RUSALCA – Fisheries Ecology and Oceanography

Reported by
Brenda L. Norcross, Brenda A. Holladay, Morgan S. Busby, Kathryn Mier

Prior to the August RUSALCA 2004 cruise, we hypothesized that the frontal structure of the northern Bering Sea and the Chukchi Sea defines fish communities (species composition and abundance) by preventing transfer among water masses and that the physical oceanographic structures on either side of the fronts should determine suitable fish habitat. The unique frontal structure found in the Chukchi Sea presents a barrier to fish species, resulting in different communities on either side of the front (Weingartner 1997). Distinct communities of larval fishes are associated with specific water masses in the Chukchi Sea (Wyllie-Echeverria et al. 1997). Additionally, changes in distribution of fishes in the Chukchi Sea have been associated with influx of warm Alaska Coastal Water (Gillespie et al. 1997; Smith et al. 1997a, 1997b). Therefore, changes in the climate patterns that affect the physical structure of the Arctic, in particular the warming trends that have been observed (ACIA 2004), should have a profound effect on the distribution and abundance of fishes.

Figure 1. Stations sampled by bongo net, beam trawl, and otter trawl in Bering Strait and the Chukchi Sea, 10–22 August 2004 (figure courtesy of C.W. Mecklenburg).

The Fisheries Ecology and Fish Diversity teams jointly sampled the same stations on the same cruise in August 2004 (Figure 1). We collected juvenile fish using a 3.05 m plumbstaff beam trawl (7 mm mesh body; 4 mm mesh codend liner) and sampled ichthyoplankton with a 60 cm diameter bongo with two 500 μ mesh nets. One additional station (#10) was sampled for ichthyoplankton (total = 18 stations), but not for juvenile bottom fishes (total = 17 stations). Fishes collected by beam trawl were primarily identified and measured (total length to 1 mm) at sea (Table 1). For analyses, we used presence/absence of juvenile fishes rather than abundance for numerous reasons: tows were of variable distance (82 – 289 m) and duration (1.1 – 5.8 min); the net was damaged at one site, and full beyond the codend at two additional sites; and start and end tow coordinates, allowing calculation of distance towed, were available at only five of the

17 sites examined by beam trawl. Specimens for voucher collections and of questionable identity were returned to laboratories in the United States and Russia for further examination as detailed by the Fish Diversity team. Plankton samples were shipped to the Plankton Sorting and Identification Center in Szczecin, Poland for sorting and identification to the lowest taxonomic level possible. Taxonomic identifications were verified by experts at the NMFS/Alaska Fisheries Science Center laboratory in Seattle. Larval fishes were measured for standard length to the nearest 0.1 mm. Catch in each bongo tow was converted to catch per $10m^2$ of sea surface area.

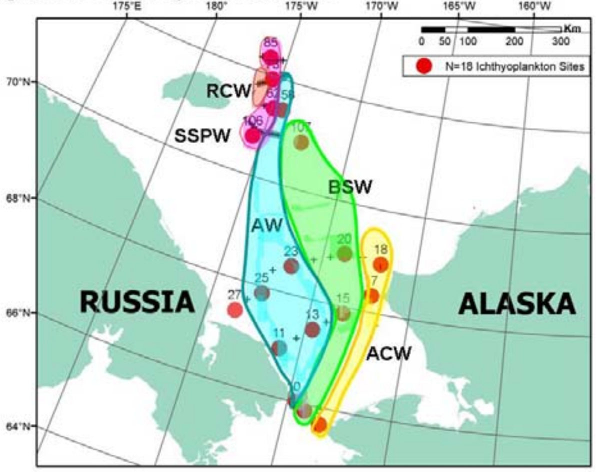
At the Montenegro RUSALCA meeting in October 2005, the Fish Ecology team reported preliminary results from analyses of juvenile bottom fish and ichthyoplankton collections in the Bering Strait and Chukchi Sea during the cruise. Since that time, we reanalyzed many of the data to produce the following in-depth, revised results.

Our overall goal of collecting juvenile demersal fishes and ichthyoplankton in RUSALCA 2004 was to document the fish species in the study area (Figure 1) and to provide a baseline from which to measure future changes. Ichthyoplankton and juvenile demersal fishes were collected at approximately 18 stations in conjunction with CTD data. CTD data were also collected at 57 additional stations. Ichthyoplankton samples contained 23 taxa representing eight families; they were dominated by Arctic Cod *Boreogadus saida*, Yellowfin Sole *Limanda aspera*, and Bering Flounder *Hippoglossoides robustus*. Juvenile demersal fish collections were composed of 32 taxa in nine families. Catches were dominated by Arctic Staghorn Sculpin *Gymnocanthus tricuspis*, Shorthorn Sculpin *Myoxocephalus scorpius*, and Hamecon *Artediellus scaber*.

Ecosystem Analysis

We successfully used cluster analyses from all stations at which a CTD was taken to identify five bottom water masses in the Chukchi Sea (Figure 2). We used results of the cluster analyses and the vertical sections of temperature and salinity at each transect obtained from Bob Pickart to interpret water mass composition. Our water mass determination was confirmed with Bob Pickart (pers. comm.) and agreed in part with Weingartner (1997). The Alaska Coastal Water (ACW), Bering Shelf Water (BSW) and Anadyr Water (AW) flowed northward from Bering Strait. The ACW, which originates in the Gulf of Alaska, passed through the Bering Sea and into the Chukchi Sea, was clearly isolated from the rest of the Chukchi Sea (Figure 2) by a well-defined front ~50 km from the coast that extends northward from Bering Strait to the Lisburne Peninsula (Weingartner 1997). BSW originates on the eastern Bering Shelf and can be seen as a distinct water mass northward into the Chukchi Sea. AW is colder and fresher and originates in the western Bering Sea in the Gulf of Anadyr and moves northward through the western side of the Bering Strait. The Resident Chukchi Water (RCW) is derived from the upper layers of the Arctic Ocean or shelf water left from the previous winter (Weingartner 1997) and is found offshore in the northern Chukchi Sea. Another water mass that we called the Siberian Sea Polynya Water (SSPW) was most likely derived from waters to the west that were being

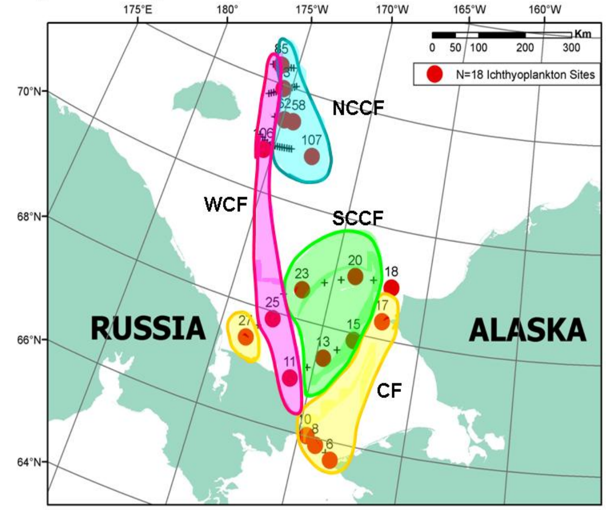
Figure 2. Bottom Depth Water Masses



transported into the Chukchi from south of Wrangell Island (Pickart, per. comm.) The Siberian Coastal Current (SCC), which was expected to flow southeastward along the coast of Russia (Weingartner 1997, 1999), was not detected in 2004. Station 27, which may or may not be the SCC, had anomalous results that did not cluster with any other station and was not included in water mass analysis.

We determined that we could successfully capture small demersal fishes as 1310 individuals were collected by beam trawl. Fish collections at beam trawl stations were classified into assemblages using cluster analysis of species present or absent (bottom). Four clusters of small bottom fishes from 17 stations (Figure 3) had spatial distributions comparable to those of the water masses: Coastal Fish (CF), South Central Chukchi Fish (SCCF), North Central Chukchi Fish (NCCF), and Western Chukchi Fish (WCF). An Analysis of Similarity (ANOSIM, Primer) calculated based on presence/absence indicated significant differences in species composition in the assemblages found in ACW and BSW (p=0.036). Subsequent Similarity Percentages (SIMPER, Primer) analysis found that contribution to observed differences was similar among all species. A significant difference was also found between species assemblages in ACW and SSPW (p=0.029). However as with ACW and BSW, contribution to observed differences was very similar among all species. There were no significant differences between other water masses. According to Biota and/or Environmental Matching (BIOENV, Primer), which is similar to multivariate analysis, the most important factor affecting habitat selection by juvenile demersal fish was sediment classification ($R_s = 0.54$) with bottom salinity ($R_s = 0.38$) and bottom temperature having less influence ($R_s = 0.37$).

Figure 3. Groups of Bottom Fishes



Larval or juvenile fishes were successfully captured at all ichthyoplankton stations, and eggs were found at eight of the 18 stations. A total of111 eggs and 498 larval fishes were collected in bongo tows. Oblique towing of bongos provide depth-integrated information, i.e., ichthyoplankton are likely derived from more than one water mass. We clustered depth-integrated temperature and salinity to derive three water masses analogous to those found in bottom waters (Figure 4). Three assemblages were from produced from cluster analyses of ichthyoplankton abundance (Figure 5). These are comparable to the bottom assemblages (CF, WCF), except the Central Chukchi Fish (CCF) are combined into one group. An ANOSIM indicated significant differences in species composition in the assemblages found in ACW and AW (p=0.008). SIMPER analysis determined that *Limanda aspera*, *Liparis gibbus*,

Figure 4. Integrated Bongo Depth Water Masses

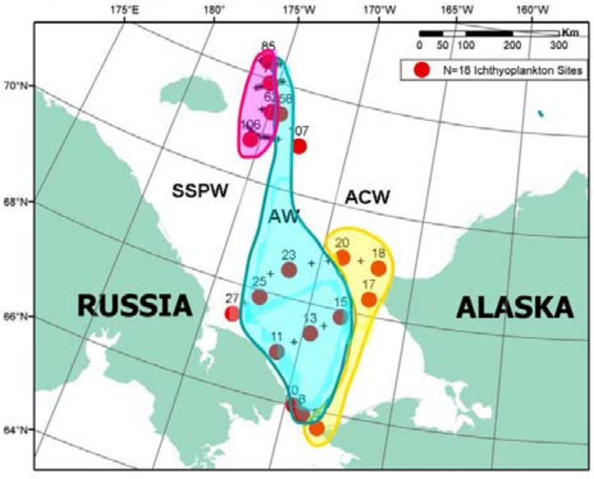
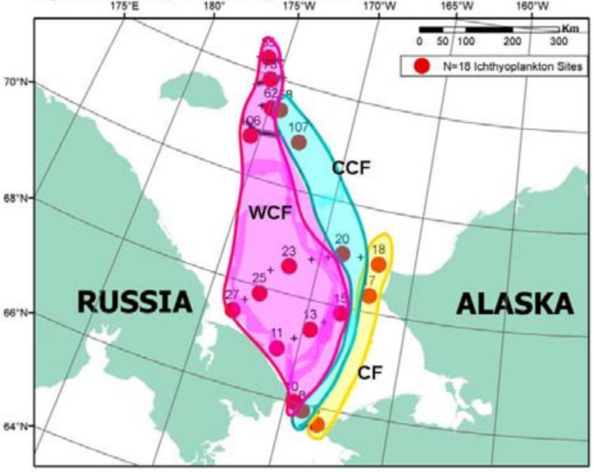


Figure 5. Groups of Ichthyoplankton



Boreogadus saida, and *Liparis* spp. accounted for over 58% of the observed difference. A significant difference was also found between species assemblages in ACW and SSPW (p=0.029). Again, SIMPER analysis showed that *Boreogadus saida*, *Limanda aspera*, and *Liparis gibbus* account for over 55% of the observed difference. There was no difference between assemblages in AW and SSPW. Water column temperature contributed the most (R_s = 0.42) to determining ichthyoplankton species composition (BIOENV, Primer). Salinity contributed only a small amount (R_s = 0.26).

Detection of Climate Change Effects

We hypothesized that the frontal structures of the northern Bering Sea and the Chukchi Sea would define fish communities (species composition) by preventing transfer among water masses and that the physical oceanographic structures on either side of the fronts should determine suitable fish habitat. Our analysis of the limited number of stations that we were able to sample in 2004 supported our hypothesis. Water masses were distinct and fish assemblage structure was reflected by water mass spatial patterns. We conclude that oceanographic parameters directly influenced species assemblages and distributions.

The critical result of this cruise was establishing a baseline of larval and juvenile fish presence, distribution, relative abundance and association with physical characteristics in the Bering Strait and Chukchi Sea in 2004. Climate changes have occurred over recent decades and are having an impact on every aspect of the ecosystem (ACIA 2004). These impacts on fishes cannot be discerned unless there is a basis against which to compare changes. Quantifying changes occurring in the Arctic now is difficult without baseline data because there is not one clear cause of ecosystem change, the effects are not abrupt, and the area over which change occurs is massive. Therefore the fact that we documented the present conditions in the Bering and Chukchi Seas from physical characteristics through higher trophic levels is vital.

Conclusions

These results go far beyond merely providing a baseline of fish distribution for future comparisons. We identified the physical mechanisms that affect species composition and distribution. This directly supports the RUSALCA objective of providing a method to identify ecosystem change. Physical characteristics can be measured and analyzed more quickly than fish can be collected and processed; yet, a well-integrated combination of physical and biological studies yields a more meaningful synthesis of the ecosystem. Indications of changes in the physical oceanography that could occur with climate change, e.g., movement or removal of frontal systems or changes in water masses characteristics, may indicate effects on the broader ecosystem. Knowledge of the baseline relationship among fishes and water masses provide the background to monitor changes in the northern Bering and Chukchi Sea ecosystem.

Recommendations for Future Research

Expanded spatial coverage is needed. Collections are needed in the northern Bering Sea, the western Chukchi Sea along the Siberian coast and south of Wrangell Island, and the northern Chukchi Sea to connect Herald Canyon to the north coast of Alaska. Such expanded collections will help determine the origin and fate of the water masses that we identified in 2004. Spatially expanded collections of fish are needed to determine the extent of fish community associations that we identified from the 2004 data.

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Table 1. Count of fishes caught by beam trawl tows, by station. Sorted by water mass.

	Water Mass	ACW			BSW				AW					RCW				Anomaly	Grand Total
	Station	6	17	18	8	15	20	107	11	13	23	25	58	62	73	85	106	27	
Cod	*Boreogadus saida*	-	-	-	-	-	-	8	-	2	-	9	2	11	3	2	1	-	38
"	*Eleginus gracilis*	11	58	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	69
"	*Theragra chalcogramma*	-	1	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5
Eelpout	*Gymnelus bilabrus*	-	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4
"	*Gymnelus hemifasciatus*	3	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	3	7
"	*Gymnelus viridis*	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
"	*Lumpenus fabricii*	31	18	14	-	1	1	-	2	10	-	4	-	-	-	-	1	6	88
"	*Lycodes mucosus*	1	-	-	1	-	-	-	-	-	1	-	-	-	-	-	-	1	4
"	*Lycodes palearis*	-	-	6	-	-	1	-	-	-	-	1	-	-	-	-	-	-	8
"	*Lycodes polaris*	-	-	-	-	-	-	5	-	-	-	-	2	-	1	-	-	-	8
"	*Lycodes raridens*	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	3
Sailfin sculpin	*Nautichthys pribilovius*	7	10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	17
Flatfish	*Hippoglossoides robustus*	-	-	13	-	4	7	1	-	17	11	11	9	-	-	-	1	-	74
"	*Limanda aspera*	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
Greenling	*Hexagrammos stelleri*	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4
Gunnel	*Pholis fasciata*	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
Poacher	*Pallasina barbata*	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
"	*Podothecus veternus*	1	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3
"	*Ulcina olrikii*	-	-	2	-	1	3	3	-	2	1	-	1	-	4	-	-	2	19
Prickleback	*Anisarchus medius*	-	-	13	-	1	12	18	-	13	8	8	26	-	3	-	-	-	102
"	*Liparis fabricii*	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	1
"	*Stichaeus punctatus*	5	57	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	63
Sculpin	*Artediellus scaber*	-	59	-	-	-	-	3	-	-	-	-	-	-	-	-	-	64	126
"	*Enophrys diceraus*	5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5
"	*Gymnocanthus tricuspis*	9	9	5	2	5	8	58	26	22	4	70	1	4	35	7	3	175	443
"	*Icelus spatula*	1	-	-	1	-	-	-	-	-	-	-	1	-	2	-	-	-	5
"	*Myoxocephalus polyacanthocephalus*	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
"	*Myoxocephalus scorpius*	27	43	3	12	-	-	6	1	12	1	8	2	6	-	-	-	69	190
"	*Myoxocephalus* sp.	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
"	*Triglops pingelii*	2	1	2	-	-	-	-	-	-	-	-	-	-	-	-	-	2	7
Snailfish	*Liparis gibbus*	1	-	-	1	-	1	-	-	-	-	-	-	-	-	-	-	-	3
"	*Liparis* sp.	-	-	-	-	-	-	-	-	4	-	-	-	-	-	-	-	-	4
"	*Liparis tunicatus*	-	-	-	-	-	-	1	-	-	-	1	-	-	-	-	1	1	4
	Grand Total	113	261	64	18	12	33	106	29	82	26	112	44	21	50	9	7	323	1310

Table 2. Average CPUE (#/10 m^2) for bongo ichthyoplankton tows, by station. Sorted by water mass.

		Water Mass	ACW				AW								RCW				Anomalies		Grand Total
		Station	6	17	18	20	8	10	11	13	15	23	25	58	62	73	85	106	27	107	
Cod	Egg	Gadidae	-	-	-	-	-	13	-	-	-	-	-	-	-	-	-	-	-	-	13
Flatfish	"	*Hippoglossoides robustus*	-	-	-	-	-	-	-	-	-	-	-	-	19.8	-	43.8	53.5	2.2	-	33.8
"	"	*Limanda* spp.	9.7	-	11.6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10.3
"	"	Pleuronectidae	4.7	-	-	-	2.7	-	-	-	-	-	-	-	-	-	-	-	-	-	3.7
Cod	Juvenile	*Boreogadus saida*	-	-	-	1.9	-	-	-	-	-	2.3	-	-	-	-	5.8	-	-	-	3.1
"	"	*Eleginus gracilis*	-	-	-	-	-	-	-	-	-	2.4	-	-	-	-	-	-	-	-	2.4
Sculpin	"	*Gymnocanthus* spp.	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	2
Cod	Larvae	*Boreogadus saida*	-	-	-	1.9	-	4.3	13.3	3	9.4	-	2.9	-	69.4	-	63.9	168	35.1	-	48
"	"	Gadidae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6.5	4.5	-	-	5.1
"	"	*Theragra chalcogramma*	-	-	-	-	-	-	-	-	4.7	-	-	-	-	-	-	-	-	6.7	5.7
Flatfish	"	*Hippoglossoides robustus*	-	-	-	3.7	-	7.4	-	-	-	6	-	2.1	-	-	5.8	-	-	-	4.6
"	"	*Hippoglossus stenolepis*	-	-	-	-	2.5	3.7	-	-	-	-	-	-	-	-	-	-	-	-	3.1
"	"	*Limanda aspera*	33.4	13.4	16.1	1.8	-	-	2.6	-	-	-	-	-	-	-	-	-	-	-	14.7
"	"	*Limanda* spp.	-	-	-	-	-	-	-	-	-	-	2.9	-	-	-	-	-	-	-	2.9
"	"	*Liopsetta glacialis*	-	-	2.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2.3
"	"	*Parophrys vetulus*	-	-	-	3.8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3.8
"	"	Pleuronectidae	-	-	-	1.8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.8
Greenling	"	*Aspidophoroides monopterygius*	-	-	-	-	2.5	-	2.4	-	5.2	-	-	-	-	-	-	-	-	-	3.4
Smelt	"	Osmeridae	-	-	2.3	-	-	4.3	-	-	-	-	-	-	-	-	-	-	-	-	3.3
Poacher	"	*Ulcina olrikii*	-	-	-	-	-	-	-	-	-	-	-	-	3.2	-	-	-	-	-	3.2
Prickleback	"	*Leptoclinus maculatus*	-	-	-	-	-	4.3	-	-	-	-	-	-	-	2.3	-	-	-	-	3.3
"	"	*Lumpenus fabricii*	-	-	-	-	-	-	-	-	-	-	-	-	3.2	2	-	-	4.4	-	3.2
"	"	*Lumpenus* spp.	-	-	-	-	-	11.1	5.5	-	5.2	-	-	-	-	2	-	1.8	-	-	5.1
"	"	*Stichaeus punctatus*	-	-	-	-	-	-	-	-	-	2.3	-	-	2.8	-	-	-	-	-	2.5
Sandlance	"	*Ammodytes hexapterus*	-	-	-	-	-	-	-	-	4.7	2.3	-	-	-	-	-	-	-	-	3.1
Sculpin	"	*Gymnocanthus* spp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5.8	1.8	-	-	3.8
"	"	*Gymnocanthus tricuspis*	-	-	-	-	-	4.3	-	-	-	-	3.3	-	-	-	-	-	-	-	3.8
"	"	*Icelus* spp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.8	-	-	1.8
"	"	*Liparis fabricii*	-	-	-	1.8	-	-	9.5	-	-	6.6	-	-	-	-	5.8	-	2.2	-	5.9
"	"	*Liparis gibbus*	-	-	-	-	-	7.4	11.8	4.7	12.7	4.4	2.9	-	2.8	2	12.6	3.6	4.3	-	7
"	"	*Liparis* spp.	-	-	-	-	2.7	4.3	7.6	-	7.5	10.7	-	-	-	-	-	-	-	-	7.3
"	"	*Liparis tunicatus*	-	-	-	-	-	4.3	-	-	-	-	-	-	-	-	-	-	-	-	4.3
		Grand Total	18.2	13.4	9.7	2.5	2.6	6.2	8.1	4.2	7.7	4.7	3	2.1	23.8	2	24.5	42.2	12.5	6.7	12.8