. Hence, for the Independent Panel Report, we used an interview/transcription technique that seemed to work well.

The following list summarizes the weaknesses of the collaboration between the scientific team and the Panel of Experts:

- Having a local person keep the meeting minutes and provide the project team with copies proved to be difficult.
- Requiring an independent panel report. Writing reports and keeping minutes are not necessarily strengths in small Alaskan communities.
- Conducting a retrospective study that attempted to answer community questions for which there were not always adequate data left panel members wondering why the scientists were not answering many of their questions.

- Scheduling meetings in Nuiqsut where people are busy with jobs, subsistence activities, and an ongoing dialogue with industry was a continual challenge.
- Some of the analyses were complex and were difficult to understand.
- Getting invoices from KSOPI was difficult.
- A panel process is not necessarily the best approach to acquire traditional knowledge about a resource.

RECOMMENDATIONS

Paying the panel for their time was critical, and we recommend any future projects involving community participation include some form of payment. We used an honorarium to pay panel members and found that they appreciated getting cash right after the meetings. We also found that cash that was contingent on participation was effective at bolstering attendance at our meetings.

Including KSOPI on our team was critical for navigating the sometimes challenging logistics associated with visiting and working in Nuiqsut. KSOPI representatives also called to in form panel members about upcoming meetings, secured space for our meetings, and helped with transportation. Having some sort of liaison in the village is critical.

We found that panel members were very eager to listen to what the scientists had to say. Verbal communication appears to be the preferred method of information transfer, particularly for scientific material. We made extensive use of PowerPoint and spent a great deal of time explaining what we were trying to accomplish with this project and why we were doing it. We found that the panel was quick to pick up on most of the concepts presented, despite the high degree of statistical content.

Because there are so many meetings in Nuiqsut held by developers and regulatory agencies pertaining to specific development projects, it was critical for us to state specifically at the onset of each meeting who we were, who we represented, and to reiterate the goals of our project and the role of the panel.

Although ABR has worked in Nuiqsut for many years and is known many residents, it was critical to the success of this project to have a cultural resources specialist on our team.

Methodology associated with panel selection was tricky and required someone with a social science background. Further, our expert was very adept at working through issues with both KSOPI and the panel, which allowed the scientific team to focus on the information transfer and technical aspects of the project. Specific recommendations include:

- Continue with the strengths listed above and attempt to remedy the weaknesses.
- Provide more materials to panel members between meetings to allow them to digest difficult concepts and have "homework" for the next meeting.
- Provide an avenue for communication between panel members and scientists between meetings for additional information exchange.
- Mail material directly to panel members to ensure that each panel member receives the documents prior to a meeting.
- Provide questionnaires to panel members at the final meeting asking them to comment on each of the study findings
- Establish early in the process who will write the panel report and initiate an outline for the report.

Appendix G.

List of Indicator Variables

Table G-1. List of indicator variables developed during the data exploration phase of the Arctic cisco project.

#	Indicator names Environmental	Description	Database Table or Reference	Reference
1	AO	(previous) December–March average of Arctic Oscillation Index	TBL_Env_Arctic_Oscillation	
2	BS.flow	Water Transport (Sv) through the Bering Strait from wind forcing	TBL_Env_Bering_Transport	
3	Dis.Mack.May	Total Arctic Red River + Norman Wells discharge for the month of May by year (10,000 m^3 s^{-1})	TBL_Env_Daily_River_Discharge	
4	Dis.Mack.sum	Total Arctic Red River + Norman Wells discharge for the early summer period (June - Aug) by year (10,000 m^3 s^{-1})	TBL_Env_Daily_River_Discharge	
5	Dis.Mack.win	Total Arctic Red River + Norman Wells discharge for the winter period (previous Dec - April) by year (1,000 m^3 s^{-1})	TBL_Env_Daily_River_Discharge	
6	Inuvik.minT.win	Winter mean minimum temperatures (previous Dec–March) at Inuvik, Mackenzier River, NWT	TBL_Weather_Mackenzie	
7	Inuvik.avgT.sum	Summer mean temperatures (June–Sept) at Inuvik, Mackenzier River, NWT	TBL_Weather_Mackenzie	
8	Tuk.minT.win	Winter mean minimum temperatures (previous Dec–March) at Tuktoyaktuk, Mackenzier Delta, NWT	TBL_Weather_Mackenzie	
9	Tuk.avgT.sum	Summer mean temperatures (June–Sept) at Tuktoyaktuk, Mackenzier Delta, NWT	TBL_Weather_Mackenzie	
10	Barrow.avgT.sum	Summer mean temperatures (June–Sept) at Barrow airport, 1950–2004 (°C)	TBL_Weather_Barrow_Monthly	
11	Barrow.avgT.win	Winter mean temperatures (previous Dec–Mar) at Barrow airport, 1950–2004 (°C)	TBL_Weather_Barrow_Monthly	
12	Barrow.minT.win	Winter mean temperatures (previous Dec–Mar) at Barrow airport, 1950–2004 (°C)	TBL_Weather_Barrow_Monthly	
13	Mack.ReySST.Jul	Mean July SST averaged over three 2x2 degree grid cells off the mouth of the Mackenzie, based on Reynolds reconstructed SST	TBL_Env_Reynolds_SST	
14	Mack.OISST.Jul	Mean July SST averaged over six (nearshore) 1x1 degree grid cells off the mouth of the Mackenzie, based on Optimum Interpolation v. 2 SST	TBL_Env_OI_SST_ICE	
15	Col.OISST.sum	Mean July–September SST averaged over 70-71N, 146-152W based on Optimum Interpolation v. 2 SST	TBL_Env_OI_SST_ICE	
16	PB.SST	Summer sea-surface temperature at Heald Point (fyke net 214), Prudhoe Bay, averaged over period of sampling	LGL Alaska Research Associates, Inc. (1991, 2006)	
17	PB.sal	Summer sea-surface salinity at Heald Point (fyke net 214), Prudhoe Bay, averaged over period of sampling	LGL Alaska Research Associates, Inc. (1991, 2006)	
18	Col.sal	Estimated annual salinity anomaly in the Colville delta during the fishing season	TBL_Colville_Salinity	
19	Mack.ice	Mean June ice concentrations (%) over 69-70N, 136-139W off the mouth of the Mackenzie R.	TBL_Env_OI_SST_ICE	
20	Col.ice.Spr	Mean June-July ice concentrations (%) over 70-71N, 146-152W off the Colville R.	TBL_Env_OI_SST_ICE	
21	Col.ice.Oct	Mean Oct ice concentrations (%) over 70-71N, 146-152W off the Colville R.	TBL_Env_OI_SST_ICE	
22	Wind.avg	Average alongshore wind speed (m/s) from July 1 - August 31, coastal Beaufort Sea, based on NCEP / NCAR winds	TBL_Env_NCEP_Daily_Winds	
23	Wind.E	Sum of all positive (easterly) daily wind speeds between July 1 - August 31, coastal Beaufort Sea, based on NCEP / NCAR winds, divided by 62 (easterly wind per day)	TBL_Env_NCEP_Daily_Winds	
24	Wind.Dhse	Mean hourly wind speed (m/s) at Deadhorse Airport for the period July 1 - August 31	Fechhelm et al. (2005), Fig. 4	LGL (2004). Nearshore Beaufort Sea Fish Monitoring in the Prudhoe Bay Region, 2003. Final Report
25	Sag.dis	Average daily discharge (cfs) for Sagavanirktok River as measured at Pump Station 3, May 1 - September 30	TBL_Env_Daily_River_Discharge	
26	Kup.dis	Average daily discharge (cfs) for Kuparuk River as measured at Deadhorse, May 1 - September 30	TBL_Env_Daily_River_Discharge	
	Biological			
27	ANWR.age0	Estimated age-0 CPUE (fish/net/24hr) averaged across numerous fyke net locations in Barter Island region	TBL_ANWR_CPUE	
28	PB.age0	CPUE of age-0 Arctic cisco (fish/net/24hr) at Prudhoe Bay estimated by LGL	Fechhelm et al. (2003)	
29	PB.age1	CPUE of age-1 Arctic cisco (fish/net/24hr) at Prudhoe Bay estimated by LGL	Fechhelm et al. (2003)	
30	PB.age2	CPUE of age-2 Arctic cisco (fish/net/24hr) at Prudhoe Bay estimated by LGL	Fechhelm et al. (2003)	
31	PB.age2+	log(CPUE+1) of age-2+ Arctic cisco (fish/net/24hr) at Prudhoe Bay estimated by LGL	Fechhelm et al. (2006), Fig. 1.8	Fig. 1.8 in Fechhelm et al. (2006). Nearshore Beaufort Sea Fish Monitoring in the Prudhoe Bay region, 2005. Report for BP Exploration (Alaska) Inc.by LGL Alaska Research Associates, Inc., Anchorage, Alaska

Table G-1. Continued.

#	Indicator names Environmental	Description	Database Table or Reference	Reference
32	PB.LSCS	Estimated log(CPUE+1) for Leaast cisco > 180 mm in Prudhoe Bay region	Fechhelm et al. (2004), Fig. 18	LGL (2004). Nearshore Beaufort Sea Fish Monitoring in the Prudhoe Bay Region, 2003. Final Report (Fig. 18, p. 41)
33	PB.BDWF	Estimated log(CPUE+1) for age 3+ broad whitefish in Prudhoe Bay region	Fechhelm et al. (2004), Fig. 24	LGL (2004). Nearshore Beaufort Sea Fish Monitoring in the Prudhoe Bay Region, 2003. Final Report (Fig. 24, p. 50)
34	PB.DLVD	Estimated log(CPUE+1) for dolly varden > 350 mm in Prudhoe Bay region	Fechhelm et al. (2006)	
35	PB.ARFL	Estimated log(CPUE+1) for Arctic flounder in Prudhoe Bay region	Fechhelm et al. (2006)	
36	PB.RBSM	Estimated log(CPUE+1) for rainbow smelt in Prudhoe Bay region	Fechhelm et al. (2006)	
37	PB.FHSC	Estimated log(CPUE+1) for fourhorn sculpin in Prudhoe Bay region	Fechhelm et al. (2006)	
38	PB.ARCD	Estimated log(CPUE+1) (fish/net/24hr) of Arctic cod in Prudhoe Bay region	Fechhelm et al. (2006)	LGL (2003). Nearshore Beaufort Sea Fish Monitoring in the Prudhoe Bay Region, 2002. Final Repor (Fig. 47, p. 84) and LGL (2004)
39	PB.age0.fin	Upper limit of final size of age 0 cohort in last week of August / first week of September	Various LGL reports, 1986-2002	
40	PB.age1.fin	Upper limit of final size of age 1 cohort in last week of August / first week of September	Various LGL reports, 1986-2002	
41	PB.age1.size	Mean size of measured age 1 fish in Prudhoe Bay	Fechhelm et al. (2003), Fig. 14	LGL (2003). Nearshore Beaufort Sea Fish Monitoring in the Prudhoe Bay Region, 2002. Final Repor (Fig. 47, p. 84) and LGL (2004)
42	PB.age2.size	Mean size of measured age 2 fish in Prudhoe Bay	Fechhelm et al. (2003), Fig. 14	
43	PB.age3.size	Mean size of measured age 3 fish in Prudhoe Bay	Fechhelm et al. (2003), Fig. 14	
44	PB.age4.size	Mean size of measured age 4 fish in Prudhoe Bay	Fechhelm et al. (2003), Fig. 14	
45	PB.age5.size	Mean size of measured age 5 fish in Prudhoe Bay	Fechhelm et al. (2003), Fig. 14	
46	PB.age6.size	Mean size of measured age 6 fish in Prudhoe Bay	Fechhelm et al. (2003), Fig. 14	
47	PB.size.rel	Combined index of relative size across ages 2-6	this report	
48	Helm.ARCS	CPUE of Arctic cisco in the Helmericks fishery	Moulton & Seavey (2005)	Moulton, L. L., and B. T. Seavey. 2005. Harvest estimate and associated information for the 2004 Colville River fall fishery. Report prepared for ConocoPhillips, Alaska, Inc., Anchorage, AK, by MJM Research, Lopez Island, WA.
49	Helm.LSCS	CPUE of Least cisco in the Helmericks fishery	Moulton & Seavey (2005)	
50	Helm.ARCS.adj	CPUE of Arctic cisco in the Helmericks fishery adjusted for effort (Residuals from regression of log(Helm.ARCS) on Helm.Eff - back-transformed to original scale??	Moulton & Seavey (2005)	
51	Helm.LSCS.adj	CPUE of least cisco in the Helmericks fishery adjusted for effort (Residuals from regression of log(Helm.LSCS) on Helm.Eff	Moulton & Seavey (2005)	
52	Helm.age5	CPUE of age 5 Arctic cisco by year of capture, commercial fishery	Moulton & Seavey (2004), Appendix table 18	Moulton, L. L., and B. T. Seavey. 2004. Harvest estimate and associated information for the 2003 Colville River fall fishery. Report prepared for ConocoPhillips, Alaska, Inc., Anchorage, AK, by MJM Research, Lopez Island, WA.
53	Helm.age6	CPUE of age 6 Arctic cisco by year of capture, commercial fishery	Moulton & Seavey (2004), Appendix table 18	
54	Helm.age7	CPUE of age 7 Arctic cisco by year of capture, commercial fishery	Moulton & Seavey (2004), Appendix table 18	
55	Helm.age8	CPUE of age 8 Arctic cisco by year of capture, commercial fishery	Moulton & Seavey (2004), Appendix table 18	
56	Col.Age5	CPUE of age 5 Arctic cisco by year of capture, Niġliq channel fishery, 76mm mesh net	Moulton & Seavey (2005), Appendix table 18	Moulton, L. L., and B. T. Seavey. 2005. Harvest estimate and associated information for the 2004 Colville River fall fishery. Report prepared for ConocoPhillips, Alaska, Inc., Anchorage, AK, by MJM Research, Lopez Island, WA.
57	Col.Age6	CPUE of age 6 Arctic cisco by year of capture, Niġliq channel fishery	Moulton & Seavey (2005), Appendix table 18	
58	Col.Age7	CPUE of age 7 Arctic cisco by year of capture, Niġliq channel fishery	Moulton & Seavey (2005), Appendix table 18	
59	Col.Age8	CPUE of age 8 Arctic cisco by year of capture, Niġliq channel fishery	Moulton & Seavey (2005), Appendix table 18	

Table G-1. Continued.

#	Indicator names Environmental	Description	Database Table or Reference	Reference
60	Niġliq.ARCS	Average CPUE of Arctic cisco in Niġliq channel, 76mm mesh (fish / 24 hrs / 18m net?)	Moulton and Seavey (2005), Table 4	
61	Nig.ARCS.adj	Average CPUE of Arctic cisco in Niġliq channel, 76mm mesh, adjsuted for effects of differences in total annual effort	this report	
62	CPUE.610	CPUE (total catch / total effort) of Arctic cisco in the upper Niġliq region (areas 610 and 630)	Moulton and Seavey (2005), Table 4	
63	CPUE.650	CPUE (total catch / total effort) of Arctic cisco in the Nanuk Lake region (area 650)	Moulton and Seavey (2005), Table 4	
64	CPUE.670	CPUE (total catch / total effort) of Arctic cisco in the Niġliq Delta region (area 670)	Moulton and Seavey (2005), Table 4	
65	Niġliq.LSCS	Average CPUE of least cisco in Niġliq channel, 76mm mesh (fish / 24 hrs / 18m net?)	Moulton & Seavey (2005), Table A13	
66	Nig.ARCS.sal	Average CPUE of Arctic cisco in Niġliq channel, 76mm mesh, adjusted for effects of local salinity and seasonal depletion	this report	
67	Col.ARCS	Combination of Helm.ARCS.adj for 1967–1984 and 1999, average of normalized CPUEs of adjusted Helmericks (Helm.ARCS.adj) and adjusted Niġliq channel (Niġliq.ARCS.adj) CPUEs where both indices overlap (1984–2002 except 1999, r = 0.83), and Nuiq.ARCS.adj for 2003–2004	this report	
68	CPUE.unexpl	Residuals from regression of Col.ARCS on recruitment 6 and 7 years earlier!	this report	
69	PB.MR	Mark-recapture estimates of abundance for small Arctic cisco only (120–250 mm, cohorts II and III). Bayesian estimates, except 1983 and 1984 (Schnabel estimates)	Moulton et al. (1986)	
70	Col.MR	Mark-recapture estimates of abundance of Arctic cisco based on tag returns from the Colville fall fishery	LGL Alaska Research Associates, Inc. (1990), Vol. IV	
	Combined / derived indices			
71	Mack.env.PC1	First Principal components of major environmental variables in Colville / Prudhoe Bay region	this report	
72	Col.env.PC1	First Principal components of major environmental variables in Mackenzie River region	this report	
73	PB.YCS	Combined index of recruitment / year-class strength based on CPUEs of age-0, age-1, and age-2 Arctic cisco at Prudhoe Bay	this report	
74	YCS.resid	Residuals from a piecewise linear regression of PB.YCS on easterly winds at Deadhorse (Wind.Dhse)	this report	
75	Age0.resid	Residuals from a piecewise linear regression of PB.age0 on easterly winds at Deadhorse (Wind.Dhse)	this report	
76	Surv.age5	"Survival rate anomalies" from age-0 to age 5 (Residuals from regression of subsistence Age-5 CPUE on recruitment index (PB.YCS), lined up by year class	this report	
77	Surv.567	"Survival rate anomalies" for adult Arctic cisco based on averaging residuals from simple linear regressions of age-6 on age- 5 CPUEs and age-7 on age-6 CPUEs (lagged to same year, i.e. different cohorts), computed for both commercial and subsistence fishery, and combined into a single index	this report	
78	CPUE.H.anom	Residuals from regression of total commercial CPUE (Helm.ARCS) on average Jul 1 - Aug 31 NCEP winds (Wind.avg) at three lags (5, 6, and 7-year lag), weighted by the average proportion of 5, 6,and 7-year olds in the catches (21, 43, and 36%, respectively).	this report	
79	CPUE.Col.anom	Residuals from regression of combined CPUE index (Col.ARCS) on average Jul 1 - Aug 31 NCEP winds (Wind.avg) at four lags (5, 6, 7 and 8-year lag), weighted by the average proportion of 5, 6, 7 and 8-year olds in the catches (30, 41, 21, and 8%, respectively).	this report	
80	CPUE.Nig.anom	Residuals from regression of total Niġliq channel CPUE (Niġliq.ARCS) on average Jul 1 - Aug 31 winds at Deadhorse at three lags (5, 6, and 7-year lag), weighted by the average proportion of 5, 6,and 7-year olds in the catches (21, 43, and 36%, respectively).	this report	
81	PB.sp.comp	Multivariate index of species composition of total catches at stations 218+220 in Prudhoe Bay	this report	
82	Col.sp.comp	Multivariate index of catch composition in Niġliq channel fishery	this report	

Table G-1. Continued.

#	Indicator names Environmental	Description	Database table or reference	Reference
	Indicators of human impacts			
83	Helm.catch	Catch of Arctic Cisco in commercial fishery, 1967–2002	this report	
84	Nig.catch	Catch of Arctic Cisco in subsistence fishery, 1985–2004 (except 1999)	this report	
85	Total.catch	Total catch of Arctic Cisco	this report	
86	Helm.Eff	Fishing effort in the Helmericks fishery (net days per 18 m of gill net)	this report	Moulton, L. L., and B. T. Seavey. 2005. Harvest estimate and associated information for the 2004 Colville River fall fishery. Report prepared for ConocoPhillips, Alaska, Inc., Anchorage, AK, by MJM Research, Lopez Island, WA.
87	Nuiq.Eff	Fishing effort in the village subsistence fishery (net days per 18 m of gill net)	this report	
88	Total.Eff	Total fishing effort in Colville delta (sum of Helm.Eff + Nuiq.Eff for years where both were estimated)	this report	
89	Causeways	Categorical variable denoting periods prior to West Dock construction, between West Dock and Endicott construction, between Endicott construction and 1993/94 breaching of West Dock, and after 1995/96 breaching of Endicott	this report	
90	Endicott.cum	Subjective rating of relative cumulative impacts of Endicott construction (+4), first breach (-2), 2nd breach (-1), and 3rd breach (0) on Arctic cisco	this report	
91	WestDock.cum	Subjective rating of relative cumulative impacts of West Dock construction (+2), 2 extensions (+1 each) and breaching (-2) on Arctic cisco	this report	
92	East.open	Subjective disturbance potential ranking of documented development activities in eastern section of Beaufort Sea during open-water season (Includes Sag delta and area east of Sag Delta to Canada boarder)	this report	
93	Central.open	Subjective disturbance potential ranking of documented development activities in cenrtal section of Beaufort Sea during open-water season (Includes area between Sag delta and Oliktok Point)	this report	
94	West.open	Subjective disturbance potential ranking of documented development activities in western section of Beaufort Sea during open-water season (Includes area from Oliktok Point to Cape Halkett)	this report	
95	Offshore.open	Subjective disturbance potential ranking of documented development activities in all offshore sectors of the Beaufort Sea during open-water season (Includes area from Canadian boarder to Cape Halkett)	this report	
96	Central.frozen	Subjective disturbance potential ranking of documented development activities in central section of Beaufort Sea during winter (frozen) season (Includes area between Sag delta and Oliktok Point)	this report	
97	West.frozen	Subjective disturbance potential ranking of documented development activities in western section of Beaufort Sea during winter (frozen) season (Includes area from Oliktok Point to Cape Halkett)	this report	
98	Colville.frozen	Subjective disturbance potential ranking of documented development activities in Colville delta during winter (frozen) season (geographically restricted subset of West.frozen)	this report	
99	Seismic.East	Total distance of seismic lines surveyed during a given year (open-water season) in eastern section (Includes Sag delta and area east of Sag Delta to Canada boarder)	this report	
100	Seismic.West	Total distance of seismic lines surveyed during a given year (open-water season) in western section (includes area west of Sag Delta to Cape Halkett - areas 'Central' + 'West' from above)	this report	
101	Seismic.Total	Total distance of seismic lines surveyed during a given year (open-water season), all of Beaufort Sea	this report	
102	Channel.crossings	Number of ice bridges constructed to cross major Colville River channels during winter	this report	
103	Drilling	Number of drilling operations in Colville delta (duration of drilling activity may have varied) during winter	this report	
104	Central.drilling	Number of drilling operations in central region during open water season	this report	

Appendix H.

A Detailed Comparison of Model-based NCEP/NCAR Winds and Observed Wind Speed and Direction at Barrow and Deadhorse

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APPENDIX H: A DETAILED COMPARISON OF MODEL-BASED NCEP/NCAR WINDS AND OBSERVED WIND SPEED AND DIRECTION AT BARROW AND DEADHORSE

NCEP/NCAR WINDS VS. BARROW WINDS

Because of the importance of deriving a suitable wind index, we conducted a more detailed comparison of NCEP/NCAR reanalysis data with high-quality measured winds at Barrow using one year, 1997, as a case study. Barrow is located at 71.32°N, 156.6°W, therefore, we compared Barrow wind speed and direction to those at 70°N, 157.5°W and 72.5°N, 157.5°W. Daily measured wind speeds at Barrow agree reasonably well with daily NCEP/NCAR winds averaged between 70°N and 72.5°N (157.5°W) with a correlation coefficient of 0.84 (Figure H-1). Barrow wind speeds agree much better with wind speeds at 72.5°N (r = 0.82) than with winds at 70°N (r = 0.63).

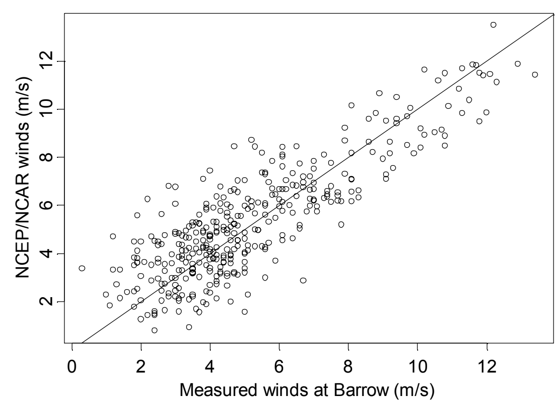

Figure H-1. Daily average NCEP/NCAR wind speeds for 1997 (average of 70°N and 72.5°N at 157.5°W) compared to daily measured wind speeds at Barrow (71.32°N, 156.6°W). Line indicates 1:1 correspondence.

A comparison of modeled and measured wind directions showed reasonable agreement between the daily average wind direction at Barrow and wind directions at 70°N and 72.5°N, as estimated by the NCEP/NCAR reanalysis (Figure H-2). Note that outlying points result from the circular nature of the data (i.e., 0° is identical to 360°). There are some systematic differences that may reflect true differences in wind direction between Barrow and the grid locations. For example, north-easterly winds at Barrow (0–90°) appear to be systematically rotated clockwise relative to winds at 70°N (coming from a more easterly direction) and anticlockwise relative to winds at 72.5°N (coming from a more northerly direction).

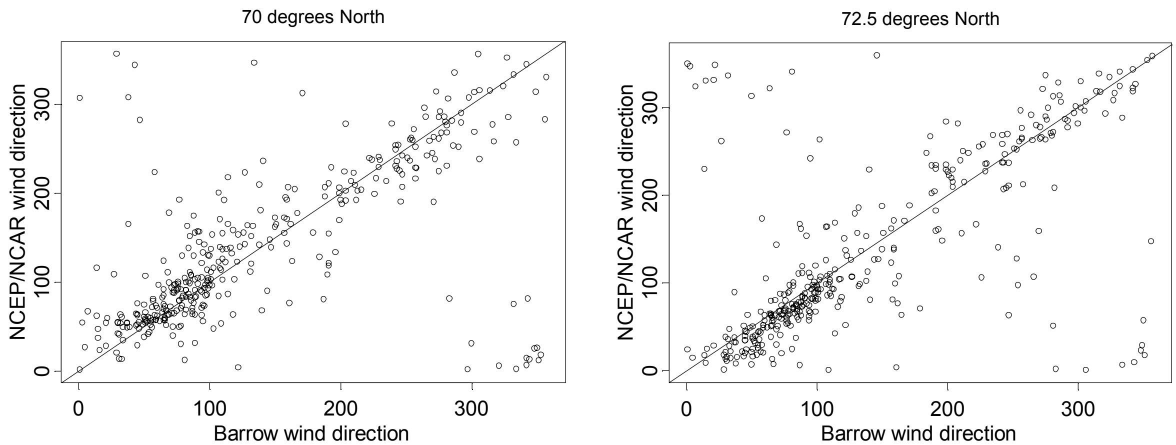

Figure H-2. Daily NCEP/NCAR wind direction at 70°N, 157.5°W and 72.5°N, 157.5°W for 1997, compared to daily measured wind direction at Barrow (71.32°N, 156.6°W). Line indicates 1:1 correspondence.

NCEP/NCAR WINDS VS. DEADHORSE WINDS

Deadhorse is located at 70.20°N, 148.48°W and we compared measured winds at Deadhorse to model-derived winds for the nearest grid point at 70°N, 147.5°W. We used the most recent years with complete data (2000–2004) for comparisons. Daily averaged wind speeds at Deadhorse agreed only poorly with NCEP/NCAR modelled winds at the nearest grid point (Figure H-3). There was only a moderate positive correlation between modelled and measured winds ($r = 0.497$) and modelled winds were biased high at low wind speeds (<5 m/s) and biased low at high wind speeds relative to the measured winds at Deadhorse. The mean wind speed was nearly identical (4.61 m/s for NCEP/NCAR winds and 4.57 m/s for Deadhorse winds).

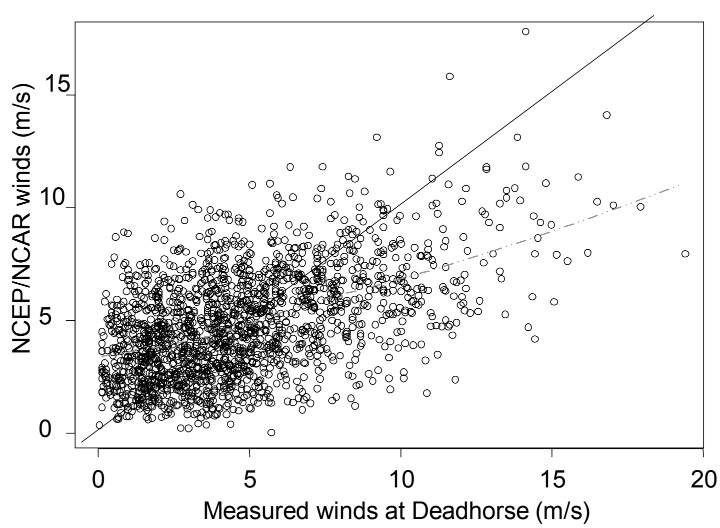

Figure H-3. Daily NCEP/NCAR reanalysis winds at 70°N, 147.5 W and daily averages of measured winds at Deadhorse (70.20°N, 148.48°W) with 1:1 correspondence line and a LOWESS smoother (dashed line).

Modelled mean daily wind directions at 70°N, 147.5°W agreed reasonably well with mean wind direction as measured at Deadhorse (Figure H-4), but the agreement was much poorer than at Barrow. There are some systematic differences such as a discrepancy between the modelled and measured direction of north-easterly to easterly winds, which were typically estimated to come from a more easterly direction by the model. Wind direction at Deadhorse was only measured to the nearest 10°, but this is unlikely to bias the overall pattern.

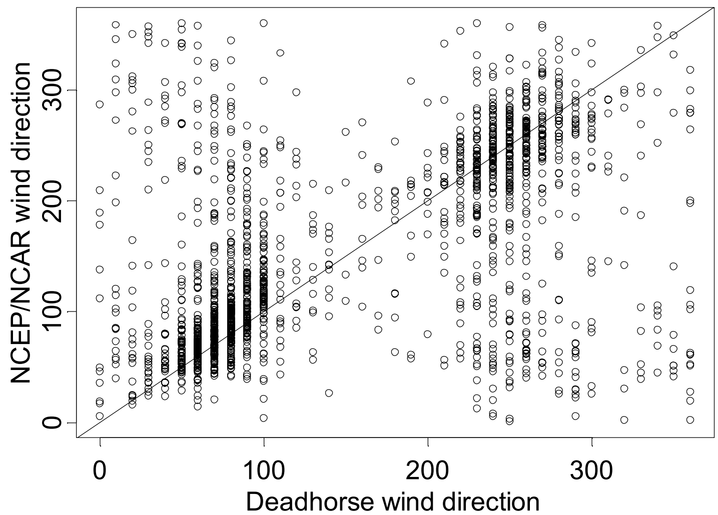

Figure H-4. Daily NCEP/NCAR wind direction at 70°N, 147.5°W for 2000–2004, compared to daily measured wind direction at Deadhorse (70.20°N, 148.48°W).

In summary, model-derived daily wind speed and direction agreed well with measured winds at Barrow, but much less so with measured winds at Deadhorse. At present it is unclear whether the poor agreement with Deadhorse winds reflects poor NCEP/NCAR model fits in this region compared to Barrow (e.g., due to topographic steering by the Brooks Range, which is not accounted for in modelled winds) or whether measurements at the Deadhorse airport that are not representative of the larger area (e.g., due to local effects on measurements).

ALONGSHORE WIND INDEX BASED ON NCEP/NCAR REANALYSIS WINDS

Because Deadhorse winds may not be reflective of alongshore winds in the Beaufort Sea, we developed alternative indices of alongshore easterly winds. To examine winds most representative of the coastal Beaufort Sea between the Mackenzie and Colville rivers, we chose NCEP/NCAR reanalysis winds for five grid points at 70°N from 147.5°W to 137.5°W (inclusive). The E-W and N-S wind components are highly correlated among these locations. Correlations decrease with distance and decrease faster for the N-S component (v-wind), which is typically much smaller:

Table H-1. Correlations among five grid points for east-west component of wind (u-wind).

	N70.W147.5	N70.W145	N70.W142.5	N70.W140	N70.W137.5
N70.W147.5	1.000	0.986	0.946	0.885	0.808
N70.W145	0.986	1.000	0.986	0.946	0.883
N70.W142.5	0.946	0.986	1.000	0.986	0.944
N70.W140	0.885	0.946	0.986	1.000	0.985
N70.W137.5	0.808	0.883	0.944	0.985	1.000

Table H-2. Correlations among five grid points for north-south component of wind (v-wind).

	N70.W147.5	N70.W145	N70.W142.5	N70.W140	N70.W137.5
N70.W147.5	1.000	0.973	0.877	0.735	0.602
N70.W145	0.973	1.000	0.960	0.849	0.720
N70.W142.5	0.877	0.960	1.000	0.959	0.867
N70.W140	0.735	0.849	0.959	1.000	0.969
N70.W137.5	0.602	0.720	0.867	0.969	1.000

Average wind speeds at the selected grid points are generally weakest in spring and summer (March – July) and strongest in winter, particularly in January. However, the difference in wind speed between summer and winter is relatively moderate.

Table H-3. Average wind speed at 5 locations by month (averaged over 1961–2004 period).

	N70.W147.5	N70.W145	N70.W142.5	N70.W140	N70.W137.5
Jan	5.37	5.42	5.52	5.66	5.78
Feb	4.63	4.70	4.85	5.02	5.15
Mar	4.49	4.50	4.58	4.73	4.89
Apr	4.42	4.33	4.31	4.37	4.49
May	4.46	4.42	4.43	4.51	4.61
June	4.49	4.55	4.63	4.73	4.86
July	4.40	4.37	4.44	4.61	4.79
Aug	4.56	4.60	4.74	4.96	5.16
Sept	5.04	5.06	5.19	5.38	5.57
Oct	5.15	5.14	5.20	5.33	5.47
Nov	5.06	5.00	5.01	5.12	5.25
Dec	4.79	4.79	4.88	5.07	5.25

To examine the relationship between alongshore winds and Arctic cisco recruitment, we derived two transport indices by (1) averaging alongshore (rotated) winds across these five locations over the July-August period and (2) summing alongshore wind speeds over all days with easterly winds. These indices are described in detail in the Data Exploration section of the report.

COMPARISON OF ANNUAL INDICES

We compared our annual indices derived from the NCEP/NCAR reanalysis data to the Deadhorse wind index used in Fechhelm et al. (2005). The Deadhorse index is positively correlated both with average NCEP/NCAR alongshore winds ($r = 0.76$) and with the sum of easterly winds ($r = 0.70$). The two NCEP/NCAR indices are strongly correlated (0.89). The Deadhorse index reflects the east-west wind component only. The north-south component is relatively small and the minor rotation required to compute alongshore winds in this region would make little difference. Furthermore, it is not clear how much Deadhorse winds should be rotated to get an estimate of alongshore winds because winds at Deadhorse are likely to be rotated relative to the shoreline.

While interannual variability follows similar patterns, the correspondence between absolute values of the average winds is poor. NCEP/NCAR winds along the coast are generally much smaller in magnitude than measured winds at Deadhorse and they tend to be negative (westerly) far more often (Figure H-5). These differences may, in part, be due to the fact that hourly winds were averaged to derive the Deadhorse index (Fechhelm et al. 2005), while the NCEP/NCAR data reflect daily average wind vectors. Furthermore, the sea-breeze phenomenon may tend to increase wind speeds at Deadhorse in summer (Tom Weingartner, UAF, pers. comm.). The agreement was particularly poor in 1984, 1985, and 2003. NCEP winds greatly underestimated winds at Deadhorse in 1984 and 1985, and greatly overestimated winds in 2003.

Despite tailoring the NCEP indices to reflect July and August alongshore winds in the eastern and western Beaufort Sea, respectively, the Deadhorse wind index was a much better (linear) predictor of age-0 recruitment to the Prudhoe Bay region (r = 0.65) than the NCEP/NCAR winds (0.43 and 0.48 for sum of easterly winds and average daily winds, respectively). Therefore, we continued to include Deadhorse winds in the analysis because it seems likely that NCEP/NCAR winds in the region are poorly estimated, possibly as a result of sparse observations and orographic effects from the Brooks Range.

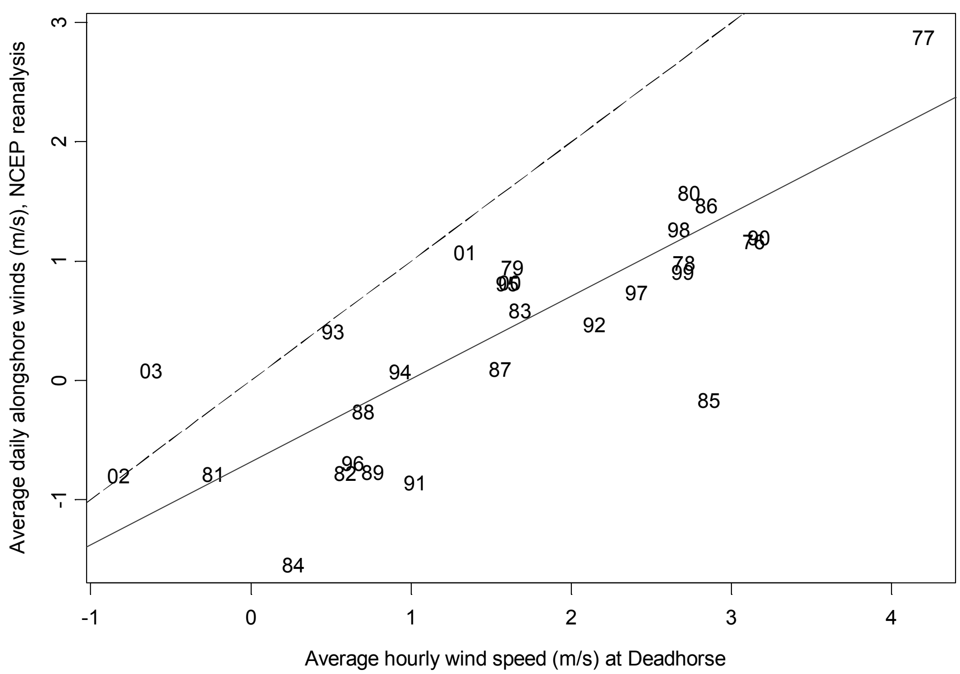

Figure H-5. Comparison of average daily alongshore winds from NCEP reanalysis and average hourly winds at Deadhorse airport. Dashed line reflects 1:1 correspondence, solid line is generalized least-squares regression line (assuming first-order auto-correlated residuals).

Appendix I.

Statistical Model Output for Data Exploration

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APPENDIX I: STATISTICAL MODEL OUTPUT FOR DATA EXPLORATION

Model IV.5.1: Index of average annual salinities in the Niġliq channel during fall fishery
Type of model: Linear model
Dependent variable: Salinity
Independent variables:
Area (categorical, levels: Upper Niġliq, Nanuk, Niġliq delta)
Julian day (polynomial term, 5^{th}-order)
Year (categorical, levels: 1981, 1982, …, 2004, except 1999)

S-Plus code for linear model (lm) and model output from analysis:

```
Call: lm(formula = Salinity ~ Area + poly(Julian, 5) + factor(Year)-1)
Residuals:
    Min     1Q Median   3Q   Max
 -11.52 -1.261 0.1969 1.49 10.15

Coefficients:
                    Value Std. Error  t value Pr(>|t|)
         Area610   7.4888   0.1647    45.4660   0.0000
         Area650  16.2979   0.1877    86.8141   0.0000
         Area670  19.6267   0.2037    96.3460   0.0000
poly(Julian, 5)1  75.9969   3.1515    24.1144   0.0000
poly(Julian, 5)2 -19.2953   2.9846    -6.4650   0.0000
poly(Julian, 5)3   5.7016   2.9442     1.9366   0.0531
poly(Julian, 5)4  -6.8303   2.9716    -2.2985   0.0218
poly(Julian, 5)5  11.4716   2.9331     3.9111   0.0001
   factor(Year)1  -1.0837   0.5411    -2.0027   0.0455
   factor(Year)2  -4.9533   0.3238   -15.2957   0.0000
   factor(Year)3  -0.7831   0.1953    -4.0090   0.0001
   factor(Year)4   1.2550   0.1078    11.6458   0.0000
   factor(Year)5   0.9008   0.0765    11.7679   0.0000
   factor(Year)6   0.2352   0.0538     4.3713   0.0000
   factor(Year)7   0.0547   0.0483     1.1321   0.2579
   factor(Year)8  -0.5726   0.0547   -10.4657   0.0000
   factor(Year)9  -0.5509   0.0538   -10.2385   0.0000
  factor(Year)10   0.2183   0.0332     6.5806   0.0000
  factor(Year)11   0.1700   0.0329     5.1712   0.0000
  factor(Year)12   0.0934   0.0409     2.2827   0.0227
  factor(Year)13  -0.2259   0.0317    -7.1212   0.0000
  factor(Year)14  -0.4702   0.0350   -13.4333   0.0000
  factor(Year)15  -0.3853   0.0260   -14.8210   0.0000
  factor(Year)16  -0.0193   0.0269    -0.7176   0.4732
  factor(Year)17   0.3440   0.0290    11.8510   0.0000

Residual standard error: 2.845 on 834 degrees of freedom
Multiple R-Squared: 0.9706
F-statistic: 1101 on 25 and 834 degrees of freedom, the p-value is 0
```

```
Type I (sequential) Sum of Squares

                  Df Sum of Sq  Mean Sq  F Value Pr(F)
           Area   2  23360.30 11680.15 1442.976     0
poly(Julian, 5)   5   4016.13   803.23   99.231     0
           Year  17  12732.11   748.95   92.526     0
      Residuals 834   6750.80     8.09

Type III Sum of Squares
                  Df Sum of Sq  Mean Sq  F Value Pr(F)
           Area   2  21973.06 10986.53 1357.285     0
poly(Julian, 5)   5   5323.77  1064.75  131.541     0
           Year  17  12732.11   748.95   92.526     0
      Residuals 834   6750.80     8.09
```

<u>Model V.II.1</u>: Index of average annual CPUE off ANWR based on 7 survey stations
Type of model: Linear model
Dependent variable: log(CPUE) of age-0 Arctic cisco
Independent variables:
Station (categorical, levels: BL02, JL12, JL14, KL05, KL10, SC01, SC04)
Year (categorical, levels: 1988, 1989, 1990, 1991)

S-Plus code for linear model (lm) and model output from analysis:

```
Call: lm(formula = log(CPUE + 1) ~ year + station)
Residuals:
     Min      1Q   Median     3Q   Max
 -0.9508 -0.4625 -0.06104 0.4655 1.464

Coefficients:
               Value Std. Error  t value Pr(>|t|)
(Intercept)   2.4711   0.1625    15.2113   0.0000
      year1  -0.2645   0.2429    -1.0892   0.2922
      year2   0.8772   0.1300     6.7471   0.0000
      year3  -0.6981   0.0900    -7.7530   0.0000
   station1  -0.5777   0.3127    -1.8472   0.0833
   station2  -0.1951   0.1702    -1.1463   0.2685
   station3  -0.2976   0.1185    -2.5116   0.0231
   station4  -0.2305   0.0912    -2.5283   0.0224
   station5  -0.2669   0.0742    -3.5976   0.0024
   station6  -0.0813   0.0719    -1.1301   0.2751

Residual standard error: 0.8075 on 16 degrees of freedom
Multiple R-Squared: 0.8989
F-statistic: 15.8 on 9 and 16 degrees of freedom, the p-value is 2.294e-006
```

Analysis of variance table (Type I, sequential sum of squares):

```
          Df Sum of Sq  Mean Sq  F Value       Pr(F)
     year  3  74.22187 24.74062 37.94560 0.000000168
  station  6  18.51859  3.08643  4.73377 0.005925686
Residuals 16  10.43204  0.65200
```

Estimated annual means:

```
 year1988 year1989 year1990  year1991
  2.55649 2.027419 4.923632 0.3768945
```

Appendix J.

Estimation of Age-0 Abundances Off the Arctic National Wildlife Refuge During 1988–1991

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APPENDIX J: ESTIMATION OF AGE-0 ABUNDANCES OFF THE ARCTIC NATIONAL WILDLIFE REFUGE DURING 1988–1991

During four years from 1988 through 1991, the Fish and Wildlife Service conducted fyke net collections at various locations in the coastal waters off the Arctic National Wildlife Refuge (ANWR) (Figures J-1–J-3). Sampling locations varied some among years but three areas were sampled every year, and Beaufort Lagoon was sampled in three of the four years (Table J-1). The data were summarized in annual reports (Fruge et al. 1989, Palmer and Dugan 1990, Underwood et al. 1992, Underwood et al. 1994). We used these data primarily to obtain an annual index of abundance for age-0 Arctic cisco along the coast and to estimate the timing of arrival at these sampling locations, which are located about half-way between the Mackenzie River and the Colville River. Within each area, two stations were sampled consistently throughout the sampling period (Table J-2).

Table J-1. Areas (west to east) sampled for Arctic cisco off the coast of ANWR between 1988 and 1991.

Year	Camden Bay (CP, SC)	Kaktovik Lagoon (KL)	Jago Lagoon (JL)	Pokok Bay (PB)	Beaufort Lagoon (BL)
1988	X	X	X	X	
1989	X	X	X		X
1990	X	X	X		X
1991	X	X	X		X

Table J-2. Number of fyke net samples by station and year

	BL02	BL04	BL12	BL13	BS10	BS11	CP10	JL12	JL14	KL05	KL10	PB01	PB02	SC01	SC04
1988	0	0	0	0	0	0	0	41	43	45	44	52	32	46	0
1989	21	18	0	0	0	0	0	54	55	52	56	0	0	59	55
1990	61	48	34	26	6	6	18	44	48	49	56	0	0	54	51
1991	56	49	0	0	0	0	0	41	49	44	51	0	0	55	32

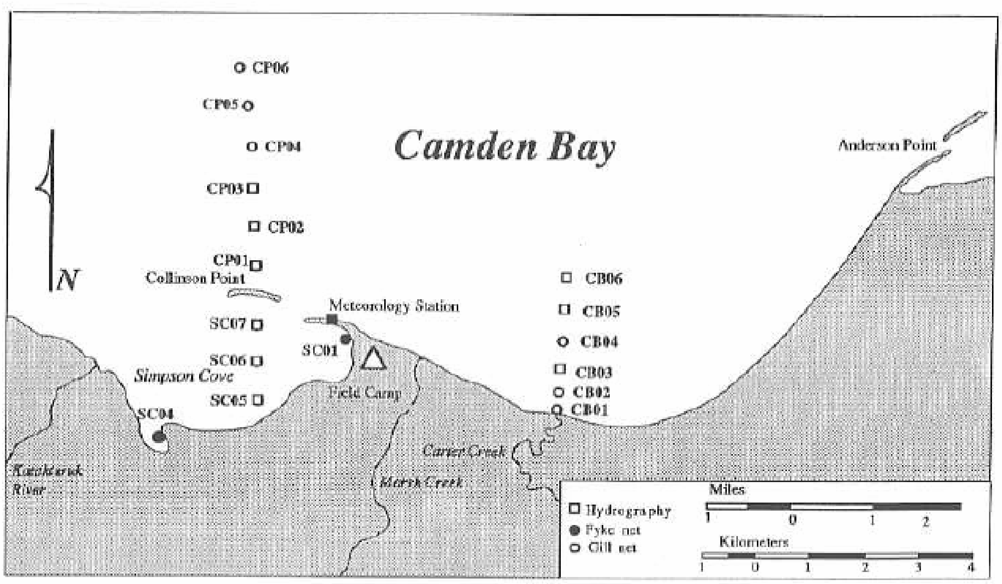

Figure J-1. Stations sampled during 1991 in Camden Bay (from Underwood et al. 1994). SC01 and SC04 were sampled regularly using a fyke net.

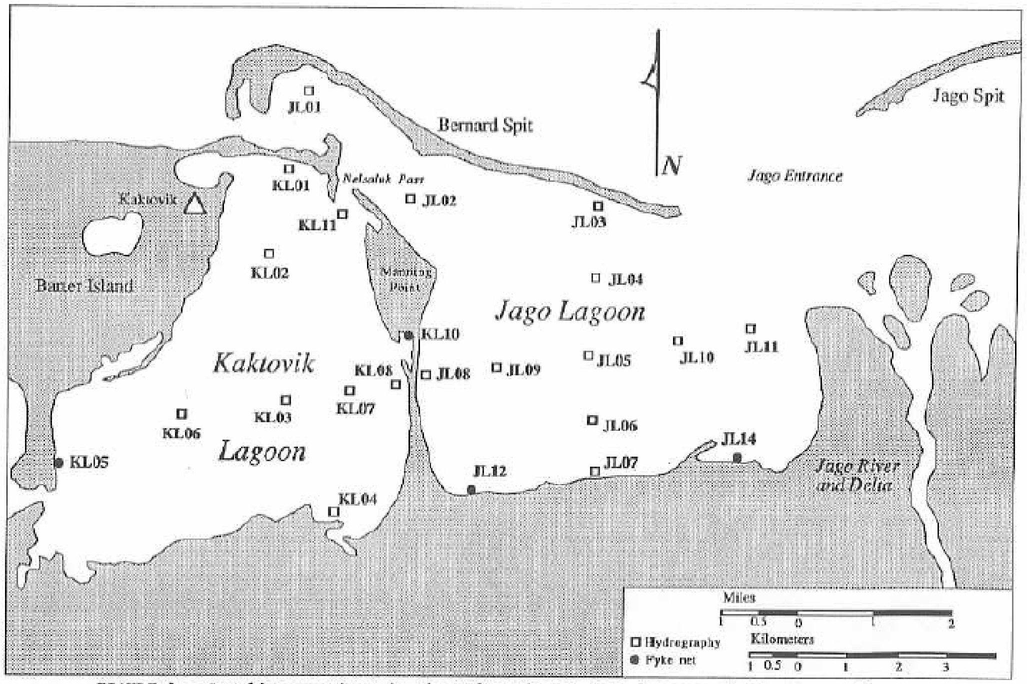

Figure J-2. Stations sampled during 1991 in Kaktovik and Jago lagoons (from Underwood et al. 1994). Stations KL05 and KL10 in Kaktovik Lagoon and stations JL12 and JL14 in Jago Lagoon were sampled regularly and in each year, 1988–1991

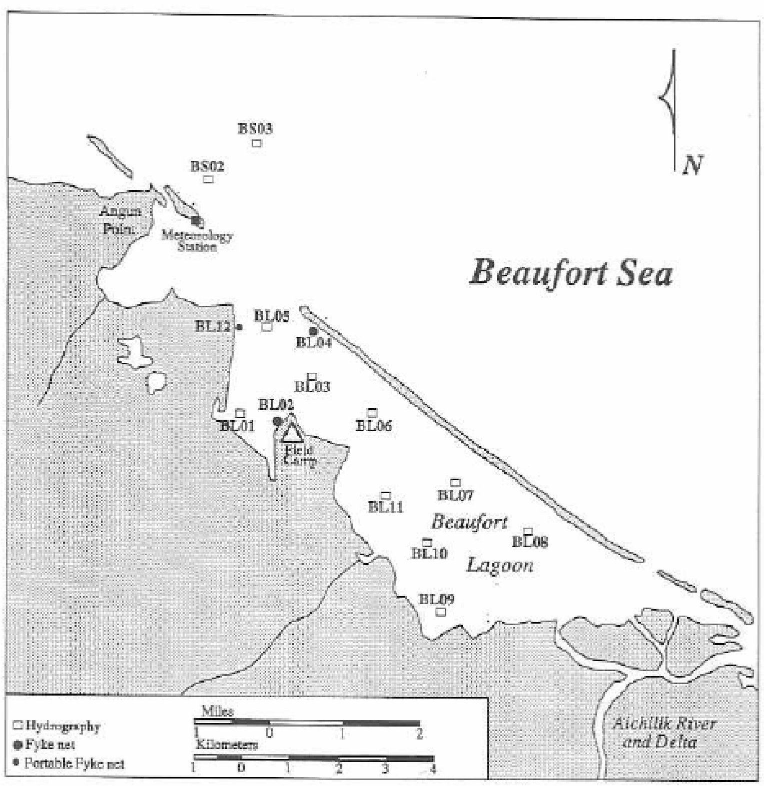

Figure J-3. Stations sampled during 1991 in Beaufort Lagoon (from Underwood et al. 1994). Stations BL02 and BL04 were sampled regularly 1989–1991 (not sampled in 1988).

To obtain a consistent estimate of year-class strength for Arctic cisco off ANWR, we first estimated the proportion of age-0 fish based on length-frequency data. Length-frequencies by year and area show distinct modes for age-0 and age-1 fishes, and a separate mode for older fishes with a marked gap between these two size groups, suggesting that the catch consists of the youngest and older year classes only, while intermediate year classes are missing (Figure J-4). This pattern is consistent with young fishes migrating along the coast from east to west and older, maturing Arctic cisco returning to the Mackenzie River. The presence of age-1 fishes suggests that some young-of-the-year Arctic cisco overwinter in this region or farther east. The lack of intermediate year-classes suggests they continue their migration to the west.

The length-frequency distribution allowed us to separate age-0 and age-1 fishes and estimate the proportion of age-0 fishes in the catch. There were large differences in the modal size among years. However, within a given year, modes are fairly consistent among areas. For example, the youngest age group is considerably larger in 1989 compared to the other years (Figure J-5). Because sizes are relatively consistent among stations, we plotted length-frequencies by year, which results in separate modes for age classes 0 and 1 with minimal overlap (Figure J-6). An improved separation of cohorts was possible by plotting length-frequencies separately for different time periods. We divided the season into five periods that clearly separates cohorts by size in most cases and shows the seasonal increase in modal length (Figure J-7). We used histograms by period and year to determine the maximum size of age-0 fishes for each year and period.

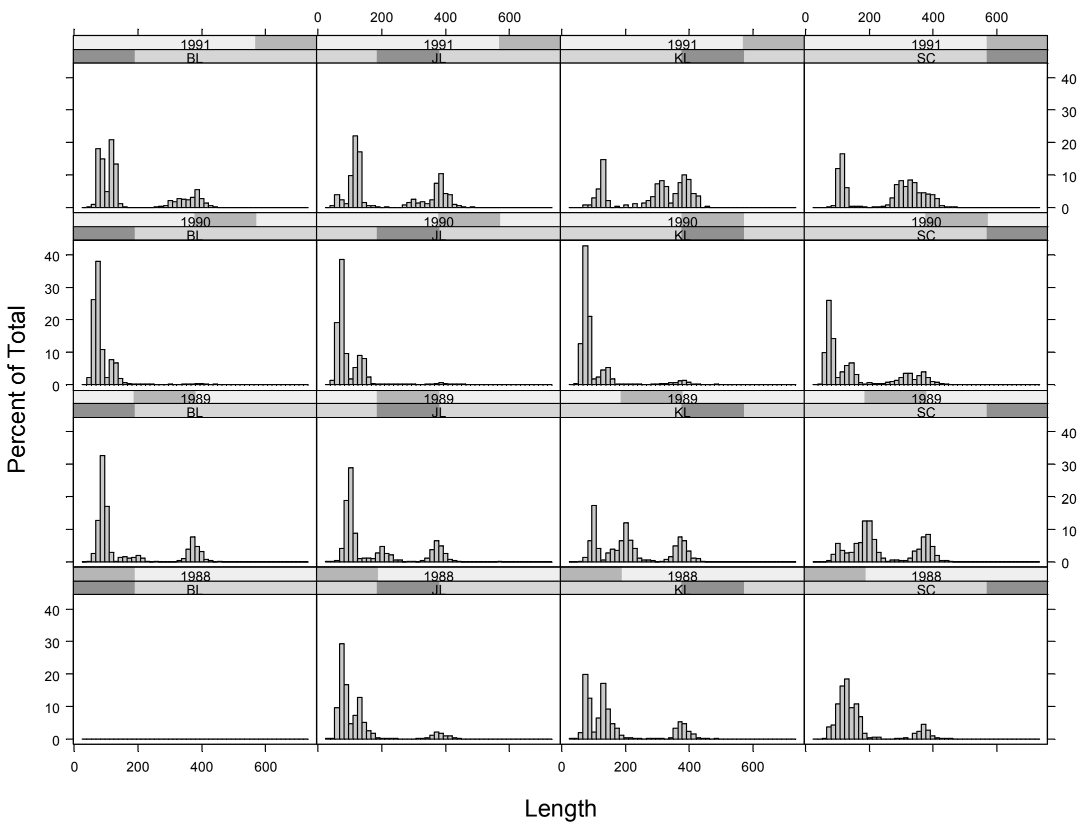

Figure J-4. Length-frequency distribution of all Arctic cisco captured off ANWR by area and year (four major sampling areas only).

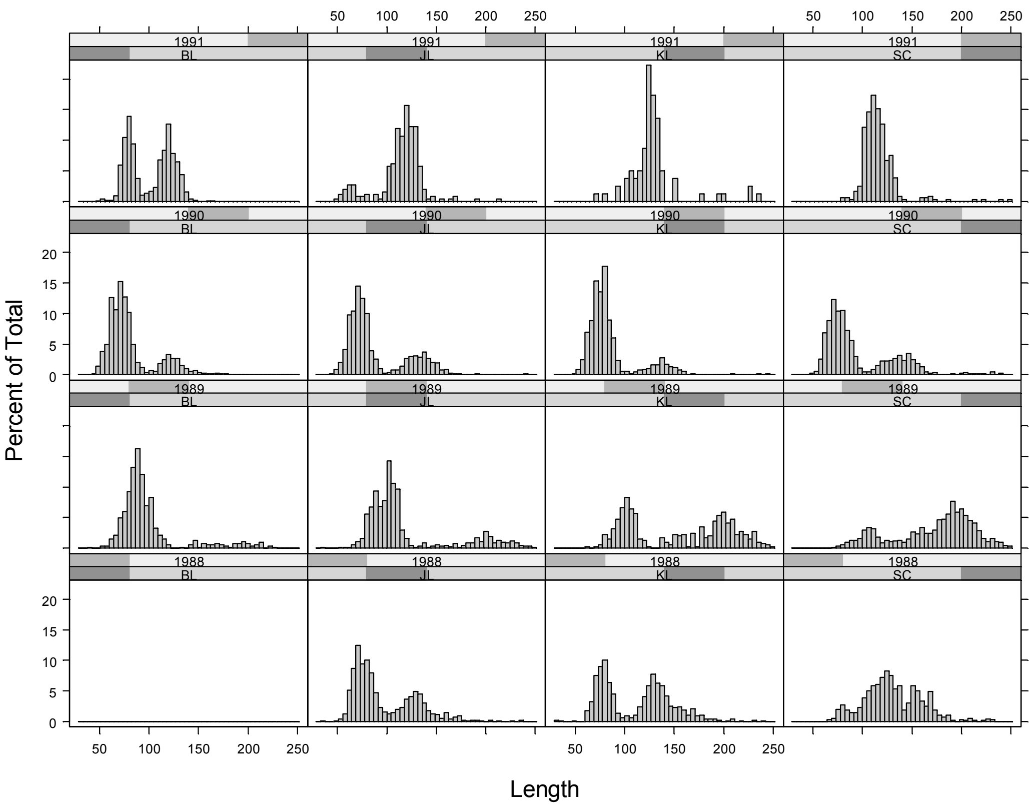

Figure J-5. Length-frequency distribution of all Arctic cisco captured off ANWR by area and year (four major areas only), truncated at 250 mm

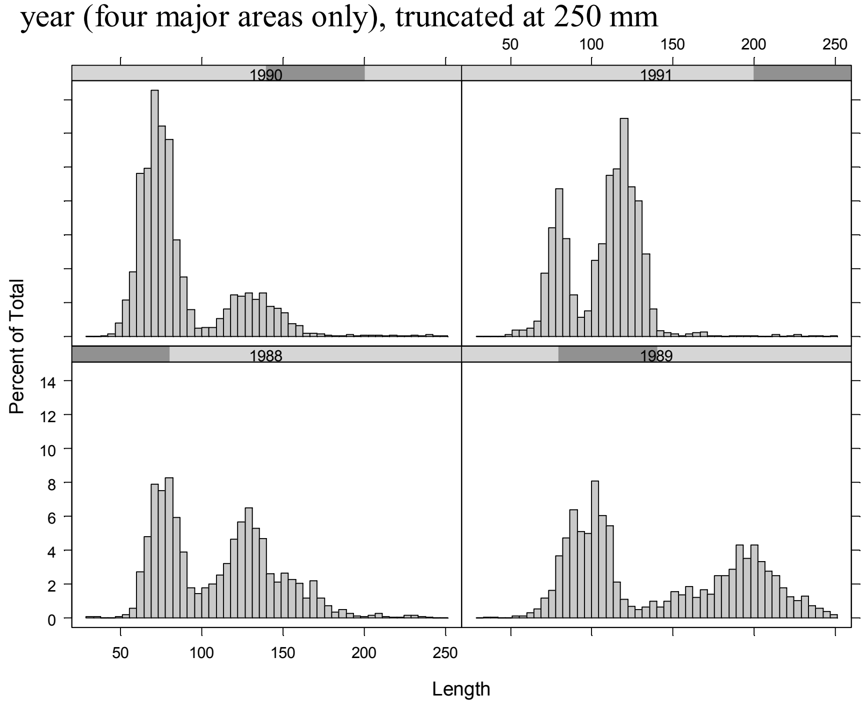

Figure J-6. Length-frequency distribution of all Arctic cisco captured off ANWR by year (four major areas only), truncated at 250 mm.

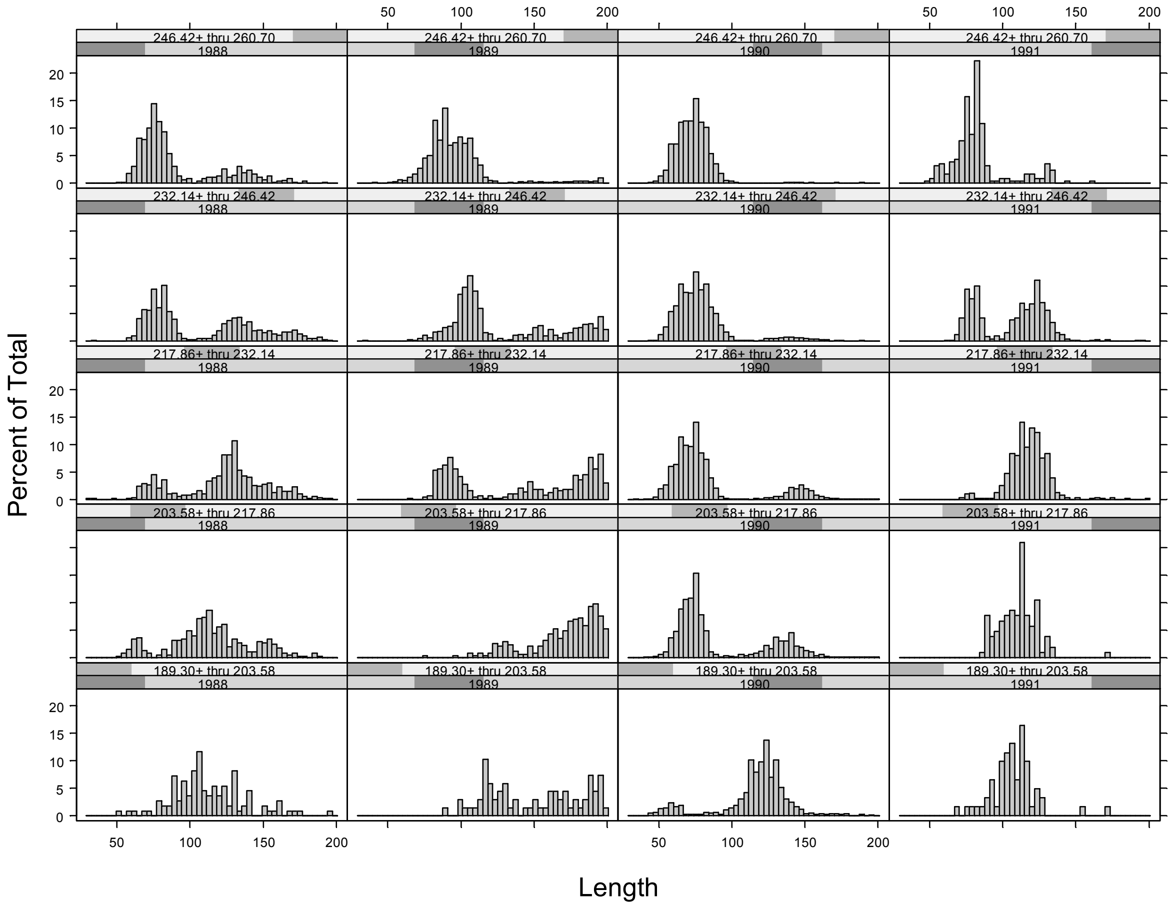

Figure J-7. Length-frequency distribution of all Arctic cisco captured off ANWR by year and period (Julian dates 190–203, 204–217, 218–232, 233–246, 247–260), truncated at 200 mm.

A visual examination of the length-frequency plots yielded the following maximum sizes (in mm) for each year / period combination:

Julian Dates	1988	1989	1990	1991
190 - 203	70	80	75	70
204 - 217	80	90	95	80
218 - 232	95	112	100	85
233 - 246	100	122	105	90
247 - 260	105	130	110	95

These values were used to estimate the proportion of age-0 fish at each station. The total catch at each station was then multiplied by the estimated proportion to obtain the estimated number of age-0 fish by station, year, and day. For certain days, no Arctic cisco was measured at some stations. We estimated the proportion of age-0 Arctic cisco on these days based on average proportions at the same station during the 10-day period prior to and following the day in question. CPUE of age-0 Arctic cisco varied greatly over the course of a season and among years. By far the highest CPUEs were observed in 1991 at all stations as exemplified by Kaktovik Lagoon (Figure J-8). Patterns were similar at the other stations.

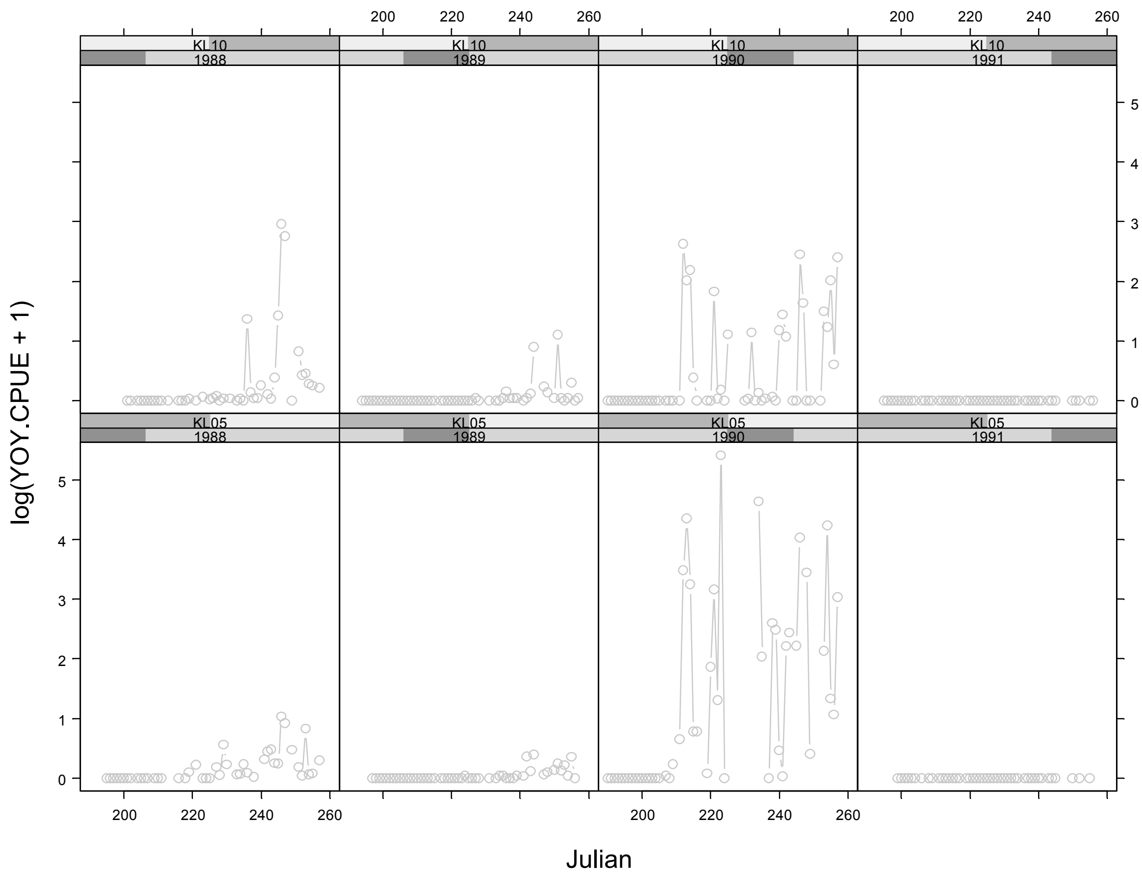

Figure J-8. Daily CPUE values of age-0 Arctic cisco at two stations in Kaktovik Lagoon (KL05 and KL10) during four summers (1988–1991).

We obtained an annual index of year-class strength for each station by computing the average CPUE as cumulative catch divided by cumulative effort between Julian dates 200 and 258. These were combined into a single indicator of annual average CPUE off ANWR using an ANOVA of log(CPUE) on year, as described in Chapter 4.

Appendix K.

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APPENDIX K: ANALYSIS OF CATCH DATA FROM THE SUBSISTENCE AND COMMERCIAL FISHERIES FOR ARCTIC CISCO

SUBSISTENCE (NUIQSUT VILLAGE) FISHERY

Each year since 1985, fishermen interviews have been conducted to obtain catch estimates (number of fish) and effort estimates (net days per 18-m net) for the Arctic cisco fishery (Moulton and Seavey 2005; Moulton et al. 2006). About 85–90% of all sets made in the fishery were reflected in theses interviews (Larry Moulton, pers. comm., March 2005). For each set, the year, area (one of 8 different sections of the Colville river and delta), a unique fisherman ID, a unique net ID, mesh size, net length, duration of the set, and date the net was checked were recorded in the database.

The major areas where fishing took place changed somewhat over time (Table K-1, 50 = Main River near Nuiqsut; 100 = Kupigruak Channel in Outer Delta; 150 = East Channel in Outer Delta; 200 = Lower Colville River; 610 = Upper Niġliq; 630 = Uyagagvik area of Upper Niġliq; 650 = Nanuk Lake; 670 = Niġliq Delta). However, the upper Niġliq, Nanuk Lake, and Niġliq Delta have been fished to some extent in most years. In recent years, most of the fishing effort has occurred in the Niġliq Delta, which is farther from the village than the upper Niġliq and Nanuk Lake areas. However, fishing effort shifted back towards the Nanuk Lake area in 2004 (Table K-1).

Table K-1. Number of sets by fishing area and year, all nets

	MJM100	MJM150	MJM200	MJM50	MJM610	MJM630	MJM650	MJM670
1986	149	12	0	0	138	0	13	54
1987	54	0	0	0	132	0	18	12
1988	20	4	0	0	54	0	15	24
1989	1	0	0	0	57	0	11	22
1990	0	0	0	0	147	0	105	23
1991	0	0	0	37	140	0	142	4
1992	5	0	0	0	184	96	203	18
1993	0	0	0	0	59	57	135	68
1994	4	0	0	0	71	0	96	0
1995	14	7	5	0	23	19	79	109
1996	32	0	0	0	7	0	38	105
1997	2	0	0	0	126	0	80	108
1998	0	0	0	0	84	0	51	129
2000	0	0	0	0	20	0	65	122
2001	0	0	0	0	70	0	12	135
2002	0	0	0	0	80	0	26	357
2003	0	0	0	0	8	0	93	324
2004	0	0	0	0	17	0	172	159

The fishery has used a variety of different mesh sizes to catch Arctic cisco, least cisco, and other species. The majority of sets (58.9% across years) were made using a 76-mm net (Table K-2). Other commonly used nets were 89 mm (26%), 64 mm (6.9%), and 83 mm (6.0%) (Table K-3).

The proportion of sets made with a 76-mm mesh size varied from 47% in 2000 to 73% in 1986. In terms of effort, the percentage for the 76-mm mesh net by year ranged from 42% to 74% of total effort (Table K-4).

Table K-2. Number of sets using 76-mm net by fishing area and year

	MJM100	MJM150	MJM200	MJM50	MJM610	MJM630	MJM650	MJM670
1986	127	6	0	0	86	0	11	36
1987	47	0	0	0	78	0	16	9
1988	12	2	0	0	34	0	11	22
1989	1	0	0	0	42	0	6	8
1990	0	0	0	0	83	0	71	18
1991	0	0	0	14	58	0	97	2
1992	5	0	0	0	97	48	90	14
1993	0	0	0	0	11	30	82	31
1994	2	0	0	0	25	0	78	0
1995	12	4	2	0	7	10	60	28
1996	30	0	0	0	5	0	35	42
1997	2	0	0	0	65	0	56	38
1998	0	0	0	0	31	0	38	65
2000	0	0	0	0	3	0	18	74
2001	0	0	0	0	36	0	7	75
2002	0	0	0	0	49	0	15	202
2003	0	0	0	0	8	0	61	218
2004	0	0	0	0	15	0	149	112

Table K-3. Number of sets by mesh size and year

	51	57	64	70	73	76	83	89	95	102	108	114	121	127
1986	0	0	5	0	0	266	51	39	0	5	0	0	0	0
1987	0	0	5	7	0	150	20	34	0	0	0	0	0	0
1988	0	0	2	2	5	81	7	14	0	3	2	1	0	0
1989	0	0	5	0	0	57	15	14	0	0	0	0	0	0
1990	2	0	14	0	0	172	5	81	0	0	0	0	0	1
1991	0	1	45	0	0	171	14	87	0	0	0	1	2	2
1992	0	0	80	39	0	254	20	108	4	0	0	1	0	0
1993	0	0	31	13	0	154	20	94	7	0	0	0	0	0
1994	0	0	12	8	0	105	3	43	0	0	0	0	0	0
1995	0	0	12	5	0	123	46	65	0	0	0	1	0	4
1996	0	0	5	0	0	112	12	53	0	0	0	0	0	0
1997	0	0	8	0	0	161	34	113	0	0	0	0	0	0
1998	0	0	14	0	0	134	1	115	0	0	0	0	0	0
2000	0	0	0	0	0	95	19	93	0	0	0	0	0	0
2001	0	0	5	0	0	118	11	83	0	0	0	0	0	0
2002	0	0	41	0	0	266	28	125	0	1	0	0	0	2
2003	5	0	49	19	0	287	0	65	0	0	0	0	0	0
2004	0	0	16	0	0	276	0	56	0	0	0	0	0	0

Table K-4. Proportion of total fishing effort attributable to 76-mm net by year

1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	2000	2001	2002	2003	2004
73	69	69	63	63	53	50	48	61	48	62	51	51	46	54	57	68	79

Based on the 76-mm net, CPUE in the subsistence fishery has declined over time, while effort increased from the late 1980s to the 1990s (Figure K-1, left panels). Daily catch and effort show a strong negative relationship, most evident on the log-scale (Figure K-1, right panel), suggesting that depletion (reduction in fish density due to removal of fish) is occurring over time within a season.

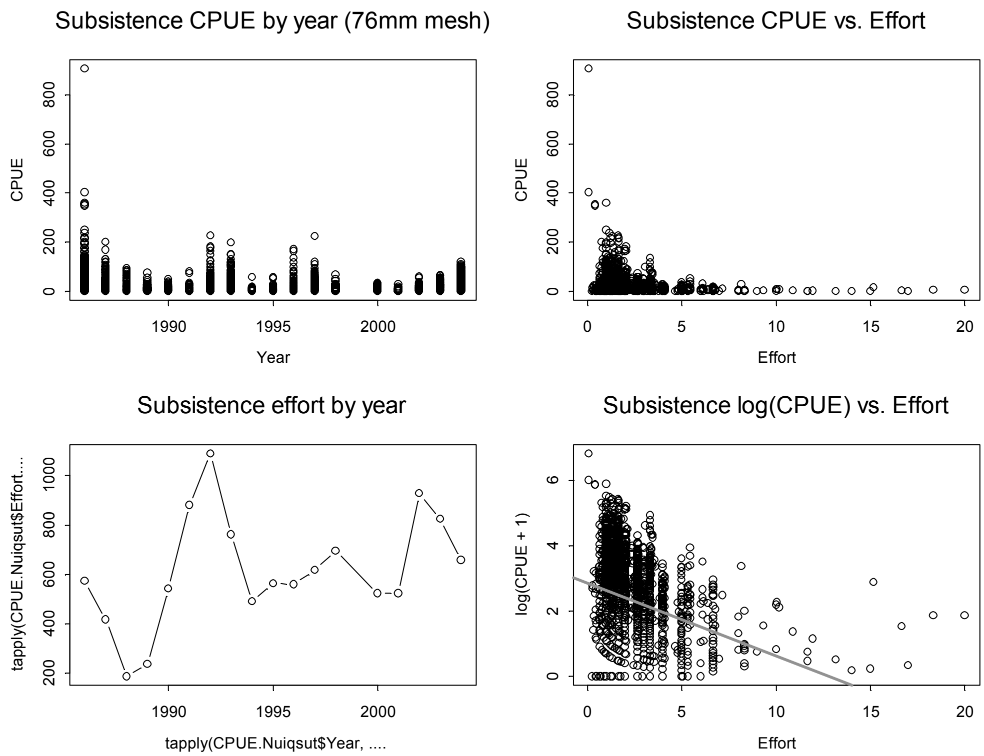

Figure K-1. Daily CPUEs and total effort by year, and CPUE vs. effort for Arctic cisco caught in subsistence fishery.

Total effort has shifted among fishing areas and has recently been concentrated in the Niġliq delta (Figure K-2, top panels). Average annual CPUE has fluctuated greatly over time with very low catches between 1998 and 2001 (Figure K-2, middle panels). Annual average CPUE appears to be independent of total annual effort (Figure K-2, bottom panels). The apparent negative relationship in the Niġliq delta can be attributed to the fact that recent low catches coincided with the highest effort values, which reflect the shift of fishing effort from upriver locations to the Niġliq delta. Similar trends are evident in the commercial CPUE over the same time period. CPUEs by year for the four main fishing areas (including the commercial fishery, which occurs in the outer delta of the main channel, show the relatively close agreement between catch rates in different areas (Figure K-3).

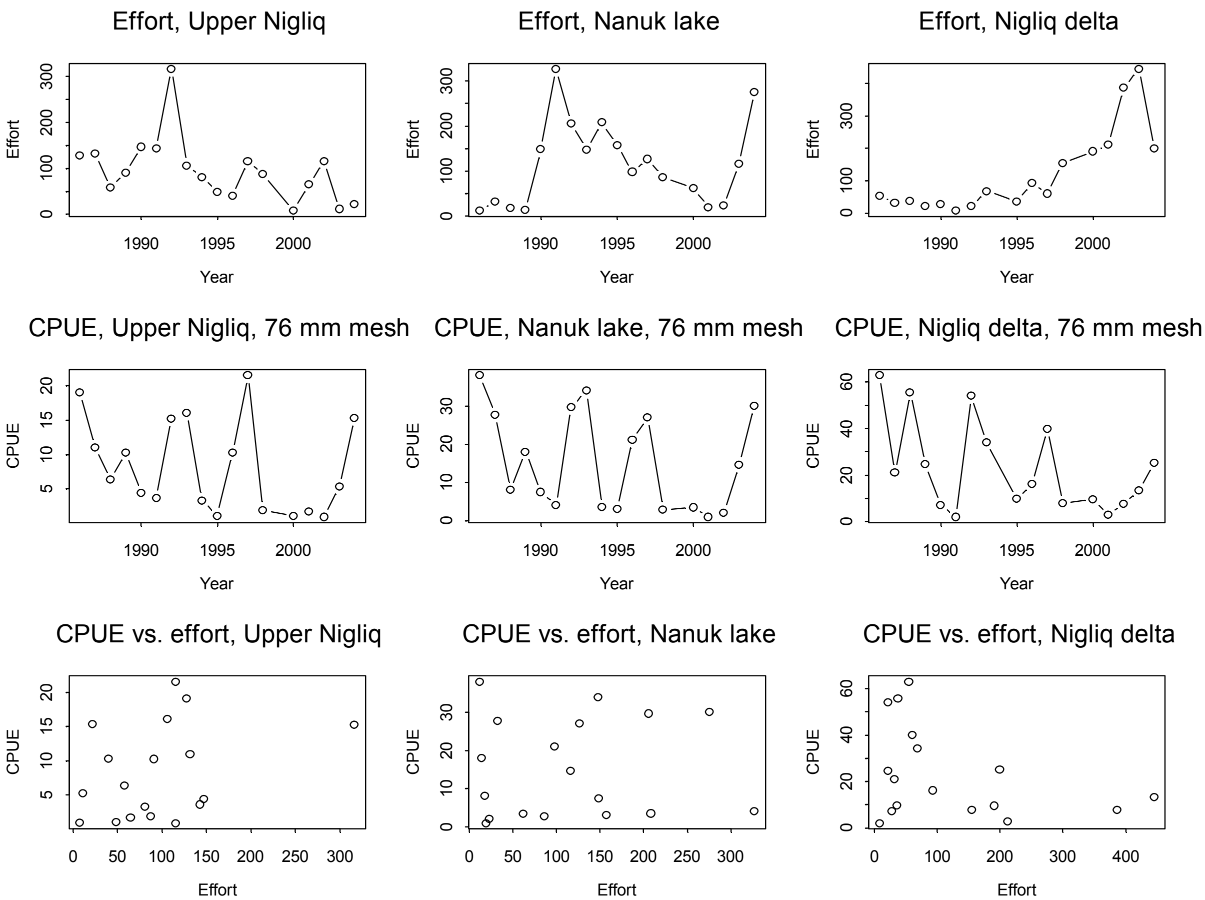

Figure K-2. Total annual effort and annual average CPUE over time and CPUE vs. effort in three regions (76 mm mesh only).

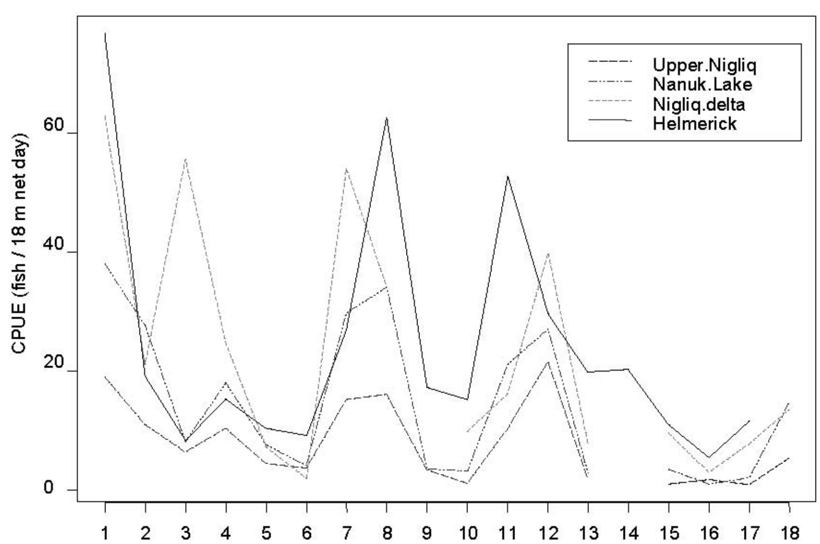

Figure K-3. CPUE of Arctic cisco in four regions from 1986–2003 (1-18 on x-axis) in fish / 18 m net day (76-mm mesh).

CPUE is strongly correlated among regions with the weakest correlation observed between the Helmericks fishery and the Niġliq delta (Table K-5). In the Niġliq channel, CPUE tends to increase from the upper Niġliq towards the delta, which is particularly evident in years with high CPUEs (Figure K-3). CPUE in the commercial fishery (outer delta of main channel) is similar to CPUE in the outer Niġliq channel, if the adjusted measure of effort in the commercial fishery (converted from "fish per 46 m net days" to "fish per 18 m net days) is comparable to that in the subsistence fishery.

Years with high CPUE showed more pronounced peaks in the delta fisheries compared to the Nanuk Lake and upper Niġliq areas (Figure K-3). This relationship suggests that strong year classes show up in larger numbers near the ocean and that abundance fluctuations are dampened up-river, with the lowest fluctuations observed in the upper Niġliq channel. Unusually high CPUEs were observed in the Niġliq delta in 1988 (Figure K-3). CPUEs during 1988 were consistently high across most of the 24 sets made in the Niġliq delta, even though CPUEs were very low in all other areas.

Table K-5. Correlations among CPUE (76-mm mesh) in four different regions, 1986–2003

	Upper.Nigliq	Nanuk.Lake	Nigliq.delta	Helmerick
Upper.Nigliq	1.000	0.939	0.784	0.760
Nanuk.Lake	0.939	1.000	0.735	0.850
Nigliq.delta	0.784	0.735	1.000	0.597
Helmerick	0.760	0.850	0.597	1.000

To assess whether estimated abundance indices are consistent across gear types, we also estimated CPUE by year based on the catches made with the 89-mm net. CPUEs were reasonably consistent among locations, although CPUEs in the upper Niġliq were only weakly correlated with CPUE in the other areas. Correlations of CPUE among nets and regions ranged from 0.19 to 0.97 and were mostly larger than 0.5, suggesting good agreement. The pattern of CPUE over time based on the 89-mm mesh is similar to that in the 76-mm nets with obvious peaks occurring in the same years (Figure K-4). This similarity is further confirmation that the CPUE values reflect real variations in abundance. CPUEs for the larger mesh nets may differ from that in other nets because the nets preferentially sample fish of certain size and age classes and the abundance of different age classes can vary greatly.

Table K-6. Correlations among CPUE in four different regions based on two different nets, 1986–2003, Upper three rows reflect CPUEs based on the 89mm mesh net.

	89-mm mesh			76-mm mesh			.
	Upper Nigliq	Nanuk Lake	Nigliq delta	Upper Nigliq	Nanuk Lake	Nigliq delta	Helmerick
89-mm mesh							
Upper.Nigliq	1.000	0.356	0.186	0.627	0.514	0.265	0.513
Nanuk.Lake	0.356	1.000	0.969	0.557	0.651	0.349	0.270
Nigliq.delta	0.186	0.969	1.000	0.529	0.586	0.521	0.045
76-mm mesh							
Upper.Nigliq	0.627	0.557	0.529	1.000	0.939	0.771	0.717
Nanuk.Lake	0.514	0.651	0.586	0.939	1.000	0.730	0.798
Nigliq.delta	0.265	0.349	0.521	0.771	0.730	1.000	0.546
Helmerick	0.513	0.270	0.045	0.717	0.798	0.546	1.000

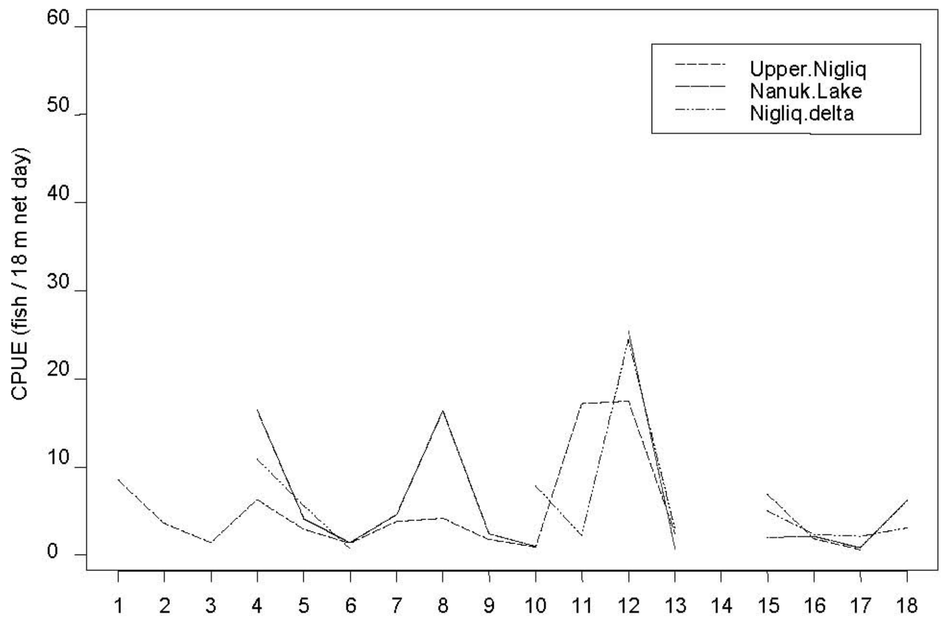

Figure K-4. CPUE of Arctic cisco in three regions from 1986–2003 in fish / 18 m net day (89 mm mesh)

Because CPUEs are consistent among locations we could combine the four CPUE series based on the 76-mm mesh net into a single "best" estimate of annual CPUE. However, it is not clear how the individual series should be weighted, as they are not collected at randomly chosen locations. One possibility is to weight each region within a given year by the effort expended in that region. However, that weighting scheme will bias the average because there are clear trends in the effort series and the mean CPUE (as well as its variance) differs among regions.

Annual average CPUE values may also be biased because of depletion within a year, which is obvious in most years by a negative slope in scatterplots of CPUE against day of year (Figure K-5). Depletion was most obvious in the Niġliq delta (Figure K-, declining CPUE in 12 out of 17 years, binomial probability = 0.049) and least obvious in the upper Niġliq region (where CPUE showed a clear decline in only 8 or 9 out of 17 years, in spite of high effort) (Figure K-6). Depletion may bias estimates of abundance because the average CPUE will be underestimated in years with high fishing effort. To account for a potential relationship between CPUE and fishing effort, effort-corrected CPUE values were computed for analysis (Chapter 3, section V.2).

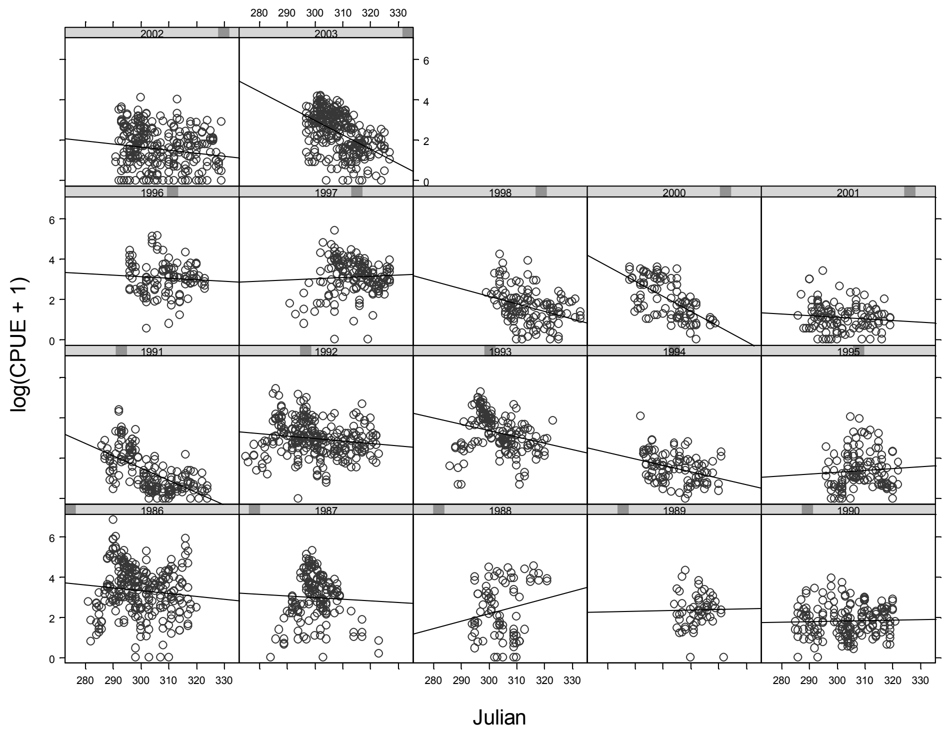

Figure K-5. CPUE of Arctic cisco in the subsistence fishery (76 mm net, all areas) by Julian date and year.

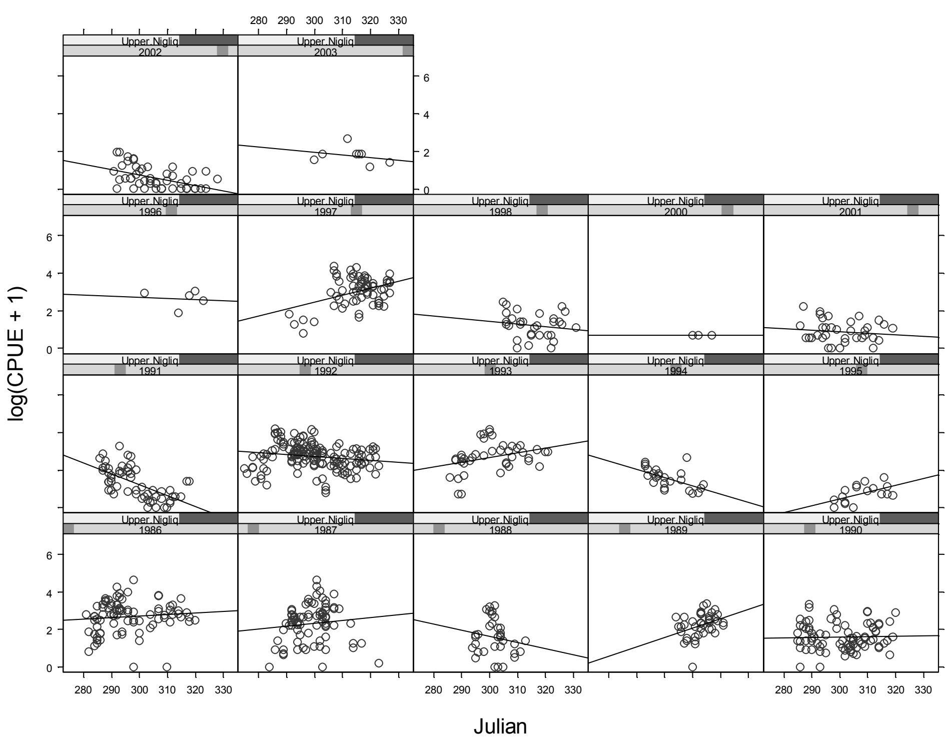

Figure K-6. CPUE of Arctic cisco in the subsistence fishery (76-mm net, Upper Niġliq) by Julian date and year.

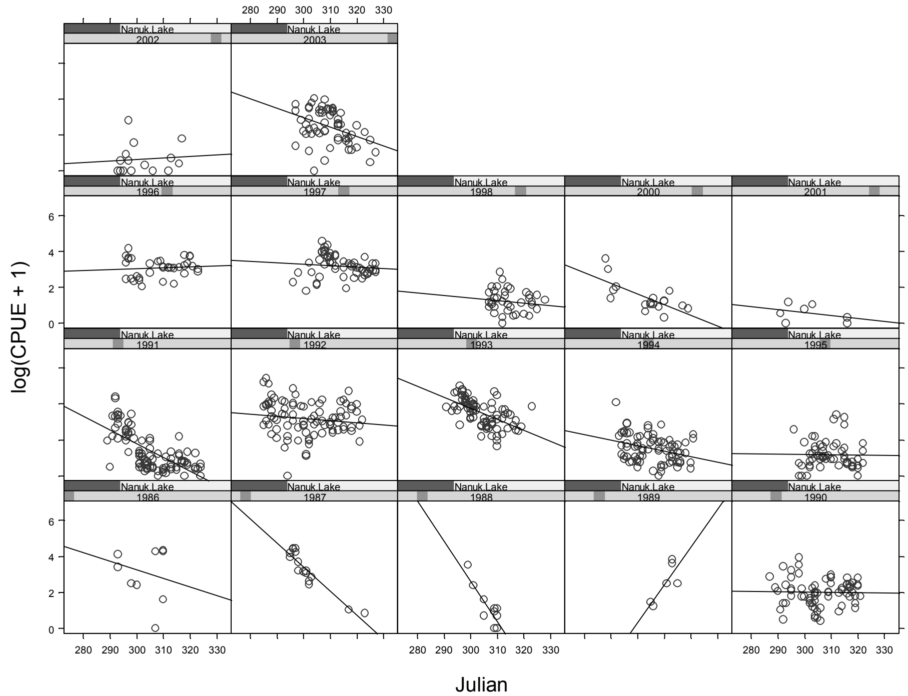

Figure K-7. CPUE of Arctic cisco in the subsistence fishery (76-mm net, Nanuk lake) by Julian date and year.

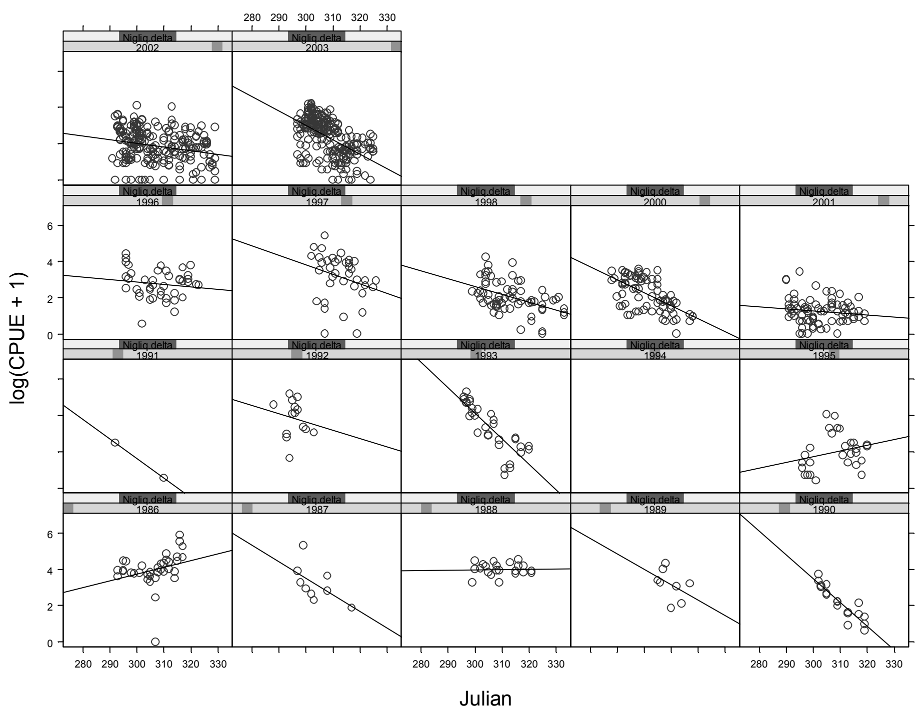

Figure K-8. CPUE of Arctic cisco in the subsistence fishery (76-mm net, Niǵliq delta) by Julian date and year.

COMMERCIAL (HELMERICKS) FISHERY

Fishing effort in the Helmericks fishery decreased over time from more than 1400 net days of 46-m net in the late 1960s–early 1970s to less than 200 net days in recent years (Figure K-9). On average, CPUE since the mid-1980s has been higher than CPUE prior to the mid-1980s.

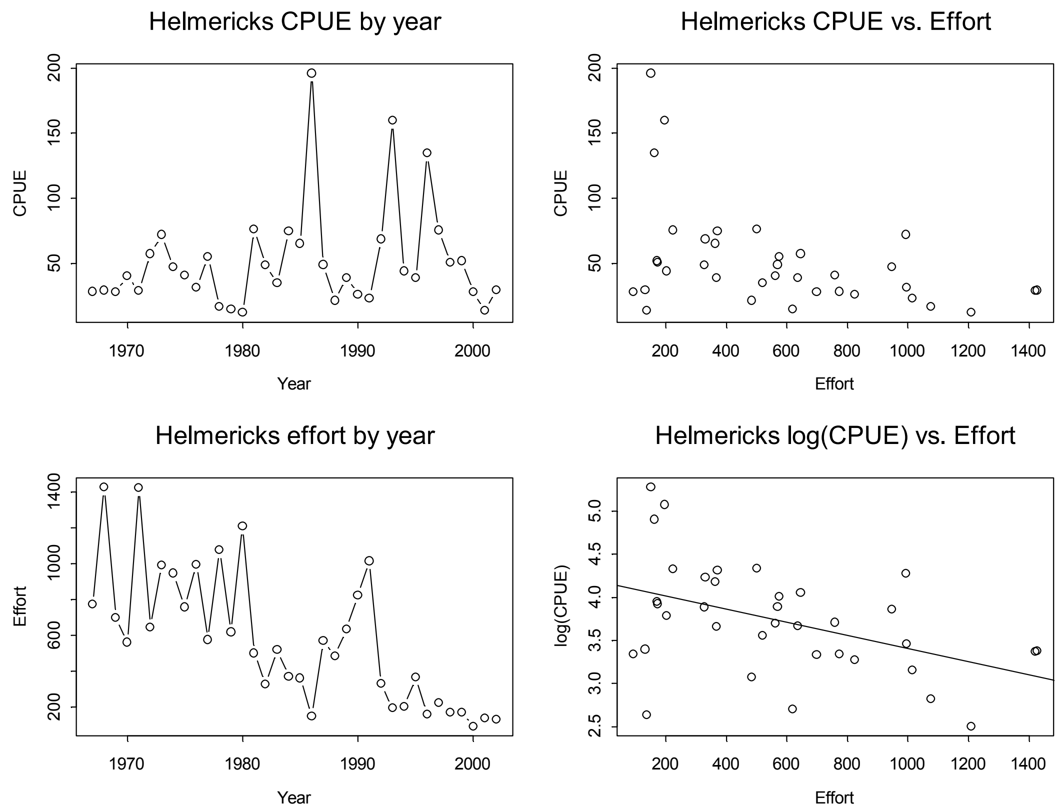

Figure K-9. CPUE, effort, and CPUE vs. effort for Arctic cisco caught in commercial fishery.

There is an obvious inverse relationship between CPUE and effort in the commercial fishery. Moulton and Seavey (2004) argued that this requires an adjustment to CPUE to avoid overestimating CPUE during years with low effort. They argued for the adjustment in part because the same trend was obvious in both Arctic cisco and least cisco. There is no strong relationship between catches of Arctic and least cisco ($r = 0.22$, $p = 0.195$) but both show a very similar decline in CPUE with effort (Figure K-10). While these relationships suggest that catch rates are affected by within-season depletion, there is no obvious relationship between effort and CPUE of Arctic cisco at the daily scale. To the contrary, there is a weak positive correlation

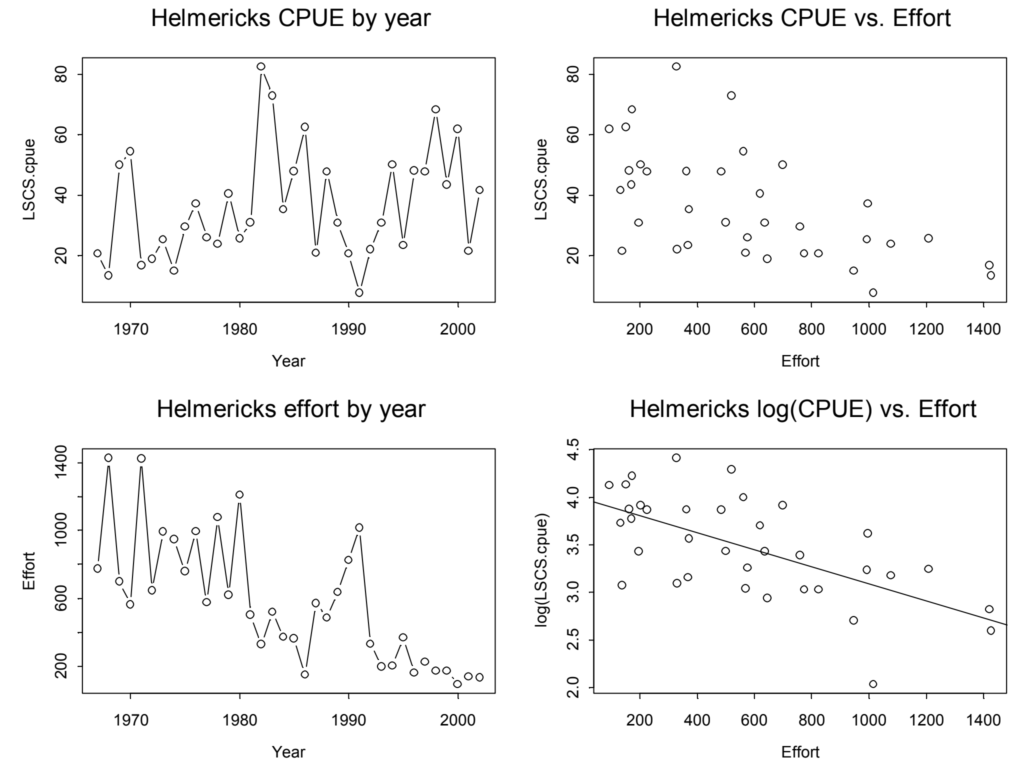

Figure K-10. CPUE, effort, and CPUE vs. effort for least cisco caught in commercial fishery.

between daily (log-transformed) catch rates and daily effort (r = 0.026, p = 0.408). Therefore, the effect does not seem to be a "saturation effect" (i.e., when many nets are fishing simultaneously there are not enough fish to go around for each net to have a high CPUE). Rather, the effect may be a result of depletion over the course of the season, such that when total effort during the season is high the abundance and density of fish decreases over time and the average density over the entire season, and, therefore, average CPUE, will be lower.We investigated possible serial depletion by looking at daily catch rates for each year in the Helmericks fishery (Figure K-11). There was little evidence of depletion in most years. In fact, 23 of 35 years showed an increase in log (CPUE) over the course of the season, which is evident of a highly dynamic population. Evidence of depletion was found in some of the years with the highest effort (1971, 1978, 1991) but not in other years with equally high effort (1968, 1980). Therefore, evidence of depletion is weak and it is unlikely that the observed decrease in CPUE with increasing effort is due to depletion during years with high effort. There is a strong decreasing trend in effort over time (Figure K-9) which could induce a spurious negative correlation between effort and CPUE. However, the negative correlations remained strong (r = -0.51 for Arctic cisco and r = -0.64 for least cisco, CPUE on log-scale) when the linear trend in effort was removed.

Our analyses do not provide compelling evidence for any specific mechanism that could be responsible for the observed negative correlation between effort and CPUE. Nevertheless, the relationship is real and we used both "raw" and effort-adjusted CPUE values for further analyses.

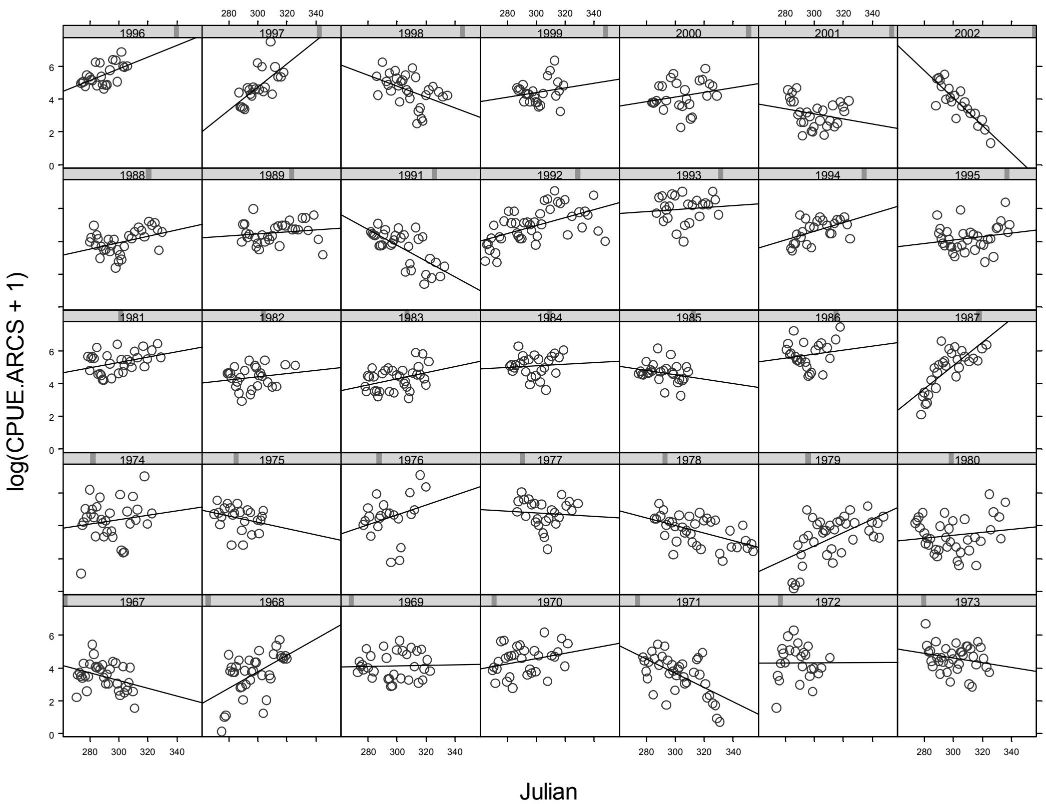

Figure K-11. CPUE of Arctic cisco (log-scale) in the commercial fishery against Julian date by year.

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Moulton, L.L., and Seavey, B.T. 2004. Harvest estimate and associated information for the 2003 Colville River fall fishery. MJM Research, Lopez Island, WA, 50 + append.

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Appendix L.
Statistical Model Results for Hypothesis Testing

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APPENDIX L: STATISTICAL MODEL RESULTS FOR HYPOTHESIS TESTING

L.1 Effects of wind-driven transport on young-of-the year recruitment

<u>Model L.1.1a</u>

Type of model: Linear model with threshold
Dependent variable: log(CPUE+1) of age-0 Arctic cisco (`log(PB.age0 + 1)`)
Independent variables: Average wind speed at Deadhorse (`Wind.Dhse`)
Independently estimated parameter: Threshold (`th = 0.54 m/s`)

S-Plus code for linear model (lm) and model output from analysis:

```
Call: lm(formula = log(PB.age0 + 1) ~ pmax(0, Wind.Dhse))

Residuals:
    Min      1Q Median     3Q   Max
 -1.741 -0.5734 0.2349 0.5802 1.721

Coefficients:
                     Value Std. Error t value Pr(>|t|)
       (Intercept) -0.5802  0.3241    -1.7902  0.0879
pmax(0, Wind.Dhse)  1.7283  0.1921     8.9971  0.0000

Residual standard error: 0.9064 on 21 degrees of freedom
Multiple R-Squared: 0.794
F-statistic: 80.95 on 1 and 21 degrees of freedom, the p-value is 1.192e-008
AICc = 65.9
```

<u>Model L.1.1b</u>

Type of model: Linear model with threshold
Dependent variable: log(CPUE+1) of age-0 Arctic cisco (`log(PB.age0 + 1)`)
Independent variables: Average wind speed at Deadhorse (`Wind.Dhse`)
Threshold (Breakpoint) fixed at 0 m/s

```
Call: lm(log(PB.age0 + 1) ~ pmax(0, Wind.Dhse - th))

Residuals:
    Min     1Q     Median     3Q   Max
 -1.577 -0.283 7.699e-006 0.4909 1.841

Coefficients:
                         Value Std. Error t value Pr(>|t|)
            (Intercept) 0.0000 0.2572     0.0000  1.0000
pmax(0, Wind.Dhse - th) 1.9491 0.2018     9.6608  0.0000

Residual standard error: 0.8559 on 21 degrees of freedom
Multiple R-Squared: 0.8163
F-statistic: 93.33 on 1 and 21 degrees of freedom, the p-value is 3.533e-009
AICc = 66.2
```

Model L.1.2a

Type of model: Linear model with threshold
Dependent variable: Combined recruitment index (PB.YCS)
Independent variables: Average wind speed at Deadhorse (Wind.Dhse)
Independently estimated parameter: Threshold (th = 0.02 m/s)

```
Call: lm(formula = PB.YCS ~ pmax(0, Wind.Dhse - th))

Residuals:
     Min      1Q  Median     3Q   Max
 -0.7523 -0.2459 0.05462 0.2237 1.039

Coefficients:
                         Value Std. Error t value Pr(>|t|)
            (Intercept) 0.1353 0.1725     0.7846  0.4407
pmax(0, Wind.Dhse - th) 0.7377 0.1002     7.3656  0.0000

Residual standard error: 0.489 on 23 degrees of freedom
Multiple R-Squared: 0.7023
F-statistic: 54.25 on 1 and 23 degrees of freedom, the p-value is 1.718e-007
AICc = 43.09
```

Model L.1.2b

Type of model: Linear model with threshold
Dependent variable: Combined recruitment index (PB.YCS)
Independent variables: Average wind speed at Deadhorse (Wind.Dhse)
Threshold (Breakpoint) fixed at 0 m/s

```
Call: lm(PB.YCS ~ pmax(0, Wind.Dhse))

Residuals:
     Min      1Q  Median     3Q   Max
 -0.7515 -0.2468 0.05352 0.2213 1.038

Coefficients:
                    Value Std. Error t value Pr(>|t|)
       (Intercept) 0.1277 0.1734     0.7368  0.4687
pmax(0, Wind.Dhse) 0.7355 0.0999     7.3653  0.0000

Residual standard error: 0.489 on 23 degrees of freedom
Multiple R-Squared: 0.7023
F-statistic: 54.25 on 1 and 23 degrees of freedom, the p-value is 1.719e-007
AICc = 40.2
```

Model L.1.3

Type of model: Simple linear regression model
Dependent variable: a) log(CPUE+1) of age-0 Arctic cisco (log(PB.age0 + 1))
or b) Combined recruitment index (PB.YCS)
Independent variables: Average wind speed at Deadhorse (Wind.Dhse)

a) age-0 CPUE:

```
Call: lm(formula = log(PB.age0 + 1) ~ Wind.Dhse)
Residuals:
    Min      1Q Median     3Q   Max
 -1.852 -0.7821 0.2617 0.7519 1.656

Coefficients:
              Value Std. Error t value Pr(>|t|)
(Intercept) -0.1433  0.3299    -0.4345  0.6684
  Wind.Dhse  1.4889  0.1939     7.6783  0.0000

Residual standard error: 1.023 on 21 degrees of freedom
Multiple R-Squared: 0.7374
F-statistic: 58.96 on 1 and 21 degrees of freedom, the p-value is 1.58e-007
AICc = 71.51
```

b) combined recruitment index:

```
Call: lm(formula = PB.YCS ~ Wind.Dhse)
Residuals:
     Min      1Q  Median     3Q   Max
 -0.7633 -0.3166 0.02458 0.4124 1.005

Coefficients:
             Value Std. Error t value Pr(>|t|)
(Intercept) 0.2962 0.1629     1.8183  0.0821
  Wind.Dhse 0.6483 0.0932     6.9589  0.0000

Residual standard error: 0.5085 on 23 degrees of freedom
Multiple R-Squared: 0.678
F-statistic: 48.43 on 1 and 23 degrees of freedom, the p-value is 4.299e-007
AICc = 42.19
```

Model L.1.4

Type of model: Threshold model (one-step intervention)

Dependent variable: a) log(CPUE+1) of age-0 Arctic cisco (`log(PB.age0 + 1)`)
or b) Combined recruitment index (`PB.YCS`)

Independent variables: Average wind speed at Deadhorse (`Wind.Dhse`)

Independently estimated parameter: Threshold (`th = 1.46 m/s`)

a) age-0 CPUE:

```
Call: lm(formula = log(PB.age0 + 1) ~ I(Wind.Dhse > 1.46))
Residuals:
   Min      1Q  Median      3Q   Max
 -1.29 -0.2478 -0.2478 0.09631 2.013

Coefficients:
                      Value Std. Error t value Pr(>|t|)
        (Intercept)  2.0197  0.1641    12.3108  0.0000
I(Wind.Dhse > 1.46)  1.7718  0.1641    10.8003  0.0000

Residual standard error: 0.7801 on 21 degrees of freedom
```

```
Multiple R-Squared: 0.8474
F-statistic: 116.6 on 1 and 21 degrees of freedom, the p-value is 4.949e-010
AICc = 62.00
```

b) combined recruitment index:

```
Call: lm(formula = PB.YCS ~ I(Wind.Dhse > 1.46))
Residuals:
     Min      1Q   Median      3Q    Max
 -0.8135 -0.3369 -0.05953 0.3801 0.8759

Coefficients:
                      Value Std. Error t value Pr(>|t|)
        (Intercept)  1.2107  0.0987    12.2613  0.0000
I(Wind.Dhse > 1.46)  0.7182  0.0987     7.2736  0.0000

Residual standard error: 0.4933 on 23 degrees of freedom
Multiple R-Squared: 0.697
F-statistic: 52.91 on 1 and 23 degrees of freedom, the p-value is 2.11e-007
AICc = 43.53
```

Model L.1.5

Type of model: Linear model with threshold
Dependent variable: a) log(CPUE+1) of age-0 Arctic cisco (`log(PB.age0 + 1)`)
or b) Combined recruitment index (`PB.YCS`)
Independent variables: Average easterly wind speed along coast (`Wind.avg`)
Independently estimated parameter: Threshold (a) `th = -1.34 m/s`
(b) `th = -1.44 m/s`

a) age-0 CPUE:

```
Call: lm(log(PB.age0 + 1) ~ pmax(0, Wind.avg - th))

Residuals:
    Min      1Q  Median    3Q   Max
 -3.525 -0.7458 -0.1998 1.293 3.118

Coefficients:
                        Value Std. Error t value Pr(>|t|)
           (Intercept) 0.0000 0.7578     0.0000  1.0000
pmax(0, Wind.avg - th) 1.1570 0.4345     2.6626  0.0150

Residual standard error: 1.753 on 20 degrees of freedom
Multiple R-Squared: 0.2617
F-statistic: 7.09 on 1 and 20 degrees of freedom, the p-value is 0.01495
AICc = 95.4
```

b) combined recruitment index:

```
Call: lm(PB.YCS ~ pmax(0, Wind.avg - th))

Residuals:
    Min      1Q   Median     3Q   Max
 -1.601 -0.5089 -0.07719 0.6568 1.231
```

```
Coefficients:
                        Value Std. Error t value Pr(>|t|)
           (Intercept) 0.2513 0.3460     0.7265  0.4752
pmax(0, Wind.avg - th) 0.5557 0.1841     3.0186  0.0063

Residual standard error: 0.7705 on 22 degrees of freedom
Multiple R-Squared: 0.2929
F-statistic: 9.112 on 1 and 22 degrees of freedom, the p-value is 0.006317
AICc = 63.6
```

Model L.1.6

Type of model: Linear model with threshold

Dependent variable: a) log(CPUE+1) of age-0 Arctic cisco (`log(PB.age0 + 1)`) or b) Combined recruitment index (`PB.YCS`)

Independent variables: Sum of easterly wind speeds along coast (`Wind.E`)

Independently estimated parameter: Threshold (a) `th = 1.05 m/s`
(b) `th = 1.03 m/s`

a) age-0 CPUE:

```
Call: lm(log(PB.age0 + 1) ~ pmax(0, Wind.E - th))

Residuals:
    Min     1Q  Median    3Q Max
 -3.427 -1.266 -0.4122 1.218 3.2

Coefficients:
                      Value Std. Error t value Pr(>|t|)
         (Intercept) 0.4122 0.6494     0.6347  0.5328
pmax(0, Wind.E - th) 1.7428 0.6852     2.5435  0.0193

Residual standard error: 1.773 on 20 degrees of freedom
Multiple R-Squared: 0.2444
F-statistic: 6.47 on 1 and 20 degrees of freedom, the p-value is 0.01934
AICc = 95.9
```

b) combined recruitment index:

```
Call: lm(PB.YCS ~ pmax(0, Wind.E - th))

Residuals:
    Min     1Q  Median     3Q   Max
 -1.415 -0.578 -0.1085 0.5341 1.628

Coefficients:
                      Value Std. Error t value Pr(>|t|)
         (Intercept) 0.6242 0.3079     2.0276  0.0549
pmax(0, Wind.E - th) 0.6789 0.3129     2.1697  0.0411

Residual standard error: 0.8316 on 22 degrees of freedom
Multiple R-Squared: 0.1763
F-statistic: 4.708 on 1 and 22 degrees of freedom, the p-value is 0.04111
AICc = 67.3
```

L.2 Effects of temperature and ice conditions on Arctic cisco recruitment

<u>Model L.2.1</u>

Type of model:	Multiple Linear Regression
Dependent variable:	Annual combined recruitment index (PB.YCS)
Independent variables:	First Principal Component of environmental variability in central Beaufort Sea (Col.env.PC1) First Principal Component of environmental variability in Mackenzie Delta region (Mack.env.PC1)

```
Call: lm(formula = PB.YCS ~ Mack.env.PC1 + Col.env.PC1)

Residuals:
    Min      1Q   Median     3Q   Max
 -1.259 -0.6741 -0.04076 0.6598 1.406

Coefficients:
               Value Std. Error t value Pr(>|t|)
 (Intercept)  1.2821  0.1912     6.7066  0.0000
Mack.env.PC1 -0.2091  0.1879    -1.1130  0.2796
 Col.env.PC1  0.1652  0.1540     1.0730  0.2967

Residual standard error: 0.8951 on 19 degrees of freedom
Multiple R-Squared: 0.06689
F-statistic: 0.681 on 2 and 19 degrees of freedom, the p-value is 0.5181
```

<u>Model L.2.2:</u>

Type of model:	Multiple Linear Regression
Dependent variable:	Annual combined recruitment anomalies (YCS.resid)
Independent variables:	First Principal Component of environmental variability in central Beaufort Sea (Col.env.PC1) First Principal Component of environmental variability in Mackenzie Delta region (Mack.env.PC1)

```
Call: lm(YCS.resid ~ Mack.env.PC1 + Col.env.PC1)

Residuals:
     Min     1Q  Median     3Q    Max
 -0.6179 -0.181 0.04768 0.1449 0.9592

Coefficients:
               Value Std. Error t value Pr(>|t|)
 (Intercept)  0.0833  0.0920     0.9057  0.3764
Mack.env.PC1 -0.1640  0.0904    -1.8140  0.0855
 Col.env.PC1  0.1461  0.0741     1.9714  0.0634

Residual standard error: 0.4308 on 19 degrees of freedom
Multiple R-Squared: 0.1784
F-statistic: 2.063 on 2 and 19 degrees of freedom, the p-value is 0.1546
```

L.3 Effects of discharge on Arctic cisco recruitment

Model L.3.1a:

Type of model: Simple Linear Regression
Dependent variable: Annual combined recruitment anomalies (YCS.resid)
Independent variable: Sagavanirktok River discharge (Sag.dis)

```
Call: lm(YCS.resid ~ Sag.dis)

Residuals:
     Min      1Q   Median     3Q    Max
 -0.8689 -0.2105 -0.02445 0.2592 0.9253
Coefficients:
              Value Std. Error t value Pr(>|t|)
(Intercept) -0.5246  0.4908    -1.0689  0.2979
    Sag.dis  0.0002  0.0001     1.2233  0.2354

Residual standard error: 0.4607 on 20 degrees of freedom
Multiple R-Squared: 0.06961
F-statistic: 1.496 on 1 and 20 degrees of freedom, the p-value is 0.2354
```

Model L.3.1b:

Type of model: Simple Linear Regression
Dependent variable: (a) Annual recruitment anomalies (YCS.resid)
(b) Age-0 recruitment index
Independent variable: detrended Sagavanirktok River discharge series (Sag.detrend) (linear trend removed)

(a) Annual recruitment anomalies

```
Call: lm(YCS.resid ~ Sag.detrend)
Residuals:
     Min      1Q   Median     3Q    Max
 -0.7145 -0.2651 -0.07906 0.3942 0.6909

Coefficients:
             Value Std. Error t value Pr(>|t|)
(Intercept) 0.0636 0.0894     0.7118  0.4848
Sag.detrend 0.0004 0.0002     2.4396  0.0241

Residual standard error: 0.4193 on 20 degrees of freedom
Multiple R-Squared: 0.2293
F-statistic: 5.952 on 1 and 20 degrees of freedom, the p-value is 0.02414
```

(b) Age-0 recruitment index

```
Call: lm(Age0.resid ~ Sag.detrend)
Residuals:
    Min      1Q  Median     3Q   Max
 -1.568 -0.4687 -0.1058 0.4614 1.397

Coefficients:
             Value  Std. Error t value Pr(>|t|)
(Intercept) 0.0704  0.1826     0.3855  0.7044
Sag.detrend 0.0005  0.0003     1.6016  0.1266
```

```
Residual standard error: 0.8165 on 18 degrees of freedom
Multiple R-Squared: 0.1247
F-statistic: 2.565 on 1 and 18 degrees of freedom, the p-value is 0.1266
```

Model I.4.1a:

Type of model:	Generalized Additive Model (non-parametric smooth)
Dependent variable:	(a) Annual recruitment anomalies (YCS.resid)
	(b) Age-0 recruitment anomalies (Age0.resid)
Independent variables:	Mean minimum temperature during winter, Inuvik
	Average spring (May) discharge, Mackenzie River
	Ice concentration in the spring (June), Mackenzie Delta

a) Annual recruitment anomalies (YCS.resid)

```
Generalized Additive Model    Family: gaussian
                           Link function: identity
Formula:
YCS.resid ~ s(Dis.Mack.May, k = 4) + s(Inuvik.minT.win, k = 4) +
    s(Mack.ice, k = 4)

Parametric coefficients:
              Estimate  std. err.    t ratio    Pr(>|t|)
(Intercept)   0.058528      0.103     0.5683    0.57899

Approximate significance of smooth terms:
                          edf       chi.sq     p-value
   s(Dis.Mack.May)      1.529       3.6057     0.34591
s(Inuvik.minT.win)      1.747        4.333     0.27294
       s(Mack.ice)          1      0.10747     0.74799

R-sq.(adj) =  0.113   Deviance explained = 32.4%
GCV score = 0.27896   Scale est. = 0.20149   n = 19
```

Model selection, all subsets :

Model terms	**Adjusted R^2**	**AIC_c**
Dis.Mack.May, Mack.ice Inuvik.minT.win	0.11	37.6
Dis.Mack.May, Mack.ice	0.08	33.6
Dis.Mack.May, Inuvik.minT.win	0.18	33.3
Inuvik.minT.win, Mack.ice	0.06	34.1
Inuvik.minT.win	0.12	30.7
Dis.Mack.May	0.13	30.3
Mack.ice	0.02	31.8
None (Null model)	**0**	**21.5**

a) Age-0 recruitment anomalies (Age0.resid)

```
Generalized Additive Model    Family: gaussian
                           Link function: identity
```

```
Formula:
Age0.resid ~ s(Dis.Mack.May, k = 4) + s(Inuvik.minT.win, k = 4) +
    s(Mack.ice, k = 4)

Parametric coefficients:
              Estimate  std. err.    t ratio    Pr(>|t|)
(Intercept)    0.15938     0.1779     0.8958    0.38521

Approximate significance of smooth terms:
                          edf       chi.sq     p-value
   s(Dis.Mack.May)      1.715       3.7441     0.32915
s(Inuvik.minT.win)          1      0.29069     0.59808
       s(Mack.ice)          1       0.6029     0.45014

R-sq.(adj) =  -0.00189   Deviance explained = 20.5%
GCV score = 0.79994   Scale est. = 0.60142   n = 19
AICc = 56.5
AICc (Null model) = 47.9
```

Model L.4.1b:

Type of model: Generalized Additive Model (non-parametric smooth)
Dependent variable: (a) Annual recruitment anomalies (YCS.resid)
(b) Age-0 recruitment anomalies (Age0.resid)
Independent variables: Mean minimum temperature during winter, Inuvik
Average winter (Dec-Apr) discharge, Mackenzie River
Ice concentration in the spring (June), Mackenzie Delta

a) Annual recruitment anomalies (YCS.resid)

```
Generalized Additive Model    Family: gaussian
                        Link function: identity
Formula:
YCS.resid ~ s(Dis.Mack.win, k = 4) + s(Inuvik.minT.win, k = 4) +
    s(Mack.ice, k = 4)

Parametric coefficients:
              Estimate  std. err.    t ratio    Pr(>|t|)
(Intercept)   0.058528     0.1087     0.5384    0.59856

Approximate significance of smooth terms:
                          edf       chi.sq     p-value
   s(Dis.Mack.win)          1      0.67855     0.42354
s(Inuvik.minT.win)      1.617       3.0464     0.41453
       s(Mack.ice)          1      0.29984     0.59238

R-sq.(adj) =  0.0112   Deviance explained =   21%
GCV score = 0.29664   Scale est. = 0.22456   n = 19
AICc = 37.5
AICc (Null model) = 21.5
```

a) Age-0 recruitment anomalies (Age0.resid)

```
Generalized Additive Model    Family: gaussian
                        Link function: identity
Formula:
```

```
Age0.resid ~ s(Dis.Mack.win, k = 4) + s(Inuvik.minT.win, k = 4) +
    s(Mack.ice, k = 4)

Parametric coefficients:
              Estimate  std. err.    t ratio    Pr(>|t|)
(Intercept)    0.15938     0.1905     0.8368    0.41584

Approximate significance of smooth terms:
                          edf       chi.sq     p-value
   s(Dis.Mack.win)          1     0.066862     0.79948
s(Inuvik.minT.win)          1      0.53861     0.47432
       s(Mack.ice)          1      0.10566     0.74963

R-sq.(adj) =  -0.148   Deviance explained = 4.32%
GCV score = 0.87303   Scale est. = 0.68924   n = 19
AICc = 57.0
AICc (Null model) = 47.9
```

II.1 Effects of summer temperature and wind conditions on Arctic cisco survival

Model II.1.1:

Type of model:	Generalized Additive Model
Dependent variable:	Age 0-5 survival anomalies (Surv.age5), lag 0 (lagged to reflect conditions during first summer)
Independent variables:	Summer climate conditions, Colville region (Col.env.PC1) Summer upwelling winds (Wind.Dhse)

```
Generalized Additive Model    Family: gaussian
                              Link function: identity
Formula:
Surv.age5 ~ s(Col.env.PC1, k = 4) + s(I(Wind.Dhse^2), k = 4)

Parametric coefficients:
              Estimate  std. err.    t ratio    Pr(>|t|)
(Intercept)   0.010508     0.2159    0.04866    0.96182

Approximate significance of smooth terms:
                         edf       chi.sq     p-value
   s(Col.env.PC1)      1.794       6.5532     0.13174
s(I(Wind.Dhse^3))          1      0.33418     0.57167

R-sq.(adj) =  0.175   Deviance explained = 30.3%
GCV score = 1.1071   Scale est. = 0.88602   n = 19
AICc = 61.2
```

Model selection, all subsets:

Model terms	Adjusted R^2	AIC_c
Col.env.PC1, Wind.Dhse^2	0.18	61.2
Col.env.PC1	**0.22**	**57.9**
Wind.Dhse^2	0.09	60.9
None (Null model)	0	59.0

Best GAM model :

```
Generalized Additive Model    Family: gaussian
                        Link function: identity
Formula:
Surv.age5 ~ s(Col.env.PC1, k = 4)

Parametric coefficients:
              Estimate  std. err.    t ratio    Pr(>|t|)
(Intercept)   0.010508     0.2106    0.04991    0.9608

Approximate significance of smooth terms:
                      edf       chi.sq     p-value
s(Col.env.PC1)      1.845        7.406     0.098999

R-sq.(adj) =  0.216   Deviance explained = 29.6%
GCV score = 0.99074   Scale est. = 0.84237   n = 19
AICc = 57.9
```

Closest parametric model (quadratic fit):

```
Call:
lm(Surv.age5 ~ Col.env.PC1 + Col.env.PC1^2)

Residuals:
     Min       1Q   Median       3Q      Max
-1.43750 -0.62573 -0.05342  0.42406  2.09601

Coefficients:
                      Estimate Std. Error t value Pr(>|t|)
(Intercept)            0.01051    0.21065   0.050   0.9608
Col.env.PC1           -1.41784    0.91821  -1.544   0.1421
Col.env.PC1^2          1.95924    0.91821   2.134   0.0487 *
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 0.9182 on 16 degrees of freedom
Multiple R-Squared: 0.3024,     Adjusted R-squared: 0.2152
F-statistic: 3.469 on 2 and 16 DF,  p-value: 0.05606
AICc = 58.3
```

The fits included several influential outliers (1989, 1991, 1994). Model fits improved (lower R^2 and P-values) with each removed outlier.

Best model fits at each lag:

	Full model			Best model	
Lag (k)*	**Adj. R^2**	**P-value**	**Best model (terms)**	**Adj. R^2**	**P-value**
0	0.18	0.114	Col.env.PC1, Col.env.PC1^2	0.30	0.056
1	-0.07	0.670	Null		
2	-0.08	0.754	Null		
3	0.10	0.159	Wind.Dhse^3	0.09	0.109
4	0.09	0.232	Null		
5	0.07	0.225	Null		

* Environmental conditions at age k

Model II.1.2:

Type of model: Multiple linear regression
Dependent variable: Age 5-7 survival anomalies (Surv.567)
Independent variables: Summer climate conditions, Colville region (Col.env.PC1)
Summer upwelling winds (Wind.Dhse)

```
Call:
lm(formula = Surv.567 ~ Col.env.PC1 + I(Wind.Dhse^3), data = Annual.ind,
    subset = j)

Residuals:
    Min      1Q  Median      3Q     Max
-1.2044 -0.4616 -0.1033  0.2443  1.7027

Coefficients:
                Estimate Std. Error t value Pr(>|t|)
(Intercept)     0.079432   0.215854   0.368   0.7172
Col.env.PC1    -0.205739   0.093730  -2.195   0.0415 *
I(Wind.Dhse^3) -0.004378   0.017441  -0.251   0.8046
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 0.7746 on 18 degrees of freedom
Multiple R-Squared: 0.2122,     Adjusted R-squared: 0.1247
F-statistic: 2.425 on 2 and 18 DF,  p-value: 0.1168
AICc = 56.1
```

Best submodel :

```
Call: lm(formula = Surv.567 ~ Col.env.PC1)

Residuals:
     Min       1Q   Median       3Q      Max
-1.18925 -0.51146 -0.07262  0.28033  1.63597

Coefficients:
            Estimate Std. Error t value Pr(>|t|)
(Intercept)  0.04594    0.16547   0.278   0.7843
Col.env.PC1 -0.20495    0.09134  -2.244   0.0370 *
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 0.7553 on 19 degrees of freedom
Multiple R-Squared: 0.2095,     Adjusted R-squared: 0.1679
F-statistic: 5.035 on 1 and 19 DF,  p-value: 0.03696
```

Two outliers removed (1985 und 1986):

```
Call: lm(formula = Surv.567 ~ Col.env.PC1)

Residuals:
    Min      1Q  Median      3Q     Max
-1.0055 -0.3605 -0.1475  0.3260  1.2163

Coefficients:
            Estimate Std. Error t value Pr(>|t|)
(Intercept) -0.12538    0.13312  -0.942   0.3595
Col.env.PC1 -0.15279    0.07526  -2.030   0.0583 .
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
Residual standard error: 0.5749 on 17 degrees of freedom
Multiple R-Squared: 0.1952,     Adjusted R-squared: 0.1478
F-statistic: 4.122 on 1 and 17 DF,  p-value: 0.05828
```

Robust regression:

```
Call: lmRobMM(formula = Surv.567 ~ Col.env.PC1)

Residuals:
    Min     1Q  Median     3Q   Max
 -1.029 -0.409 -0.1084 0.4579 1.954

Coefficients:
              Value Std. Error t value Pr(>|t|)
(Intercept) -0.0989  0.1820    -0.5435  0.5931
Col.env.PC1 -0.1405  0.1023    -1.3740  0.1854

Residual scale estimate: 0.6325 on 19 degrees of freedom
35 observations deleted due to missing values

Proportion of variation in response explained by model: 0.09836
```

III.1 Effects of salinity, year, Julian day, and/or fishing area on daily CPUE of Arctic cisco in the Niġliq fishery

Model III.1.1:

Type of model:	Generalized Additive Model
Dependent variable:	daily log(CPUE+1)
Independent variables:	daily average salinity (non-parametric smooth term)

```
Family (error distribution): gaussian
Link function: identity

Formula:
log(CPUE + 1) ~ s(Salinity)

Parametric coefficients:
            Estimate Std. Error t value Pr(>|t|)
(Intercept)  2.35094    0.04134   56.87   <2e-16 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Approximate significance of smooth terms:
              edf Est.rank     F p-value
s(Salinity) 6.293    9.000 11.41  <2e-16 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

R-sq.(adj) =  0.134   Deviance explained = 14.3%
GCV score = 1.0535   Scale est. = 1.0409    n = 609
```

Model III.1.2:

Type of model:	Generalized Additive Model
Dependent variable:	daily log(CPUE+1)

Independent variables:

- Salinity (non-parametric smooth term)
- Year (categorical, levels: 1986, 1987, … , 2004, except 1999)
- Fishing area (categorical, levels: Upper Nigliq, Nanuk, Nigliq delta)
- Julian day (continuous, non-parametric smooth term)

```
Family (error distribution): gaussian
Link function: identity

Formula:
log(CPUE + 1) ~ s(Salinity) + factor(Year) + Area + s(Julian)

Parametric coefficients:
                 Estimate Std. Error t value Pr(>|t|)
(Intercept)       2.80097    0.20178  13.881  < 2e-16 ***
factor(Year)1987 -1.04005    0.30962  -3.359 0.000833 ***
factor(Year)1988  0.61915    0.36907   1.678 0.093969 .
factor(Year)1989  0.17115    0.26916   0.636 0.525113
factor(Year)1990 -1.05434    0.21207  -4.972 8.76e-07 ***
factor(Year)1991 -1.66346    0.20946  -7.942 1.05e-14 ***
factor(Year)1992  0.20604    0.19329   1.066 0.286893
factor(Year)1993  0.16540    0.20276   0.816 0.414975
factor(Year)1994 -0.86146    0.24875  -3.463 0.000573 ***
factor(Year)1995 -0.99470    0.27075  -3.674 0.000261 ***
factor(Year)1996 -0.16535    0.22043  -0.750 0.453494
factor(Year)1997  0.23320    0.21905   1.065 0.287492
factor(Year)1998 -1.08306    0.23818  -4.547 6.63e-06 ***
factor(Year)2000 -1.32525    0.25433  -5.211 2.62e-07 ***
factor(Year)2001 -1.48948    0.28335  -5.257 2.07e-07 ***
factor(Year)2002 -1.18610    0.25341  -4.681 3.57e-06 ***
factor(Year)2003 -0.58679    0.23639  -2.482 0.013338 *
factor(Year)2004  0.02197    0.24541   0.090 0.928686
AreaNigliq.delta  0.13920    0.09401   1.481 0.139230
AreaUpper.Nigliq -0.05277    0.11631  -0.454 0.650200
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Approximate significance of smooth terms:
              edf Est.rank     F  p-value
s(Salinity) 6.667    9.000 6.001 4.64e-08 ***
s(Julian)   4.726    9.000 8.096 2.36e-11 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

R-sq.(adj) =   0.58   Deviance explained = 60.1%
GCV score = 0.53162   Scale est. = 0.50422   n = 609
```

<u>Model III.1.3:</u>

Type of model: Linear Model (Multiple linear regression)
Dependent variable: daily log(CPUE+1)
Independent variables:

- Year (categorical, levels: 1981, 1982, …, 2004, except 1999)

- Julian day (5th order polynomial term)
- Salinity (7th order polynomial term)
- Fishing area (effect not significant, results not shown)

```
Call: lm(log(CPUE + 1) ~ Year + poly(Julian, 5) + poly(Salinity, 7))
Residuals:
    Min      1Q Median     3Q   Max
 -2.496 -0.4032  0.031 0.4793 2.573

Coefficients:
                      Value Std. Error  t value Pr(>|t|)
       (Intercept)   2.2705   0.0365    62.1385   0.0000
             Year1  -0.5078   0.1557    -3.2618   0.0012
             Year2   0.4375   0.1075     4.0715   0.0001
             Year3   0.0969   0.0552     1.7553   0.0797
             Year4  -0.2163   0.0324    -6.6786   0.0000
             Year5  -0.2432   0.0236   -10.3108   0.0000
             Year6   0.0981   0.0157     6.2560   0.0000
             Year7   0.0698   0.0137     5.0828   0.0000
             Year8  -0.0582   0.0168    -3.4734   0.0006
             Year9  -0.0523   0.0182    -2.8785   0.0041
            Year10   0.0251   0.0118     2.1332   0.0333
            Year11   0.0494   0.0104     4.7493   0.0000
            Year12  -0.0512   0.0119    -4.3111   0.0000
            Year13  -0.0584   0.0113    -5.1725   0.0000
            Year14  -0.0595   0.0119    -4.9908   0.0000
            Year15  -0.0361   0.0085    -4.2477   0.0000
            Year16   0.0004   0.0082     0.0479   0.9618
            Year17   0.0278   0.0100     2.7768   0.0057
  poly(Julian, 5)1  -7.7934   0.9016    -8.6444   0.0000
  poly(Julian, 5)2   0.2575   0.7898     0.3260   0.7445
  poly(Julian, 5)3   2.5337   0.7530     3.3647   0.0008
  poly(Julian, 5)4  -1.8419   0.7519    -2.4496   0.0146
  poly(Julian, 5)5  -0.9603   0.7535    -1.2743   0.2031
poly(Salinity, 7)1  10.8731   0.9715    11.1924   0.0000
poly(Salinity, 7)2  -3.0552   0.8266    -3.6960   0.0002
poly(Salinity, 7)3  -1.7865   0.8504    -2.1008   0.0361
poly(Salinity, 7)4  -1.9674   0.8056    -2.4423   0.0149
poly(Salinity, 7)5  -0.0988   0.7383    -0.1338   0.8936
poly(Salinity, 7)6  -1.3954   0.7393    -1.8873   0.0596
poly(Salinity, 7)7  -1.2777   0.7587    -1.6841   0.0927

Residual standard error: 0.7133 on 579 degrees of freedom
Multiple R-Squared: 0.5968
F-statistic: 29.55 on 29 and 579 degrees of freedom, the p-value is 0

Type I (sequential) Sum of Squares
                    Df Sum of Sq  Mean Sq  F Value         Pr(F)
             Year   17  328.2218 19.30717 37.95064 0.000000e+000
  poly(Julian, 5)    5   27.9411  5.58823 10.98436 4.052632e-010
poly(Salinity, 7)    7   79.8675 11.40964 22.42707 0.000000e+000
        Residuals  579  294.5629  0.50874
```

```
Type III Sum of Squares
                   Df Sum of Sq  Mean Sq  F Value Pr(F)
             Year  17  269.4199 15.84823 31.15166     0
  poly(Julian, 5)   5   47.7646  9.55293 18.77747     0
poly(Salinity, 7)   7   79.8675 11.40964 22.42707     0
        Residuals 579  294.5629  0.50874
```

III.2. Effect of salinity on annual average catch rates of Arctic cisco

Model III.2.1:

Type of model: Simple linear regression model
Dependent variable: Annual CPUE anomalies (CPUE.Col.anom)
Independent variables: Annual average salinity in the Nigliq channel of Colville (Col.sal)

```
Call: lm(formula = CPUE.Col.anom ~ Col.sal)

Residuals:
     Min       1Q   Median       3Q      Max
-1.15696 -0.33920  0.09508  0.39831  0.63003

Coefficients:
            Estimate Std. Error t value Pr(>|t|)
(Intercept) -0.97476    0.41207  -2.366   0.0310 *
Col.sal      0.06871    0.02706   2.539   0.0219 *
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 0.5441 on 16 degrees of freedom
Multiple R-Squared: 0.2872,     Adjusted R-squared: 0.2426
F-statistic: 6.446 on 1 and 16 DF,  p-value: 0.02189
```

Model III.3.1a:

Type of model: Multiple linear regression model
Dependent variable: Annual CPUE anomalies (CPUE.Col.anom)
Independent variables: Annual average salinity in the Nigliq channel of Colville (Col.sal)
First principal component of summer temperature conditions

```
Call: lm(CPUE.Col.anom ~ Col.sal + Col.env.PC1)

Residuals:
     Min       1Q   Median       3Q      Max
-0.47399 -0.38040  0.02233  0.27934  0.75581

Coefficients:
            Estimate Std. Error t value Pr(>|t|)
(Intercept) -1.48452    0.36234  -4.097  0.00109 **
Col.sal      0.09262    0.02302   4.024  0.00126 **
Col.env.PC1  0.20556    0.05631   3.651  0.00262 **
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
Residual standard error: 0.3949 on 14 degrees of freedom
Multiple R-Squared: 0.6706,     Adjusted R-squared: 0.6235
F-statistic: 14.25 on 2 and 14 DF,  p-value: 0.0004209
AICc = 24.7
```

Model III.3.1b:

Type of model: Multiple linear regression model
Dependent variable: Annual CPUE anomalies (CPUE.Col.anom)
Independent variables: Annual average salinity in the Nigliq channel of Colville (Col.sal)
Summer SST in coastal Beaufort Sea, Colville region

```
Call: lm(CPUE.Col.anom ~ Col.sal + Col.OISST.sum)

Residuals:
     Min       1Q   Median       3Q      Max
-0.87208 -0.18308  0.05214  0.28777  0.67190

Coefficients:
              Estimate Std. Error t value Pr(>|t|)
(Intercept)   -2.06602    0.48817  -4.232 0.000837 ***
Col.sal        0.09188    0.02596   3.540 0.003268 **
Col.OISST.sum  0.38069    0.13919   2.735 0.016113 *
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 0.4454 on 14 degrees of freedom
Multiple R-Squared: 0.5809,     Adjusted R-squared: 0.521
F-statistic: 9.703 on 2 and 14 DF,  p-value: 0.002271
AICc = 28.8
```

Model III.3.1c:

Type of model: Multiple linear regression model
Dependent variable: Annual CPUE anomalies (CPUE.Col.anom)
Independent variables: Annual average salinity in the Nigliq channel of Colville (Col.sal)
October ice cover index for coastal Beaufort Sea, Colville region

```
Call: lm(CPUE.Col.anom ~ Col.sal + Col.ice.Oct)

Residuals:
    Min      1Q  Median      3Q     Max
-1.0860 -0.3637  0.1704  0.2699  0.8706

Coefficients:
             Estimate Std. Error t value Pr(>|t|)
(Intercept) -1.062619   0.534613  -1.988   0.0668 .
Col.sal      0.086698   0.030897   2.806   0.0140 *
Col.ice.Oct -0.005540   0.004945  -1.120   0.2815
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 0.5286 on 14 degrees of freedom
```

```
Multiple R-Squared: 0.4099,     Adjusted R-squared: 0.3256
F-statistic: 4.862 on 2 and 14 DF,  p-value: 0.02492
AICc = 34.6
```

Model III.3.2:

Type of model:	Multiple linear regression model
Dependent variable:	Annual CPUE anomalies (CPUE.Col.anom)
Independent variables:	Annual average salinity in the Nigliq channel of Colville (Col.sal) Easterly wind speed at Deadhorse, averaged over preceding 6 years

```
Call: lm(CPUE.Col.anom ~ Col.sal + Wind.Dhse(6-yr avg))

Residuals:
    Min      1Q  Median      3Q     Max
-0.7947 -0.2410  0.1187  0.2183  0.5044

Coefficients:
            Estimate Std. Error t value Pr(>|t|)
(Intercept)  1.43855    0.74905   1.920  0.07401 .
Col.sal      0.04336    0.02181   1.988  0.06536 .
Wind.Dhse   -1.35260    0.38121  -3.548  0.00292 **
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 0.4143 on 15 degrees of freedom
Multiple R-Squared: 0.6125,     Adjusted R-squared: 0.5608
F-statistic: 11.85 on 2 and 15 DF,  p-value: 0.0008173
```

IV. Environmental effects on size-at-age of Arctic cisco

Model IV.1:

Type of model:	Generalized Additive Model
Dependent variable:	Final size-at-age-0 (PB.age0.fin)
Independent variables:	First principal component of climate variables (Col.env.PC1) Average summer wind speed at Deadhorse

```
Generalized Additive Model
Family: gaussian
Link function: identity

Formula: PB.age0.fin ~ s(Col.env.PC1, k = 4) + s(Wind.Dhse, k = 4)

Parametric coefficients:
             Estimate  std. err.    t ratio    Pr(>|t|)
(Intercept)     105.69      3.361      31.44    1.1117e-10

Approximate significance of smooth terms:
                     edf       chi.sq     p-value
s(Col.env.PC1)      1.798       19.444     0.012052
  s(Wind.Dhse)          1       4.9774     0.051982

R-sq.(adj) =  0.634   Deviance explained = 71.9%
GCV score =  207.5   Scale est. = 146.88    n = 13
AICc = 114.6
```

Model IV.2:

Type of model: Simple linear regression model
Dependent variable: Final size-at-age-0 (PB.age0.fin)
Independent variables: First principal component of climate variables (Col.env.PC1)

```
Call: lm(PB.age0.fin ~ Col.env.PC1)

Residuals:
    Min      1Q  Median      3Q     Max 
-31.758  -8.836  -1.941   7.379  28.821 

Coefficients:
            Estimate Std. Error t value Pr(>|t|)    
(Intercept)  104.300      4.242  24.587 5.77e-11 ***
Col.env.PC1    7.192      2.296   3.132  0.00954 ** 
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1 

Residual standard error: 15.21 on 11 degrees of freedom
Multiple R-Squared: 0.4714,     Adjusted R-squared: 0.4234 
F-statistic:  9.81 on 1 and 11 DF,  p-value: 0.009541 
```
AIC_c = 114.2

Model IV.3:

Type of model: Simple linear regression model
Dependent variable: Final size-at-age-0 (PB.age0.fin)
Independent variables: Average summer SST, coastal Beaufort Sea (Col.OISST.sum)

```
Call: lm(PB.age0.fin ~ Col.OISST.sum)

Residuals:
      Min        1Q    Median        3Q       Max 
-32.68328  -8.38714   0.07336   4.80439  35.80467 

Coefficients:
              Estimate Std. Error t value Pr(>|t|)    
(Intercept)     80.633     12.194   6.613  3.8e-05 ***
Col.OISST.sum   13.868      6.201   2.237    0.047 *  
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1 

Residual standard error: 17.35 on 11 degrees of freedom
Multiple R-Squared: 0.3126,     Adjusted R-squared: 0.2501 
F-statistic: 5.002 on 1 and 11 DF,  p-value: 0.04698 
```
AIC_c = 117.6

Model IV.4:

Type of model: Generalized Additive Model
Dependent variable: Relative size-at-age (PB.size.rel)
Independent variables: First principal component of climate variables (Col.env.PC1)
Average summer wind speed at Deadhorse

```
Generalized Additive Model
Family: gaussian
Link function: identity

Formula:
PB.size.rel ~ s(Col.env.PC1, k = 4) + s(Wind.Dhse, k = 4)

Parametric coefficients:
              Estimate  std. err.    t ratio    Pr(>|t|)
(Intercept)    0.85734   0.006575      130.4    3.9818e-13

Approximate significance of smooth terms:
                     edf       chi.sq     p-value
s(Col.env.PC1)      2.185       5.4618     0.23112
  s(Wind.Dhse)      2.805        71.99     0.00046236

R-sq.(adj) =  0.873   Deviance explained = 92.6%
GCV score = 0.0010422   Scale est. = 0.00056192  n = 13
AICc = -32.1
```

Model IV.5:

Type of model: Generalized Additive Model
Dependent variable: Relative size-at-age (PB.size.rel)
Independent variables: Abundance of all coregonids in Prudhoe Bay (competitors)

```
Generalized Additive Model
Family: gaussian
Link function: identity

Formula:
PB.size.rel ~ s(competitors, k = 4)

Parametric coefficients:
              Estimate  std. err.    t ratio    Pr(>|t|)
(Intercept)    0.84851    0.01159      73.22    4.6521e-14

Approximate significance of smooth terms:
                edf       chi.sq     p-value
s(competitors) 1.786       16.961     0.017938

R-sq.(adj) =  0.565   Deviance explained = 63.6%
GCV score = 0.0020989   Scale est. = 0.0016116  n = 12
AICc = -33.7
(AICc not directly comparable to models IV.4 and IV.6 because of one fewer
observation)
```

Model IV.6:

Type of model: Threshold model
Dependent variable: Relative size-at-age (PB.size.rel)
Independent variables: Wind speed as categorical variable (east or west, i.e. average wind larger than 0 or not)

```
Call: lm(PB.size.rel ~ I(Wind.Dhse > 0))

Residuals:
      Min        1Q    Median        3Q       Max 
-0.045774 -0.016967 -0.008236  0.015955  0.082250 

Coefficients:
                     Estimate Std. Error t value Pr(>|t|)    
(Intercept)           0.72634    0.02372  30.624 5.33e-12 ***
Wind.Dhse > 0         0.15483    0.02578   6.005 8.87e-05 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1 

Residual standard error: 0.03354 on 11 degrees of freedom
Multiple R-Squared: 0.7662,     Adjusted R-squared: 0.745 
F-statistic: 36.06 on 1 and 11 DF,  p-value: 8.866e-05 
AICc = -44.9
```

Model IV.7:

Type of model: Linear model (Analysis of covariance model)
Dependent variable: Relative size-at-age (PB.size.rel)
Independent variables: Abundance of all coregonids in Prudhoe Bay (competitors)
Wind speed as categorical variable (east or west, i.e. average wind larger than 0 or not)

```
Call: lm(PB.size.rel ~ I(Wind.Dhse > 0) + competitors)

Residuals:
      Min        1Q    Median        3Q       Max 
-0.019314 -0.014447  0.002086  0.013355  0.019456 

Coefficients:
                     Estimate Std. Error t value Pr(>|t|)    
(Intercept)           0.83035    0.03884  21.377 5.04e-09 ***
I(Wind.Dhse > 0)TRUE  0.12193    0.01586   7.689 3.03e-05 ***
competitors          -0.01048    0.00372  -2.817   0.0201 *  
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1 

Residual standard error: 0.01707 on 9 degrees of freedom
Multiple R-Squared: 0.9357,     Adjusted R-squared: 0.9214 
F-statistic: 65.44 on 2 and 9 DF,  p-value: 4.347e-06 
AICc = -53.4
```

V. Effects of other species on Arctic cisco recruitment

Model V.1:

Type of model: Multiple or simple linear regression model
Dependent variable: a) Age-0 recruitment anomalies
b) combined recruitment anomalies

Independent variables: CPUE of all coregonids in Prudhoe Bay (competitors)
First principal component of climate variables (Cor.env.PC1)

a) Age-0 recruitment anomalies (Best model):

```
Call: lm(Age0.resid ~ competitors + Col.env.PC1)

Residuals:
    Min      1Q  Median      3Q     Max 
-1.1098 -0.5089  0.1091  0.4495  0.8240 

Coefficients:
            Estimate Std. Error t value Pr(>|t|)   
(Intercept)  2.25336    0.58049   3.882  0.00189 **
competitors -0.30450    0.07682  -3.964  0.00162 **
Col.env.PC1  0.17096    0.07696   2.221  0.04471 * 
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1 

Residual standard error: 0.5859 on 13 degrees of freedom
Multiple R-Squared: 0.5992,     Adjusted R-squared: 0.5375 
F-statistic: 9.716 on 2 and 13 DF,  p-value: 0.002626
```

AIC_c = 36.6

b) combined recruitment anomalies (best model):

```
Call: lm(YCS.resid ~ competitors)

Residuals:
     Min       1Q   Median       3Q      Max 
-0.93197 -0.43039 -0.02377  0.36761  0.65983 

Coefficients:
            Estimate Std. Error t value Pr(>|t|)  
(Intercept)  0.98452    0.47524   2.072   0.0560 .
competitors -0.12638    0.06225  -2.030   0.0605 .
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1 

Residual standard error: 0.4827 on 15 degrees of freedom
Multiple R-Squared: 0.2155,     Adjusted R-squared: 0.1632 
F-statistic: 4.121 on 1 and 15 DF,  p-value: 0.06047
```

<u>Model V.2:</u>

Type of model: Multiple or simple linear regression model
Dependent variable: a) detrended Age-0 recruitment anomalies
b) detrended combined recruitment anomalies
Independent variables: detrended CPUE of all coregonids in Prudhoe Bay (competitors)
First principal component of climate variables (Cor.env.PC1)

a) detrended Age-0 recruitment anomalies

```
Call: lm(formula = age0.resid (detrended) ~ competitors (detrended) + Col.env.PC1)

Residuals:
     Min       1Q   Median       3Q      Max 
-1.14519 -0.40177  0.04303  0.53071  0.77708
```

```
Coefficients:
              Estimate Std. Error t value Pr(>|t|)
(Intercept)         -0.02705    0.14649  -0.185   0.8564
competitors.detrend -0.16139    0.24560  -0.657   0.5226
Col.env.PC1          0.18666    0.08530   2.188   0.0475 *
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 0.5839 on 13 degrees of freedom
Multiple R-Squared: 0.3833,     Adjusted R-squared: 0.2884
F-statistic:  4.04 on 2 and 13 DF,  p-value: 0.04319
AICc = 36.5
```

b) detrended combined recruitment anomalies

```
Call: lm(YCS.detrend ~ competitors.detrend, data = dat)

Residuals:
    Min      1Q  Median      3Q     Max
-0.8330 -0.1859  0.0068  0.2842  0.7300

Coefficients:
                         Estimate Std. Error t value Pr(>|t|)
(Intercept)             7.923e-18  1.149e-01 6.9e-17    1.000
competitors.detrend    -2.146e-01  1.732e-01  -1.238    0.236

Residual standard error: 0.4594 on 14 degrees of freedom
Multiple R-Squared: 0.09874,    Adjusted R-squared: 0.03436
F-statistic: 1.534 on 1 and 14 DF,  p-value: 0.2359
AICc = 26.4
```

VI. Effects of causeways and breaching on Arctic cisco

Model VI.1:

Type of model:	Analysis of Variance (ANOVA) model
Dependent variable:	a) Age-0 recruitment anomalies b) combined recruitment anomalies
Independent variable:	Causeway construction phases (categorical variable, 3 levels): 1: pre-Endicott construction (1981-1985) 2: post-Endicott construction, prior to breaching (1986-1993) 3: post-breaching (current configuration, 1996-2005)

a) Age-0 recruitment anomalies:

```
Call: aov(Age0.resid ~ Causeways)

Analysis of Variance table:
          Df Sum of Sq  Mean Sq  F Value      Pr(F)
Causeways  2  5.934810 2.967405 5.848466 0.01104202
Residuals 18  9.132873 0.507382

Multiple comparisons:
95 % simultaneous confidence intervals for specified
linear combinations, by the Tukey method
```

```
critical point: 2.5519
response variable: Age0.resid

intervals excluding 0 are flagged by '****'

    Estimate Std.Error Lower Bound Upper Bound
1-2   -0.369     0.406      -1.410       0.667
1-3    0.828     0.406      -0.208       1.860
2-3    1.200     0.356       0.288       2.110 ****
```

a) combined recruitment anomalies:

```
Call: aov(YCS.resid ~ Causeways)

Analysis of Variance table:
          Df Sum of Sq   Mean Sq  F Value      Pr(F)
Causeways  2  1.734311 0.8671553 5.049337 0.01678133
Residuals 20  3.434730 0.1717365

Multiple comparisons:
95 % simultaneous confidence intervals for specified
linear combinations, by the Tukey method

critical point: 2.53
response variable: YCS.resid

intervals excluding 0 are flagged by '****'

    Estimate Std.Error Lower Bound Upper Bound
1-2   -0.659     0.236     -1.2600     -0.0617 ****
1-3   -0.141     0.227     -0.7150      0.4330
2-3    0.518     0.197      0.0211      1.0200 ****
```

Model VI.2:

Type of model:	Simple linear regression model
Dependent variable:	a) Age-0 recruitment anomalies
	b) combined recruitment anomalies
Independent variable:	Cumulative disturbance potential, Endicott

a) Age-0 recruitment anomalies

```
Call: lm(Age0.resid ~ Endicott.cum)
Residuals:
    Min      1Q  Median     3Q   Max
 -1.562 -0.2673 0.01575 0.5299 1.857

Coefficients:
               Value Std. Error t value Pr(>|t|)
 (Intercept)  0.0748  0.3546     0.2109  0.8350
Endicott.cum -0.0905  0.3711    -0.2439  0.8096

Residual standard error: 0.8547 on 21 degrees of freedom
Multiple R-Squared: 0.002826
F-statistic: 0.05951 on 1 and 21 degrees of freedom, the p-value is 0.8096
```

b) combined recruitment anomalies

```
Call: lm(YCS.resid ~ Endicott.cum)
Residuals:
     Min      1Q Median     3Q    Max
 -0.8121 -0.2018 0.0552 0.1789 0.9797
```

```
Coefficients:
                Value Std. Error t value Pr(>|t|)
 (Intercept) -0.3139  0.1883    -1.6672  0.1090
Endicott.cum  0.3737  0.1963     1.9038  0.0695

Residual standard error: 0.4545 on 23 degrees of freedom
Multiple R-Squared: 0.1361
F-statistic: 3.624 on 1 and 23 degrees of freedom, the p-value is 0.06953
```

Model VI.3:

Type of model: Analysis of Variance (ANOVA) model
Dependent variable: a) Age 0-5 survival anomalies
b) Age 5-7 survival anomalies
Independent variable: Causeway construction phases (categorical variable, 3 levels):
1: pre-Endicott construction (1981-1985)
2: post-Endicott construction, prior to breaching (1986-1993)
3: post-breaching (current configuration, 1996-2005)

a) Age 0-5 survival anomalies:

```
Call: aov(Surv.age5 ~ Causeways)

Analysis of variance table:

          Df Sum of Sq  Mean Sq  F Value    Pr(F)
Causeways  2   2.56440 1.282199 1.443997 0.266976
Residuals 15  13.31928 0.887952
```

b) Age 5-7 survival anomalies

```
Call: aov(Surv.567 ~ Causeways)

Analysis of variance table:

          Df Sum of Sq  Mean Sq F Value      Pr(F)
Causeways  2  4.604305 2.302152 4.72758 0.02436426
Residuals 16  7.791394 0.486962

Multiple pairwise comparisons among periods:

95 % simultaneous confidence intervals for specified
linear combinations, by the Tukey method

critical point: 2.5802
response variable: Surv.567

intervals excluding 0 are flagged by '****'

    Estimate Std.Error Lower Bound Upper Bound
1-2   1.6000     0.552       0.173       3.020 ****
1-3   1.6100     0.546       0.203       3.020 ****
2-3   0.0134     0.339      -0.862       0.888
```

Model VI.4:

Type of model: Simple linear regression model
Dependent variable: a) Age 0-5 survival anomalies
b) Age 5-7 survival anomalies
Independent variable: Cumulative disturbance potential, Endicott

a) Age 0-5 survival anomalies:

```
Call: lm(Surv.age5 ~ Endicott.cum)

Residuals:
    Min      1Q  Median     3Q   Max
 -1.714 -0.6758 -0.2078 0.6465 1.977

Coefficients:
               Value Std. Error t value Pr(>|t|)
 (Intercept)  0.3678  0.4208     0.8741  0.3936
Endicott.cum -0.4801  0.4435    -1.0825  0.2933

Residual standard error: 1.011 on 18 degrees of freedom
Multiple R-Squared: 0.06112
F-statistic: 1.172 on 1 and 18 degrees of freedom, the p-value is 0.2933
```

b) Age 5-7 survival anomalies

```
Call: lm(Surv.567 ~ Endicott.cum)
Residuals:
    Min      1Q   Median     3Q   Max
 -1.064 -0.5708 -0.02628 0.5794 1.349

Coefficients:
               Value Std. Error t value Pr(>|t|)
 (Intercept)  0.8830  0.4583     1.9268  0.0691
Endicott.cum -0.9137  0.4477    -2.0407  0.0554

Residual standard error: 0.7693 on 19 degrees of freedom
Multiple R-Squared: 0.1798
F-statistic: 4.164 on 1 and 19 degrees of freedom, the p-value is 0.05543
```

Model VI.5:

Type of model: Analysis of Variance (ANOVA) model
Dependent variable: Arctic cisco combined, adjusted CPUE index (Col.ARCS)
at various lags from 0 to 6 years
Independent variable: Causeway construction phases (categorical variable, 3 levels):
1: pre-West Dock construction (pre-1976)
1: pre-Endicott construction (1976-1985)
2: post-Endicott construction, prior to breaching (1986-1993)
3: post-breaching (current configuration, 1996-2005)

Analysis of variance tables for various lags:
a) lag = 6 (Causeway construction affect catch rates 6 years later):

```
                  Df Sum of Sq   Mean Sq   F Value     Pr(F)
factor(Causeways)  3  0.370494 0.1234979 0.4940902 0.6888495
        Residuals 33  8.248354 0.2499501
```

b) lag = 5

```
                   Df Sum of Sq   Mean Sq   F Value     Pr(F)
factor(Causeways)   3   0.32651 0.1088355 0.3273061 0.8055987
        Residuals 33  10.97313 0.3325191
```

c) lag = 4

```
                   Df Sum of Sq   Mean Sq   F Value    Pr(F)
factor(Causeways)   3   0.40035 0.1334502 0.3851036 0.7644204
        Residuals 33  11.43551 0.3465305
```

d) lag = 3

```
                   Df Sum of Sq   Mean Sq   F Value    Pr(F)
factor(Causeways)   3   0.36713 0.1223755 0.3614613 0.781211
        Residuals 33  11.17240 0.3385576
```

e) lag = 2

```
                   Df Sum of Sq   Mean Sq   F Value     Pr(F)
factor(Causeways)   3   0.55278 0.1842613 0.5753685 0.6352578
        Residuals 33  10.56822 0.3202492
```

f) lag = 1

```
                   Df Sum of Sq   Mean Sq   F Value     Pr(F)
factor(Causeways)   3   0.28756 0.0958537 0.2858735 0.8352352
        Residuals 33  11.06493 0.3353010
```

g) lag = 0

```
                   Df Sum of Sq   Mean Sq   F Value     Pr(F)
factor(Causeways)   3   0.51067 0.1702227 0.5218351 0.6702525
        Residuals 33  10.76461 0.3262002
```

<u>Model VII.1.1:</u>

Type of model: Generalized Additive Model
Dependent variable: combined recruitment anomalies
Independent variable: Total disturbance potential by year, eastern section, open water season (East.open)

```
Generalized Additive Model:
Family: gaussian
Link function: identity

Formula:
YCS.resid ~ s(East.open, k = 4)

Parametric coefficients:
              Estimate  std. err.    t ratio    Pr(>|t|)
(Intercept) 8.6136e-06    0.09488 9.078e-05    0.99993

Approximate significance of smooth terms:
                    edf       chi.sq     p-value
s(East.open)      1.618       2.8441     0.43423

R-sq.(adj) =  0.0178   Deviance explained =  8.4%
GCV score = 0.25138   Scale est. = 0.22505   n = 25
```

Model VII.1.2:

Type of model: Generalized Additive Model
Dependent variable: combined recruitment anomalies
Independent variable: Total seismic line surveyed by year, eastern section (Seismic.East)

```
Generalized Additive Model:
Family: gaussian
Link function: identity

Formula:
YCS.resid ~ s(log(Seismic.East + 1), k = 4)

Parametric coefficients:
              Estimate  std. err.    t ratio    Pr(>|t|)
(Intercept) 8.6136e-06    0.09778 8.809e-05    0.99993

Approximate significance of smooth terms:
                                edf       chi.sq     p-value
s(log(Seismic.East + 1))          1    0.0065811     0.93605

R-sq.(adj) =  -0.0432   Deviance explained = 0.0286%
GCV score = 0.25981   Scale est. = 0.23902   n = 25
```

Model VII.2.1:

Type of model: Generalized Additive Model
Dependent variable: Survival anomalies ages 5-6 / 6-7 (Surv.567)
Independent variable: Total drilling operations, central section, summer (Drilling.central)

```
Generalized Additive Model:
Family: gaussian
Link function: identity

Formula:
Surv.567 ~ s(Central.drilling, k = 4)

Parametric coefficients:
              Estimate  std. err.    t ratio    Pr(>|t|)
(Intercept)    0.01282      0.153    0.08381    0.93412

Approximate significance of smooth terms:
                           edf       chi.sq     p-value
s(Central.drilling)      1.749         10.8     0.033529

R-sq.(adj) =  0.283   Deviance explained = 34.6%
GCV score = 0.5654   Scale est. = 0.49139   n = 21
AICc = 51.4
```

Model VII.2.2:

Type of model: Simple linear regression model
Dependent variable: Survival anomalies age-0 to age-5 (Surv.age5)
Independent variable: 6-year average of total seismic lines surveyed in the western Beaufort Sea during summer (Seismic.West)

```
Call: lm(Surv.age5 ~ Seismic.West)

Residuals:
    Min      1Q  Median      3Q     Max 
-1.2769 -0.6599 -0.1530  0.5179  2.3194 

Coefficients:
               Estimate Std. Error t value Pr(>|t|)  
(Intercept)  -1.0084964  0.5505411  -1.832   0.0836 .
Seismic.West  0.0018322  0.0009382   1.953   0.0666 .
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1 

Residual standard error: 0.9482 on 18 degrees of freedom
Multiple R-Squared: 0.1748,     Adjusted R-squared: 0.129 
F-statistic: 3.814 on 1 and 18 DF,  p-value: 0.06657
```

Model VII.3.1:

Type of model: Simple linear regression model
Dependent variable: Survival anomalies ages 5-6 / 6-7 (Surv.567)
Independent variable: Total disturbance potential, western section, winter (West.frozen)

```
Call: lm(Surv.567 ~ West.frozen)

Residuals:
    Min      1Q  Median      3Q     Max 
-1.3644 -0.4621 -0.1761  0.3351  1.9268 

Coefficients:
            Estimate Std. Error t value Pr(>|t|)  
(Intercept)  0.36646    0.25284   1.449   0.1635  
West.frozen -0.03056    0.01617  -1.890   0.0741 .
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1 

Residual standard error: 0.7793 on 19 degrees of freedom
Multiple R-Squared: 0.1583,     Adjusted R-squared: 0.114 
F-statistic: 3.573 on 1 and 19 DF,  p-value: 0.0741
```

AIC_c = 54.4

Model VII.3.2:

Type of model: Threshold model (threshold fixed)
Dependent variable: Survival anomalies ages 5-6 / 6-7 (Surv.567)
Independent variable: Total disturbance potential, western section, winter (West.frozen)

```
Call: lm(Surv.567 ~ I(West.frozen > 15))

Residuals:
    Min      1Q  Median      3Q     Max 
-1.2779 -0.3370 -0.1825  0.2911  1.9522 

Coefficients:
                        Estimate Std. Error t value Pr(>|t|)  
West.frozen < 15          0.2800     0.2007   1.395   0.1790  
West.frozen > 15         -0.8015     0.3476  -2.306   0.0325 *
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1 

Residual standard error: 0.7508 on 19 degrees of freedom
Multiple R-Squared: 0.2187,     Adjusted R-squared: 0.1776 
F-statistic: 5.318 on 1 and 19 DF,  p-value: 0.03255 
AICc = 52.9
```

Model VII.4.1a:

Type of model: Threshold model (threshold fixed)
Dependent variable: Arctic cisco CPUE index (Col.ARCS)
Independent variable: 6-year average of total disturbance potential, western section, during winter (West.frozen)

```
Call: lm(Col.ARCS ~ I(West.frozen > 20))

Residuals:
    Min      1Q  Median      3Q     Max 
-9.9700 -5.1848 -0.9199  3.4313 18.7234 

Coefficients:
                        Estimate Std. Error t value Pr(>|t|)    
West.frozen < 20          14.704      1.196  12.299 1.23e-14 ***
West.frozen > 20          -7.322      3.339  -2.193   0.0347 *  
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1 

Residual standard error: 6.971 on 37 degrees of freedom
Multiple R-Squared: 0.115,      Adjusted R-squared: 0.0911 
F-statistic: 4.809 on 1 and 37 DF,  p-value: 0.03468 
AICc = 266.8
```

Model VII.4.1b:

Type of model: Threshold model (threshold fixed)
Dependent variable: Arctic cisco CPUE index (Col.ARCS)
Independent variable: 6-year average of total disturbance potential, Colville delta, during winter (Colville.frozen)

```
Call: lm(Col.ARCS ~ I(Colville.frozen > 17.5))

Residuals:
    Min      1Q  Median      3Q     Max
-9.9700 -5.1848 -0.9199  3.4313 18.7234

Coefficients:
                              Estimate Std. Error t value Pr(>|t|)
Colville.frozen < 17.5          14.704      1.196  12.299 1.23e-14 ***
Colville.frozen > 17.5          -7.322      3.339  -2.193   0.0347 *
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 6.971 on 37 degrees of freedom
Multiple R-Squared: 0.115,      Adjusted R-squared: 0.0911
F-statistic: 4.809 on 1 and 37 DF,  p-value: 0.03468
AICc = 266.8
```

Model VII.4.1c:

Type of model: Threshold model (threshold fixed)
Dependent variable: Arctic cisco CPUE, adjusted for recruitment anomalies (CPUE.unexpl)
Independent variable: 6-year average of total disturbance potential, western section, during winter (West.frozen)

```
lm(CPUE.unexpl ~ I(West.frozen > 20))

Residuals:
    Min      1Q  Median      3Q     Max
-9.3040 -2.3123  0.1749  2.2513  8.7345

Coefficients:
                        Estimate Std. Error t value Pr(>|t|)
West.frozen < 20           2.272      1.295   1.754  0.09860 .
West.frozen > 20          -8.178      2.458  -3.328  0.00426 **
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 4.67 on 16 degrees of freedom
Multiple R-Squared: 0.409,      Adjusted R-squared: 0.3721
F-statistic: 11.07 on 1 and 16 DF,  p-value: 0.004264
AICc = 112.2
```

Model VII.4.1d:

Type of model: Threshold model (threshold fixed)
Dependent variable: Arctic cisco CPUE, adjusted for recruitment anomalies (CPUE.unexpl)
Independent variable: 6-year average of total disturbance potential, Colville delta, during winter (Colville.frozen)

```
Call: lm(CPUE.unexpl ~ I(Colville.frozen > 17.5))

Residuals:
    Min      1Q  Median      3Q     Max
-9.3040 -2.3123  0.1749  2.2513  8.7345

Coefficients:
                              Estimate Std. Error t value Pr(>|t|)
(Intercept)                      2.272      1.295   1.754  0.09860 .
I(Colville.frozen > 17.5)TRUE   -8.178      2.458  -3.328  0.00426 **
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 4.67 on 16 degrees of freedom
Multiple R-Squared: 0.409,      Adjusted R-squared: 0.3721
F-statistic: 11.07 on 1 and 16 DF,  p-value: 0.004264
AICc = 112.2
```

Model VIII.1:

Type of model: Generalized Additive Model
Dependent variable: Combined recruitment index (PB.YCS)
Independent variables: Index of spawner abundance (Spawners)
Average summer wind speed at Deadhorse (Wind.Dhse)

```
Family: gaussian
Link function: identity

Formula:
PB.YCS ~ s(Spawners) + s(Wind.Dhse)

Parametric coefficients:
            Estimate Std. Error t value Pr(>|t|)
(Intercept)  1.18193    0.08973   13.17 1.70e-11 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Approximate significance of smooth terms:
               edf Est.rank      F  p-value
s(Spawners)  2.414    9.000  1.393    0.254
s(Wind.Dhse) 1.000    1.000 48.909 7.41e-07 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

R-sq.(adj) =  0.738   Deviance explained = 77.6%
GCV score = 0.24442   Scale est. = 0.20127   n = 25
```