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Comparison of the Arctic cod (<u>Boreogadus saida</u>), the polar cod (<u>Arctogadus</u> glacialis), and the toothed cod (<u>A. borisovi</u>).

by

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INTRODUCTION

The codfishes <u>Boreogadus</u> and <u>Arctogadus</u> (Fig. 1), members of the Gadinae (Gadids with 3 dorsal and 2 anal fins), are two closely related genera distinguished one from the other by the palatine teeth usually present and scales cylindrical and imbricated in the latter (Nielsen and Jensen 1967). The present examination of published meristic and morphometric data indicate that the two genera can readily be separated in the field by a number of characters. Recent taxonomic studies are those of Bain and Sekerak (1978) for the Arctic cod, <u>Boreogadus saida</u> (Lepechin), and Nielsen and Jensen (1967) and Boulva (1970, 1972) for the polar cod, <u>Arctogadus glacialis</u> (Peters), and the toothed cod (also called east Siberian \overline{cod}), A. borisovi Drjagin.

This paper reviews the distribution of the two genera and examines those characters which allow to separate them.

GENERAL DISTRIBUTION

<u>Boreogadus</u> is circumpolar, being reported from most Arctic waters (Fig. 2). <u>Arctogadus borisovi</u> is abundant off nothern Russia where it penetrates brackish waters (Andriyashev, 1954) and it is occasionally reported from the Canadian Arctic Archipelago, northern Alaska and in one instance from South West Greenland (Nielsen and Jensen, 1967). <u>A. glacialis</u> has been reported mainly from marine waters in the northern part of the Chukchi Sea, northern Canada and northern Greenland; there is no report of this genus in the Barents Sea. The three species are seldom sympatric; in Cambridge Bay, N.W.T., the two species of <u>Arctogadus</u> inhabit the bay itself, a basin 80 m in maximum depth with a shallow (12 m) entrance to the sea, where this genus may be "landlocked" (Boulva 1972), while <u>Boreogadus</u> is found just outside the bay, in Dease Strait (J.G. Hunter, unpublished data). <u>Arctogadus</u> is not reported as being exploited commercially. Large quantities of <u>Boreogadus</u> have been found off Labrador (Lear 1979).

Both species of <u>Arctogadus</u> have been taken over depths of 540 m (Walters 1961) while <u>Boreogadus</u> may be found at depths greater than 900 m (Walters 1955).

GENERIC DIFFERENCES

The three main studies reviewed here (Bain and Sekerak 1978, Boulva 1970 and Nielsen and Jensen 1967) have made biometric measurements according to the same criteria (Hubbs and Lagler 1958). The fact that Boulva has worked on fresh unpreserved samples while the other two publications report using preserved samples is not believed to be a source of error here, given the consistency of the results between the two studies dealing with Arctogadus.

a) Meristic characters

Data on ten meristic characters are available both for <u>Arctogadus</u> and <u>Boreogadus</u> (Bain and Sekerak 1978, Boulva 1972). Of these, four present differences permitting a more or less reliable separation of the two genera, the number of gill rakers providing the best separation (Table 1).

<u>Rays of the second dorsal fin</u> - Means from five samples (N= 4 or more in each sample) of <u>Boreogadus</u> varied from 14.0 to 16.0 rays while same for five (N= 9 or more in each sample) samples of <u>Arctogadus</u> ranged from 17.7 to 19.5. Extreme counts of rays overlap at 15 to $\overline{18}$.

Rays of the first anal fin – Means from five samples (N= 4 or more in each sample) of <u>Boreogadus</u> varied from 15.9 to 17.9 rays while same for five samples (N= 9 or more in each sample) of <u>Arctogadus</u> ranged from 18.8 to 21. Extreme counts of rays overlap at 16 to 21.

Total gill rakers on anterior arch - This is the meristic character showing the best separation between the two genera, with little overlap in range of counts:

Genus	Range of extremes	Average	Range of averages	N	Localities
Boreogadus	35-47	40.9	39.3 - 42.2	174	5
Arctogadus	27-36	32.0	30.0 - 33.0	140	30

<u>Vertebrae (excluding urostyle)</u> – While there is overlap in the distribution of numbers of vertebrae (56-58), the averages of all samples are exclusive for the two genera with ranges of 54.2 to 55.8 in <u>Boreogadus</u> and of 58.0 to 59.0 in Arctogadus, with sample sizes ranging from 4 to 70 fish (Table 1).

b) Morphometric characters

Data on 18 morphometric characters expressed as percent of standard length are available for both <u>Boreogadus</u> and <u>Arctogadus</u>, five of which allow reliable separation of the two genera (Table 2).

Head length - Boreogadus has a smaller head than Arctogadus with ranges and means being respectively 24.3-27.9(26.0) and 25.0-33.2(28.5). Averages for 2 Boreogadus samples are below 26.1 while those for 4 Arctogadus samples are above 28.1.

<u>Preventral length</u> (distance from the tip of the snout to the structural base of the first ventral ray) - This is the morphometric character showing the most difference between genera with ranges and means for 1 sample of <u>Boreogadus</u> being 18.5-24.6(22.4) and for 4 samples of <u>Arctogadus</u>, 23.0-35.9(27.6). With a <u>Boreogadus</u> sample from only one locality, geographic variations cannot be assessed for this genus.

Base of dorsal 1 - This length is greater in Boreogadus, 11.8-16.8(14.1), than in <u>Arctogadus</u>, 7.5-14.5(11.1). Here also, data for <u>Boreogadus</u> are available from only one locality. The means for 4 <u>Arctogadus</u> samples range from 10.5 to 11.3.

<u>Base of dorsal 3</u> - This length is also greater in <u>Boreogadus</u> 16.2-20.3(18.4) than in <u>Arctogadus</u> 12.7-18.5(15.7). The means of 4 <u>Arctogadus</u> samples range from 15.2 to 16.0; only 1 <u>Boreogadus</u> sample is available.

Base of anal 2 - Longer in Boreogadus, 16.6-20.7(18.6) than in Arctogadus 13.2-19.0(15.4). The means from the 4 Arctogadus sample range from 15.0 to 16.0, while there is only 1 sample for Boreogadus.

<u>Barbel length</u> - Strong difference is shown for this character between <u>Boreo-gadus</u> 0.5-2.5(0.8) and <u>Arctogadus borisovi</u>, 2.2-4.9(3.6), while <u>A. glacialis</u> has a barbel quite similar in length to B. saida.

c) Sexual dimorphism

Bain and Sekerak (1978) found no significant differences between sex in the 18 morphometric and 11 meristic characters examined on <u>Boreogadus</u> while significant differences between males and females are reported in the ventral fin length (Fig. 3) of the two species of <u>Arctogadus</u> (Nielsen and Jensen, 1967 and Boulva, 1972) and in the numbers of rays in the first dorsal fin (Boulva, 1972). Further, Boulva (1972) has demonstrated significant sexual dimorphism in 10 morphometric characters of either <u>A. glacialis</u> or <u>A. borisovi</u>. In this respect, <u>Arctogadus</u> appears quite different from Boreogadus.

d) Growth patterns

Arctogadus grows longer and older than <u>Boreogadus</u> which reaches 340 mm in fork length (Lear 1979) as compared to 518 mm for <u>A</u>. <u>borisovi</u> and 494 mm for <u>A</u>. <u>gla-</u> <u>cialis</u> (Boulva, unpublished data); Arctogadus reaches 11 years of age while <u>Boreogadus</u> grows up to 6 years old (Fig. 4). As pointed out by Bain and Sekarak (1978), lengths at age published for <u>Boreogadus</u> by 3 authors are similar; this observation applies also to growth information recently made available for the Labrador coast (Wells pers. comm.). If ages have been misinterpreted, the errors appear to have been consistent; some of the variations between authors may be explained by sampling taking place at different time of the year. The only age information available for Arctogadus is given by Boulva (1970).

DISCUSSION

Several differences have been presented above, allowing a reliable separation of <u>Boreogadus</u> and <u>Arctogadus</u>. The following key is suggested to separate fish of the two genera:

- 1- "Total gill rakers" on anterior arch 35-47(40.9); "Preventral length" 18.5-24.6(22.4)% of standard length; no sexual dimorphism in the "length of the ventral fin". Maximum reported size up to 34 cm. fork length. ...Boreogadus
- 2- "Total gill rakers" on anterior arch 27-36(32.0); "Preventral length" 23.0-35.9(27.6)% of standard length; strong sexual dimorphism in "length of the ventral fin" for fish longer than 15 cm. standard length. Maximum reported size up to 52 cm. in fork length. ...Arctogadus

Other differing characters given in the previous sections may be used if the above criteria are inconclusive for certain samples. The presence or absence of palatine teeth is not used in the key as Nielsen and Jensen (1967) state that they may be lacking in <u>Arctogadus</u> even though they are generally present; they are absent in <u>Boreogadus</u>. These authors also discuss one of two specimens from South West Greenland which lacked a barbel, but otherwise was typical of <u>A</u>. borisovi.

Body colouration has not been mentioned above because <u>Boreogadus</u> is generally reported as grayish brown to brownish above, to silvery-gray below (Bain and Sekerak), a colour pattern found on occasion in <u>Arctogadus borisovi; A. glacialis</u> on the other hand is most often all black, thus quite different from <u>Boreogadus</u>.

A study of the anotomical structure of the lateral-line organs and related bones in the Gadidae by Halama (1977) presents evidence in support of the conclusions drawn above from the examination of standard measurements. There are less pores in canal of the head and in coronal commissure in <u>Boreogadus</u> than in <u>Arctogadus</u> (Table 3); this and other evidence given by Halama also indicate that Boreogadus is altogether different from Arctogadus.

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1961. Winter abundance of <u>Arctogadus glacialis</u> in the Polar basin. Copeia (2): 236-237.

	Table 1.	Range and means (par characters differing Averages are not we	renthesis) of g most between ighted to acco	the four m Boreogadu ount for sa	meristic us and <u>Arctogadus</u> . Mple size.		
SPECIES and LOCALITY	SAMPLE SIZE	2nd DORSAI FIN RAYS	L lst FIN	ANAL RAYS	TOTAL GILL RAKERS	VERTEBRAE	
Boreogadus saida							
Resolute Bay, N.W.T. (1) Miramichi Bay, N.B. (2) Point Barrow, Alaska (3)	34 3-4 37	11-17 (14) 13-16 (14)	.2) 15–20 .0) 15–17	(17.1) (16.3)	35-45 (39.3) 38-44 (40.8) 38-47 (42.2)	53-58 (55.4) 54-55 (54.3)	
East Greenland Coast (4)	19 10	14-18 (16)	.0) 16-21	(17.9)		54-58 (55.8)	
Southeastern Barents Sea (5) Soviet Arctic (Unspecified) (5) 70) 0	12-17 (14. 14-17 (15.	.7)14-20.0)15-17	(17.0) (15.9)	37-46 (41.1) 37-45 (40.9)	53-58 (55.2) 53-57 (54.2)	
Average		11-18 (14.	.8) 14-21	(16.8)	35-47 (40.9)	53-58 (55.0)	
Arctogadus borisovi							
Cambridge Bay, N.W.T. (6) Arctic (7)	34 9	17-23 (19) 16-20 (18)	.5) (<u>16</u>)19–23) 19–24	(20.9) (21)	30-36 (32.8) 31-34 (33)**	56-60 (58.1)* 57-61 (59)***	ו 6
Average		16-23 (18.	.8) 19–24	(21.0)	30-36 (32.9)	56-61 (58.6)	I
Arctogadus glacialis							
Cambridge Bay, N.W.T. (6) Arctic (7) Arctic (4)	34 22-50 13	17-24 (18) 15-20 (18) 15-20 (17)	.8) 16-24 .0) 18-24 .7) 17-20	(20.6) (20.0) (18.8)	30-35 (32.0) 27-34 (30.0)	57-59 (58.0)*** 56-61 (59.0) -	ł
Average		15-24 (18.	.2) 16-24	(19.8)	27-35 (31.0)	56-61 (58.5)	
<pre>* sample size = 29 ** sample size = 12 *** sample size = 5 **** sample size = 46 (1) Bain and Sekerak (1978) (2) McKenzie (1953) (3) Walters (1955) (3) Walters (1955)</pre>	(5) (6) (7)	Andriyashev (1964) Boulva (1970) Nielsen and Jensen ((1967)				

Table 2. Range and mean (parenthesis) expressed as percent of standard length of the six morphometric characters differing most between <u>Boreogadus</u> and <u>Arctogadus</u>. Averages are not weighted to account for sample size.

SPECIES and LOCALITY	SAMPLE SIZE	HEAD LENGTH	PREVENTRAL LENGTH	BASE DORSAL 1	BASE DORSAL 3	BASE ANAL 2	BARBEL LENGTH
Boreogadus saida	•						
Resolute Bay, N.W.T (1) Miramichi Bay, N.B.	24-25 3	24.3-27.9 (25.9) 25.1-27.0 (26.1)	18.5-24.6 (22.4)	11.8-16.8 (14.1) -	16.2-20.3 (18.4)	16.6-20.7 (18.6) -	0.5-2.5 (U.9) 0.5-0.9 (U.7)
Average		24.3-27.9 (26.0)	18.5-24.6 (22.4)	11.8-16.8 (14.1)	16.2-20.3 (18.4)	16.6-20.7 (18.6)	0.5-2.5 (0.8)
Arctogadus borisovi							
Cambridge Bay, N.W.T. ⁽³⁾ Arctic	61 9-12	25.8-33.2 (28.9) 26.0-31.5 (28.5)	24.8-35.9 (29.5) 24.0-27.5 (26.0)	9.0-14.3 (11.3) 9.9-13.0 (11.0)	12.7-17.1 (15.2) 14.0-18.5 (16.0)	13.2-17.8 (15.1) 13.5-18.0 (15.5)	2.3-4.8 (3.6) 2.2-4.9 (3.6)
Average		25.8-33.2 (28.7)	24.0-35.9 (27.8)	9.0-14.3 (11.2)	12.7-17.1 (15.6)	13.2-18.0 (15.3)	2.2-4.9 (3.6)
Arctogadus glacialis							
Cambridge Bay, N.W.T. ⁽³⁾ Arctic	63 4648	25.1-30.7 (28.1) 25.0-31.5 (28.5)	24.9-33.7 (28.3) 23.0-31.5 (26.5)	8.8-14.5 (11.2) 7.5-13.5 (10.5)	13.0-18.5 (15.3) 14.0-18.0 (16.0)	13.2-16.8 (15.0) 14.5-19.0 (16.0)	0.0-1.4 (0.5)
Average		25.0-31.5 (28.3)	23.0-33.7 (27.4)	7.5-14.5 (10.9)	13.0-18.5 (15.7)	13.2-19.0 (15.5)	0.0-1.4 (0.5)

(1) Bain and Sekerak (1978)

(2) McKenzie (1953)

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(3) Boulva (1970)

(4) Nielsen and Jensen (1967)

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Table 3.	Number of pores in canals of the head and in
	coronal commissure (from Halama, 1977).

Species (and number of specimens examined)	Supra- orbital	Infra- orbital	Temporal	Supra- temporal	Preoperculo- mandibular	
Boreogadus <u>saida</u> (6)	1	7	3	1	7	
Arctogadus glacialis (1)	3	9	4	2	13	
Arctogadus borisovi (1)	3	9	4	2	13	



Figure 1. Boreogadus saida from the Labrador coast (A) Arctogadus borisovi from Cambridge Bay, N.W.T. (B)



Fig. 2. Distribution of <u>Boreogadus saida</u> (adapted from Bain and Sekerak 1978; W.H. Lear 1979; <u>Sekerak et al. 1979</u>) and of <u>Arctogadus</u> (adapted from Boulva 1972). 1: A.D. Sekerak, L.G.L. Ltd, Toronto, pers. comm.; 2: J.G. Hunter, Fisheries and Oceans, Ste-Anne-de-Bellevue, Qué., pers. comm.

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Fig. 3. Sexual dimorphism in the length of the ventral fin in the two species of Arctogadus from Cambridge Bay, N.W.T. In both species, males have significantly (P < 0.001) longer ventral fins at a given total length (Boulva 1970).



Fig. 4 Growth in total length of <u>Boreogadus saida</u> in various locations (1: Bain and Sekerak 1978; 2: Hognestad 1968; 3 and 4: Andriyashev 1964; 5: Wells (pers. comm.) and for <u>Arctogadus</u> in Cambridge Bay, N.W.T. (6 and 7: Boulva 1970).