Journal of Marine Systems 127 (2013) 65–75

Contents lists available at ScienceDirect

Journal of Marine Systems

journal homepage: www.elsevier.com/locate/jmarsys

Distribution and diet of the bottom dwelling Arctic cod in the Canadian Beaufort Sea

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ARTICLE INFO

Available online 17 April 2012

Keywords:
Arctic cod
Beaufort Sea
Distribution
Zooplankton
Feeding
Demersal

ABSTRACT

Distribution and diet of bottom-dwelling Arctic cod were studied in the nearshore Canadian Beaufort Sea in summer of 2006–2009 using a 3 m benthic beam trawl. In total, 82 stations were visited ranging in depth from 8 to 128 m. Fish densities were generally low for benthic habitats; pelagic fish occurrence was not assessed. We observed a gradual increase in both the biomass of daily food rations and their energetic content over fish age. Overall, fish were able to obtain high food rations indicating that the Beaufort Sea Shelf has sufficient food resources for them. Demersal Arctic cod fed mainly on copepods (*Pseudocalanus* spp., *Calanus glacialis*, *Calanus hyperboreus*, *Limnocalanus macrurus* and *Jaschnovia tolli*), amphipods (*Apherusa glacialis* and *Themisto libellula*) and mysids (*Mysis oculata*). Further studies, particularly focused on combined pelagic/benthic sampling, are needed to fully assess ecology of the Arctic cod population in the Canadian Beaufort Sea.

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1. Introduction

Arctic cod (*Boreogadus saida*) is considered to be a key element of Arctic marine ecosystems given its wide distribution and integral role in overall biomass and energy pathways (Bradstreet et al., 1986). Its importance is gauged as a result of its role both as a consumer of zooplankton (Orlova et al., 2009; Walkusz et al., 2011) and as a food source for higher trophic animals such as seals (Bradstreet, 1982; Finley et al., 1990; Weslawski et al., 1994a), birds (Cairns, 1987; Lønne and Gabrielsen, 1992; Weslawski et al., 1994b) and whales (Welch et al., 1993). Due to its significance in the ecosystem, Arctic cod has received considerable attention from the scientific community in the recent years, resulting in a number of papers describing its basic biology and ecology (e.g., Bradstreet et al., 1986; Craig et al., 1982; Lønne and Gulliksen, 1989). Arctic cod spawns under the ice in winter, and is primarily pelagic throughout its larval and early juvenile life (Sameoto, 1984). It feeds on a broad range of organism, mainly crustaceans, and although is considered a generalist it modifies its diet along with its growth and gape size (Ajiad and Gjøsæter, 1990; Walkusz et al., 2011). In some location Arctic cod creates large schoolings that create apparent feeding hot-spots for predators (marine birds, seals and whales) which enhance overall transport of energy and biomass up the food chain (Crawford and Jorgenson, 1996; Welch et al., 1993). It has also been shown in the Franklin Bay (Beaufort Sea) that the fish aggregate during winter, particularly in the deeper layers to avoid predation from seals, and that these aggregation are large enough to cover requirements of predators (Benoit et al., 2008).

The majority of papers on Arctic cod distribution are devoted to pelagic (larval and early juvenile) life-stages, however, there has been some indication that Arctic cod may also spend part of their life associated with demersal habitats (Lønne and Gulliksen, 1989; Sameoto, 1984). Mecklenburg et al. (2007) reported catches of demersal Arctic cod in Chukchi Sea and Bering Strait; during their study the species was found mainly on the soft bottom (mud, sand) but clearly avoided hard substrate (gravel, rock). Recent studies from the Alaskan Beaufort Sea (Logerwell et al., 2011; Rand and Logerwell, 2011) show that Arctic cod was by far the most abundant bottom dwelling fish. Although it was virtually found at all stations, Arctic cod displayed the affinity to cold waters found in the offshore Beaufort Sea (depths > 100 m).

The aim of this paper is to describe the ecology of demersally associated Arctic cod in the Canadian Beaufort Sea, including their distribution, meristics and feeding assessed by stomach content analysis. We furthermore infer on the potential impacts of direct anthropogenic (industrial) and indirect (climate change) stressors on Beaufort Sea Arctic cod.

2. Material and methods

Arctic cod were sampled during four cruises to the Beaufort Sea in summer 2006–2009 (mid-July to mid-August) by the CCGS *Nahidik*, as part of Fisheries and Oceans Canada's Northern Coastal Marine Studies (NCMS) programme. In total, 82 stations were sampled between the Canada/Alaska border and the Eastern extent of Amundsen Gulf

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doi:10.1016/j.jmarsys.2012.04.004

Table 1
List of stations and environmental parameters recorded. Physical characteristics are presented for the bottom layer (i.e. approx. 1 m above the seafloor). Zooplankton biomass is calculated for the entire water column at the station.

Region	Station	Depth (m)	Lat. (°N)	Long. (°W)	Temp. (°C)	Salinity	Oxyg. satur. (%)	Zooplankton biomass (g m^{-2})
2006								
Mackenzie Bay	GAR 9	109	70.137	−137.789	−1.5	32.7	79.4	7.9
	GAR 8	78	70.044	−137.595	−1.5	32.6	76.8	5.3
	GAR 7	62	69.970	−137.381	−1.5	32.5	78.9	4.7
	GAR 6	65	69.898	−137.503	−1.4	32.5	80.8	4.5
	GAR 5	49	69.882	−137.199	−1.5	32.2	81.4	5.3
	GAR 4	37	69.831	−136.989	−1.5	31.9	82.2	2.6
	GAR 3	27	69.762	−136.884	−1.5	31.8	84.5	5.0
	GAR 2	15	69.663	−136.586	−1.5	30.7	88.8	1.9
	GAR 1	12	69.663	−136.386	−1.4	30.0	84.6	2.8
Herschel Island	HB 6	128	69.603	−138.382	−1.5	32.6	79.7	5.9
	HB 5	93	69.560	−138.471	−1.6	32.0	86.9	6.6
	HB 4	49	69.512	−138.508	−1.2	30.6	101.0	12.4
	HB 2	77	69.454	−138.776	−1.6	32.7	67.2	7.9
	HB 1	12	69.428	−138.878	1.9	28.8	98.6	2.8
2007								
Herschel Island	PBS A2	9	69.496	−139.010				
	PBS A4	11	69.477	−138.988				
	PBS A6	12	69.453	−138.941	−1.0	32.4	91.8	1.8
	PBS A8	10	69.431	−138.901				
	PBS A10	10	69.406	−138.864				
	PBS B1	9	69.562	−138.925				
	PBS B3	30	69.536	−138.894	−1.6	32.9	78.9	9.2
	PBS B5	54	69.513	−138.862				
	PBS B8	55	69.481	−138.824	−1.6	32.9	76.1	11.1
	PBS B13	23	69.413	−138.732	−1.3	32.5	84.3	5.3
	PBS C4	16	69.537	−138.756				
	PBS C6	16	69.512	−138.716	−1.4	32.1	94.2	1.4
	PBS C8	16	69.491	−138.679				
	PBS C10	15	69.466	−138.637	−1.3	32.1	90.7	1.8
	PBS D2	64	69.585	−138.629				
	PBS D4	57	69.561	−138.582	−1.6	32.9	78.4	
	PBS D6	51	69.541	−138.536	−0.9	32.3	85.3	8.9
	PBS D8	52	69.521	−138.491				
	PBS D10	53	69.499	−138.447				
	PBS E6	119	69.585	−138.437	−1.6	32.9	78.0	11.2
	PBS E8	115	69.570	−138.370				
	PBS E10	110	69.557	−138.309				
North of Herschel Is.	H 7.1	38	69.877	−140.005	−1.0	32.6	84.3	52.2
	H 7.3	60	69.996	−139.932	−1.2	32.7	69.3	16.2
	H 3.5	61	69.762	−138.974	−1.4	32.6	80.3	12.2
	H 3.3	39	69.705	−139.183	−1.4	32.7	79.0	5.4
C. Bathurst	CB 1.2	24	70.696	−128.840	−1.3	32.5	83.3	6.2
2008								
Herschel Island	PBS A2	9	69.507	−139.026				
	PBS A4	10	69.482	−138.985				
	PBS A6	11	69.458	−138.945	0.8	31.2	90.4	0.4
	PBS A8	10	69.435	−138.907				
	PBS A10	11	69.412	−138.870				
	PBS B5	62	69.447	−138.831				
	PBS B7	54	69.512	−138.924				
	PBS B8	68	69.467	−138.853				
	PBS C2	14	69.564	−138.792				
	PBS C4	14	69.537	−138.756	−1.1	31.8	97.2	
	PBS C6	14	69.512	−138.716	−0.1	31.5	89.7	0.4
	PBS C8	15	69.491	−138.679				
	PBS D6	50	69.541	−138.536	−1.4	32.6	80.2	13.9
	PBS D8	50	69.521	−138.490				
	H 3.1	25	69.646	−139.395	−1.4	32.6	78.7	6.9
Kugmallit Bay	KUG 10	8	69.746	−133.339				
	KUG 20	21	69.992	−133.781	4.1	29.8	95.2	0.8
	KUG 30	33	70.104	−133.879	−1.2	32.2	89.8	3.3
	KUG 50	53	70.390	−134.197	−1.5	32.3	80.6	4.1
	KUG 100	120	70.891	−134.751	−1.4	32.7	73.6	15.7
Mackenzie Bay	SCR 15	22	69.897	−136.344	−1.5	31.9	92.2	
	GRY K	45	69.913	−137.040	−1.5	32.5	73.0	
Franklin Bay	SWB 1	38	70.457	−127.455	5.1	31.7	95.0	
	SWB 0	70	70.531	−127.525	0.2	32.6	85.2	
	FRK 1	51	69.867	−125.568				
	WFA 1	55	71.156	−128.495	−1.0	32.7	83.4	
Darnley Bay	CP 1	46	70.220	−124.616				2.8
	CP 2	70	70.251	−124.654				0.5

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