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Age and Growth of Antarctic Silverfish *Pleuragramma antarcticum* Boulenger, 1902, from the Southern Weddell Sea and Antarctic Peninsula

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Summary. The length and age (determined from sagittal otoliths) of 1787 Antarctic Silverfish (*Pleuragramma antarcticum*) was analyzed from west of the Antarctic Peninsula (63 °S/64 °W) and southern Weddell Sea (73 °S – 77 °S). Otolith diameter (D) was related to standard length by

$$D\ (mm) = 0.011 \times SL^{1.034}\ (mm)\ .$$

Otolith diameters were between 0.1 mm (postlarvae) and 3.0 mm. The calculated growth from otolith readings indicated annual length increments of approximately 20 to 10 mm for fish from 2 to 12 years old. This low, but relatively constant growth is reflected in the Von Bertalanffy Growth Formula (VBGF) as

$$L_t = 308\ (1 - e^{-0.0715\ (t+1.15)})\ (mm)\ .$$

Fish in the size range known from the Weddell Sea of 34 to 245 mm standard length are thus 1 to 21 years old. Growth Performance "P" of 1.1 is at the lower limit of values observed in Antarctic fish. In spite of low "k", *Pleuragramma antarcticum* does not grow to large size. This finding is discussed in the light of adaptive demands of the species as a planktivorous pelagic nototheniid in the Antarctic.

Introduction

The pelagic nototheniid fish *Pleuragramma antarcticum* is widely distributed in the continental shelf waters around the Antarctic continent between 61 °S and 78 °S (Andriashev 1965; Fisher and Hureau 1985). Regionally, this species dominates the nectonic community, accounting for over 90% by numbers and weights (DeWitt 1970; Williams 1985; Hubold and Ekau 1987). It is a key organism in the pelagic food web (DeWitt and Hopkins 1977; Eastman 1985; Hubold 1985a). *Pleuragramma* is also an important component in the diet of seals and birds (Dearborn 1965; Volkman et al. 1980; Green and Williams 1986; Plötz 1986).

Due to the rapid digestion of fish tissues by predators, hard structures, like otoliths, are often used for identification of prey species by otolith catalogues (North et al. 1984; Hecht 1987). Conversion factors of otolitgh size to fish size, weight, and age are required for estimation of food ratios.

Otoliths are also important tools for age determinations in fish (Panella 1980), and can be used for this purpose in Antarctic species (Everson 1981). This method, so far, has not been applied to Antarctic Silverfish. Soviet estimates of the growth of *Pleuragramma* based on "direct observations and back calculations" have provided annual length increments of between 5 and 1 cm from the first to the tenth year of life in a "uniform and parabolic" fashion (Anon 1985). Based on calculations of gill surface, Kunzmann (1986) presented growth parameters well below the Soviet estimates. Kellermann (1986) estimated yearly growth increments of 27.1 – 28.2 mm from 0-group to 1-group fish. It has thus become evident, that growth of *Pleuragramma antarcticum* is at the lower end of Antarctic fish growth.

In the present investigation, we analyzed sagittal otoliths of *Pleuragramma antarcticum* to determine length at age and growth. Conversion ratios between otolith sizes and fish parameters are presented to facilitate estimates on quantitative interactions between fish and their predators.

Reading of the otoliths was aided by the considerable amount of material at hand, and the additional sagittae from postlarvae and juveniles to establish sizes of nuclei and first increments. By comparing two independent samples from west of the Antarctic Peninsula and southern Weddell Sea, we attempted to detect possible differences in length at age and growth of Antarctic Silverfish in different latitudes of the Antarctic ocean.

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Material and Methods

South of the South Shetland Islands, at approximately 63 °S/64 °W, *P. antarcticum* were sampled from the catch of commercial krill nets on the Argentinean vessel *Joaquim Vatcetis* in April 1980 (Fig. 1). Typical water temperatures in this area are about +0.5 °C (Gordon and Goldberg 1970). Representative subsamples were measured fresh on board (standard lengths, to the nearest 0.5 cm below), and sagittal otoliths were taken and stored dry for later processing.

Fish were collected in 1983 and 1985 during two expeditions of the German research vessel *Polarstern* in the southern and eastern Weddell Sea between 73 °S and 77 °S (Fig. 1). Trawls were carried out over areas of bottom depths ranging from 200 to 2300 m. Fish were collected from depths ranging from a maximum of 850 m to the surface. Water temperatures were below −1.8 °C. Catches were made using a scientific krill trawl (10×10 m opening), a 140 feet bottom trawl, a Rectangular Midwater Trawl (RMT 8), and a 3 m Agassiz Trawl. Large hauls were subsampled over the entire fish size range; smaller hauls (up to about 50 fish) were preserved entirely. Subsamples of fish were worked up on board the ship. The bulk of the material was preserved frozen or in 80% ethanol and worked up later in the lab.

Total (wet) weights and lengths of preserved fish were measured to 0.1 g and 1 mm, respectively. Standard lengths (SL) were used exclusively as caudal fins are frequently damaged.

The diameters of the otoliths were determined under a binocular microscope to 0.01 mm, then rounded to 0.1 mm. When the results from the left and right otoliths differed, the mean was taken. Maximum diameter (Fig. 2) was used because the „long axis" oriented in anterior-posterior direction used by Hecht (1987) was not always clearly defined in the circular, but irregularly shaped otoliths. Maximum diameter is also best for the analysis of *P. antarcticum* otoliths from seal stomachs (Plötz 1986).

Ring structures were visible in the otoliths, when examined in glycerine against a black background under incident (reflected) light. A small number (72) of otoliths were broken to confirm readings. Hyaline and opaque zones were distinguished (Fig. 2). These structures occurred in juvenile and adult specimens, and were taken as annual growth rings. None of the structures were considered as spawning rings, because these would probably coincide with winter rings, due to the winter spawning of *P. antarcticum*. One opaque plus one hyaline zone were considered to form an annulus (Everson 1981). All fish were caught in summer/autumn, and the marginal opaque ring was taken as the last summer ring.

Identification of growth zones in the center of the otoliths from adults is very difficult. We therefore analyzed otoliths from post-larvae and juveniles, to establish otolith diameters for small fish sizes. These sizes could then be related to age groups (0+, 1+ and 2+) by length frequency distributions available from the literature (Keller 1983; Hubold 1985b; Kellermann 1986).

From the first appearance of yolk-sac larvae in plankton catches in November (Hubold 1988) the hypothetical birthday of *P. antarcticum* can be defined as 01 November. Post-larvae of 20 mm collected in

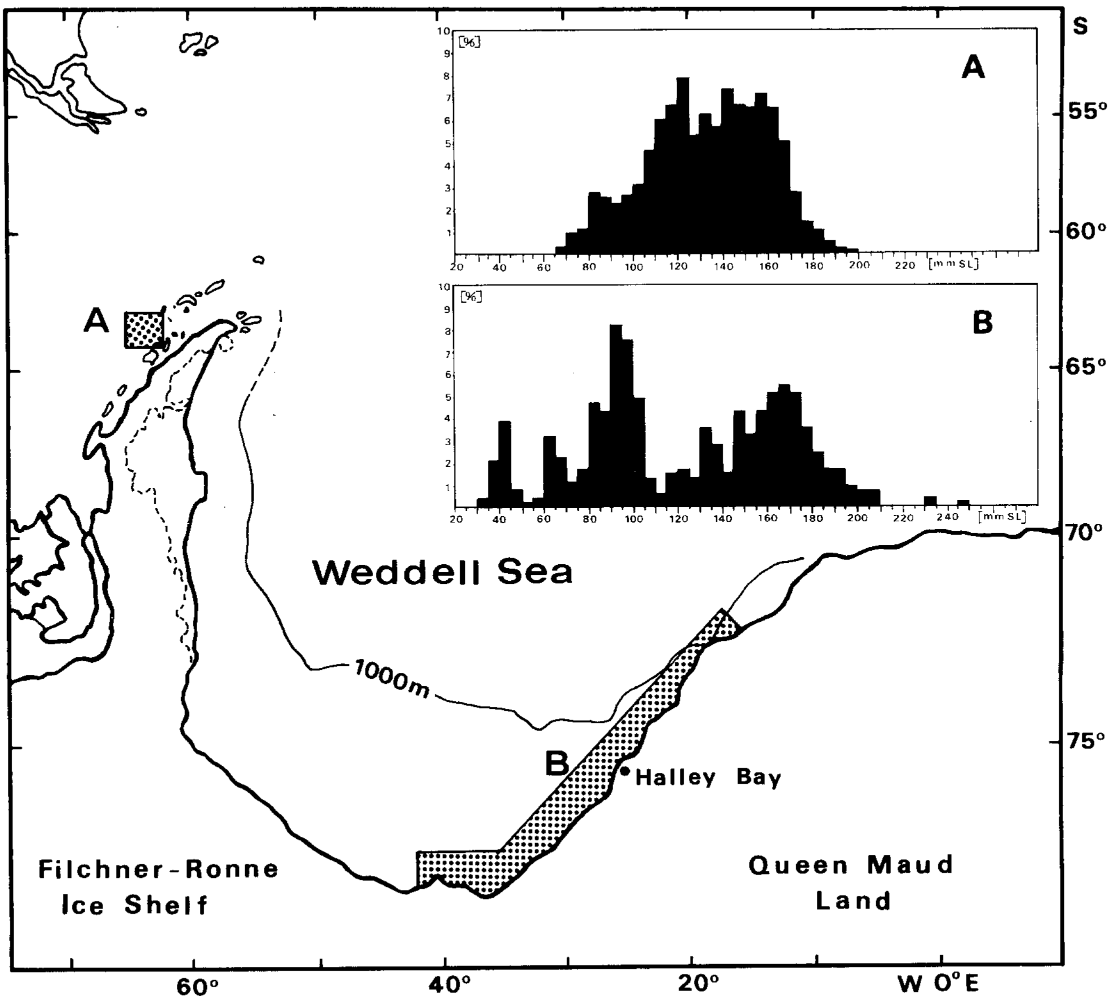

Fig. 1. Locations of *Pleuragramma antarcticum* catches and length frequency distributions in the sampling areas. *A* West of the Antarctic Peninsula at 63 °S/64 °W, by *MS Joaquim Vatcetis*, April 1980. *B* Southern Weddell Sea between 73 °S and 77 °S, by *FS Polarstern* in February 1983 and 1985

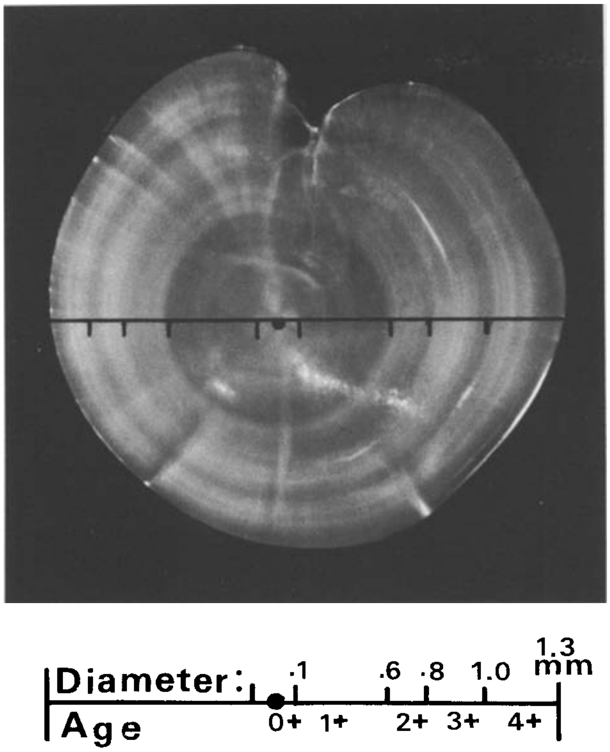

Fig. 2. Left sagittal otolith of *Pleuragramma antarcticum*. Standard length 93 mm, age group 4+. Maximum otolith diameter 1.3 mm. Collection date February 1985

February are then three months old (age-group 0+). Their otolith diameters are about 0.1 mm. Also in February, otoliths of 40 mm juveniles (age-group 1+; one year and three months old) are 0.5 mm in diameter. The inner hyaline zone (0.6 mm) of the otolith shown in Fig. 2 can therefore be attributed to age 1+. It is unclear, whether this hyaline growth ring was deposited during one entire year (i.e. February to February) or only during the summer months preceeding the collection (November to February). Seasonal growth of older juveniles seems to be restricted to summer and is mostly completed by February, as indicated by the width of the last growth zone and the appearance of a hyaline margin in fishes collected in February (Fig. 2). Juveniles of 60–70 mm belong to age-group 2+ based on size frequency distributions. The mean otolith diameter in this size group is 0.8 mm. Thus, the first opaque (summer) ring between diameters 0.6 and 0.8 mm in Fig. 2 can be attributed to growth during the third summer. The 93 mm fish in Fig. 2 was then considered to be four years and three months old (age-group 4+).

When inner ring structures were difficult to recognize, the age readings in older fish could be calibrated against the known otolith diameters at ages 0, 1+, and 2+.

Yearly growth increments from mean sizes-at-age were analyzed by use of a Ford-Walford-Plot (Beverton and Holt 1957), and L_{inf} and "k" of the Von Bertalanffy Growth Formula (VBGF) were determined. The Index of Growth Performance "P"

$$P = \log (k \cdot W_{inf})$$

(Pauly 1979) was used to compare the growth of *P. antarcticum* with that of other Antarctic fish species.

Results

Length and Weight

The sizes of *Pleuragramma antarcticum* collected by various gear in the southern Weddell Sea ranged between 34 and 245 mm SL. Pronounced modes in the length-frequency distribution occurred at the 90 mm and 165 mm length classes (omitting juveniles smaller than 60 mm; Fig. 1). An interesting feature of the length distribution are the low numbers of fishes around 100 mm; similar patterns were reported from the southern Weddell Sea in other years (Hubold and Ekau 1987).

The commercial krill trawl used west of the Antarctic Peninsula caught fish between 65 and 195 mm SL. Length frequencies of these fish show less pronounced modes at 80 and 120 mm (Fig. 1). When a normal distribution is assumed, a mean length of 135 mm is predicted. Similar distributions with means at 125 and 107 mm SL were found in the Bransfield Strait (A. W. North, personal communication; K. E. Skora, personal communication).

The total length/standard-length relation for *Pleuragramma antarcticum* was determined from frozen specimens between 6.4 and 21.9 cm SL as

$$TL = 1.092\ SL + 0.284\ (cm)\ (Hubold\ 1984)\ .$$

Subsamples of the Weddell Sea material measured fresh on board and again after one year stored frozen at −20 °C did not differ in length. Lengths and weights of alcohol preserved specimens were slightly different from those of frozen fish. These differences were statistically not significant (Wilcoxon test; $P = 0.01$). The data from both preservation methods were combined for comparison with the data from Antarctic Peninsula.

Subsamples of the Weddell Sea fishes were sexed. Of 305 analyzed specimens, most had very small (resting) gonads. Twenty fish had developing ovaries, and 48 fish had developing testes. Maximum gonad weights were 1.5 g for males and 2.1 g for females (3% and 2% of body weight, respectively). Our data cannot be used to estimate sex ratio due to the low numbers of mature individuals.

Females were slightly longer (and heavier) than males in four out of five age classes, but numbers of sexed animals did not allow for a detailed analysis. As the bulk of our fishes were juveniles, or at an early stage of the annual maturity cycle, we lumped the sexes for length and weight analysis.

Weights were available for Weddell Sea fishes only and ranged from 0.1 to 94.5 g. Based on 546 fish, preserved in alcohol or frozen, the standard-length/weight relation of *Pleuragramma antarcticum* was determined as

$$W\ (g) = 0.00170 \times SL^{3.36}\ (cm)\ (r^2 = 0.99)\ .$$

This determination agrees well with the total length/weight relation given for *P. antarcticum* from west of the Antarctic Peninsula:

$$W\ (g) = 0.00188 \times SL^{3.421}\ (Kock\ et\ al.\ 1985)\ .$$

Otolith Size and Shape

Sagittal otoliths of *Pleuragramma antarcticum* are comparatively small. Otoliths of a 20 cm specimen are about 2 mm in diameter, i.e. only half the size of that of

Table 1. Age-length-key for *Pleuragramma antarcticum* from the southern Weddell Sea

Age SL (mm)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	*n*
30	2														2
35	11														11
40	21														21
45	4														4
50		1													1
55		2													2
60		15	2												17
65		10	2												12
70			6												6
75		1	8												9
80			20	5											25
85			5	16	2										23
90			1	42	1										44
95			1	32	7										40
100				14	10	2									26
105				2	3	1	1								7
110					2		1								3
115					3	3	2								8
120					1	3	3	2							9
125						1	5	1							7
130						3	9	7							19
135							3	12							15
140						1	1	2	4						8
145						2	4	13	4						23
150							1	5	9	2					17
155							1	8	9	5					23
160								9	8	5	5				27
165								3	10	11	5				29
170									4	9	12	2			27
175								1	6	6	4	2			19
180										5	4	3	1		13
185									1	3	2	3			9
190										3	2	4			9
195										3	2				5
200										1		3			4
205												4			4
210												2		2	4
215															
220															
225															
230												2			2
235															
240															
245														1	1
n	38	29	45	111	29	16	31	63	55	53	36	25	1	3	535

Trematomus spp. (Hecht 1987; Ekau 1988). During ontogeny, otolith shape changes. Fish up to about 15 cm SL have nearly circular sagittae (Fig. 2). Only in larger fish, the exisura ostii begins to form, and otoliths become slightly oval. From about 20 cm SL onwards, the dorsal margins of the sagittae grow disproportionately and become dome shaped. Hecht (1987) described the morphology of *P. antarcticum* otoliths as relatively constant. In the present material, we found considerable variability both in shape and size of otoliths, sometimes even in individual fish.

Otoliths from postlarval *Pleuragramma antarcticum* of 18 mm SL were <0.1 mm in diameter. Otolith diameters of fish between 34 and 245 mm ranged from 0.4 to 3.0 mm. Based on 555 measurements, mean otolith diameter (D) was correlated with standard length by

Table 2. Age-length-key for *Pleuragramma antarcticum* from the Antarctic Peninsula

Age SL (mm)	2	3	4	5	6	7	8	9	10	11	12	*n*
65	4											4
70	11											11
75	2	12										14
80		26	8									34
85		2	25	4								31
90			22	5								27
95			25	7								32
100			20	19								39
105			5	43	10							58
110				42	33							75
115				50	32							82
120					60	12						72
125					22	43						65
130					12	65						77
135					3	42	25					70
140					5	43	43					91
145					3	21	44	15				83
150						12	43	27				82
155						6	34	49				89
160							40	41				81
165							17	33	12			62
170								6	14	12	2	34
175								1	4	7	5	17
180									2	3	7	12
185									1	2	3	6
190									1		1	2
195										1		1
n	17	40	105	170	180	244	246	172	34	25	18	1252

$$D\,(mm) = 0.011 \times SL^{1.034}\,(mm) \quad (n = 555,\ r^2 = 0.97)\ .$$

Otolith diameters were approximately normally distributed in the age classes, allowing a calculation of mean otolith size per age (Table 4).

Age

In the Weddell Sea, *Pleuragramma antarcticum* larvae hatch in November (Hubold 1988). Nevertheless, otoliths are hyaline in the center (dark in reflected light on black background, Fig. 2) with only weak opaque areas, indicating reduced calcium deposition during early life (Panella 1980). Diameter of the hyaline center is about 0.6 mm. This size can be attributed to juveniles of age-group 1+ by size frequency distributions (Keller 1983; Hubold 1985a, b; Kellermann 1986). Thus, the hyaline center is formed in more than one year. A first well developed opaque (summer) ring is found in otoliths of 0.8 mm diameter from juvenile fishes of 60 mm SL, which are in their third summer (age-group 2+). Thus, growth increment of the sagitta is about 0.3 mm in each of the first two years, and 0.2 mm in the following years.

Table 3. Mean lengths-at-age of *Pleuragramma antarcticum* from the southern Weddell Sea and Antarctic Peninsula, and calculated values from the Von Bertalanffy Growth Formula (VBGF)

Antarctic Peninsula				Weddell Sea			Combined	
Age group	Mean SL (mm)	Range (5 mm-class)	*n*	Mean SL (mm)	Range (mm)	*n*	Weighted mean (mm)	VBGF (mm)
0+	16[a]	11–21[a]	134[a]	21[b]	16–27[b]	43	25	24
1+	44[a]	33–53[a]	599[a]	41	34–46	38	43	44
2+	70	65–75	17	63	52–77	29	66	62
3+	79	75–85	40	79	61–95	45	79	79
4+	92	80–105	105	93	80–105	111	93	95
5+	107	85–115	170	102	88–120	29	106	110
6+	119	105–145	180	124	101–148	16	119	124
7+	134	120–155	244	131	108–155	31	134	137
8+	149	135–165	246	146	124–175	63	148	149
9+	157	145–175	172	160	141–185	55	158	160
10+	170	165–190	34	172	152–203	53	171	170
11+	174	170–195	25	174	161–195	36	174	180
12+	179	170–190	18	194	170–230	25	187	189
13+	–	–	–	(181)	–	1	(181)	197
14+	–	–	–	(222)	210–245	3	(222)	205
15+	–	–	–	–	–	–	–	212
20+	–	–	–	–	–	–	–	241
25+	–	–	–	–	–	–	–	261
n			1251			535		

[a] Data from Kellermann (1986); [b] Data from Hubold, unpublished

Table 4. Otolith diameters in the age classes of *Pleuragramma antarcticum*

Age group	Otolith diameter Mean (mm)	Mode (mm)	Range (mm)	*n*
1+	0.5	0.5	0.3–0.5	38
2+	0.8	0.8	0.7–1.1	29
3+	1.1	1.1	0.8–1.3	45
4+	1.3	1.3	1.1–1.4	111
5+	1.4	1.3	1.3–1.7	31
6+	1.7	1.7	1.3–2.2	18
7+	1.8	1.8	1.4–2.2	32
8+	2.0	1.9	1.5–2.8	53
9+	2.1	2.1	1.8–2.3	55
10+	2.2	2.2	2.0–2.5	53
11+	2.3	2.3	1.9–2.6	36
12+	2.4	2.4	2.0–3.0	29
(13+)	2.5	2.5	–	1
(14+)	2.7	2.6	2.6–2.8	3
( ) Uncertain age determinations				534

Otoliths of fish older than 10 years grow at approximately 0.1 mm per year.

Fish were aged as between 1 and 14 and between 2 and 12 years old in the southern Weddell Sea and west of the Antarctic Peninsula, respectively. Ages 13 and 14 in the Weddell Sea specimens are unreliable estimates, due to unclear otolith ring structures, and were not considered for growth calculations. The age-length-keys for the Weddell Sea (Table 1) and Peninsula (Table 2) show similar distributions of lengths-at-age for both regions. At ages 1 and 2, mean lengths-at-age of fishes from lower latitude were slightly larger than those from the southern Weddell Sea (Table 3). From age 3 onwards, mean lengths at age were rather similar in both areas.

Growth

Length-at-age data were plotted as growth curves (Fig. 3). Although there were differences in mean lenghts-at-age between the two geographical areas (Table 3), a mean growth curve could be drawn. Yearly length increments were between 20 mm and 10 mm for ages 2 to 12.

At the Peninsula, increments of the age groups 10 to 12 dropped to 0.5 cm per year. Lengths at ages over 12 years are uncertain, due to the low number of investigated fishes. The relatively large size of three 14 (?) year old fish from the Weddell Sea may indicate significant length increments at older ages, rather than a rapid decrease and approximation to L_{inf}. On the other hand, age readings over 12 years were difficult, and the larger fish were probably older than estimated.

Assuming birth on 1st November, the ages of fish collected in February (Weddell Sea) and April (Antarctic Peninsula) are 0.3 and 0.5 years older, respectively, than their age class definitions. Due to the fact, that the main seasonal growth takes place in these months, this difference is considered in the scale of the x-axis in Fig. 3. Values of t_0 accordingly have to be corrected upwards (+0.3, +0.5). With the given values, excluding the uncertain values of ages 13 and 14, the following growth parameters were determined:

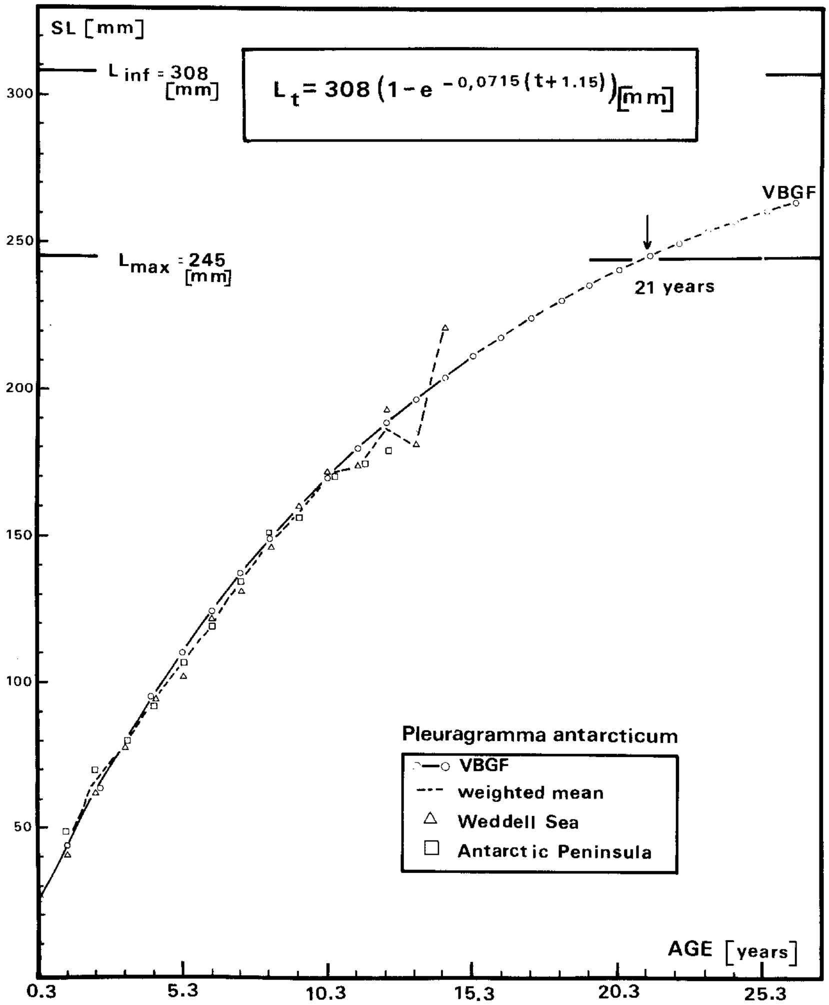

Fig. 3. Growth curves of *Pleuragramma antarcticum* based on mean measured lengths-at-age of the two investigation areas west of Antarctic Peninsula and Southern Weddell Sea; and calculated Von Bertalanffy Growth Curve of all values combined. The x-axis is shifted 0.3 years to account for summer growth between date of birth (Nov.) and collection date (Feb.–Apr.)

Antarctic Peninsula:

$L_{inf} = 303$ mm; $W_{inf} = 162$ g; $k = 0.0637$;
$t_0 = -1.5$ yrs; Growth Performance "P" = 1.01

Weddell Sea:

$L_{inf} = 389$ mm; $W_{inf} = 374$ g; $k = 0.0515$;
$t_0 = -1.4$ yrs; Growth Performance "P" = 1.29

Total (combined):

$L_{inf} = 308$ mm; $W_{inf} = 171$ g; $k = 0.0726$;
$t_0 = -1.2$ yrs; Growth Performance "P" = 1.11

A Von Bertalanffy growth function (VBGF) was fitted to the empirical data (Fig. 3; Table 3):

$$L_t = 308\ (1 - e^{-0.0715\ (t+1.15)})\ (\text{mm SL})\ .$$

The L_{max} of 245 mm reported from the Weddell Sea can be attributed to a 21 year old fish. The length at age 0+ (i.e. four months) derived from the equation is in good agreement with observed values of post-larval lengths in the Weddell Sea in January/February (Table 3).

Discussion

Pleuragramma antarcticum is a relatively small, planktivorous pelagic fish of the endemic suborder Notothenioidei. Its main distribution areas are the high Antarctic shelf seas, but the species is also frequently found at lower latitudes in the vicinity of the Antarctic Peninsula and South Orkney Islands. It is one of the few Antarctic fish species with an extended latitudinal distribution. Fish sizes tend to be largest in the extreme south (ANON 1985). Maximum length observed in several years in the Weddell Sea was 24.5 cm SL. Specimens of 26 cm total length (TL) have been reported from Olaf-Prydz-Bay (R. Williams, personal communication). At the Antarctic Peninsula, *P. antarcticum* of up to 24 cm TL (K. H. Kock, personal communication) or 19 cm SL (K. E. Skora, personal communication) have been caught. Specimens used for morphometric studies by Gerasimchuk (1986) had maximum lengths of 22 cm SL. There is no evidence, that larger fish may avoid or escape from the trawls: Otolith-based size analysis of *P. antarcticum* from the stomach contents of Weddell Seals yielded size distributions almost identical to those from trawled nets, with maximum lengths of 23.5 cm SL (Plötz 1986). Three hundred and eight millimeters thus seems to be a realistic value for L_{inf}, considering the notable length increments in fishes of the oldest observed ages. Significantly higher L_{max} for *Pleuragramma antarcticum* of 30–35 cm (Lubimova et al. 1973) and 33 cm (ANON 1985) are within the present L_{inf} estimate of the Weddell Sea fishes. Such sizes, however, can be attained only at very old ages, and thus must be regarded as rare exceptions.

From the calculated growth curve, an age of 21 years can be derived for the maximum length of 245 mm. This is more than twice the life span (9–10 years), established for "smaller species" in the Antarctic, and close to the ages of larger species such as *Dissostichus mawsoni*, *Notothenia rossii marmorata* (Kock 1985). Thus, Antarctic Silverfish grow to only moderate size in a long life, which means slow growth even in comparison to generally slow growing Antarctic fish. The 44 mm length of age-group 1+ fish (Table 3) is the result of two summers' growth increments, plus the hatching length. Subsequent increments are in the order of 18–19 mm per year, i.e. less than the previously estimated 27–30 mm per year. Hence, in the Weddell Sea, 80 mm fish are three, not two years old, and 150–170 mm fish are 8–10 years old rather than "close to five" (c.f. ANON 1985).

To compare the growth of *P. antarcticum* with other Antarctic fish species, "k", L_{inf}, and "P" can be used. Compilations of known growth parameters of Antarctic fish, e.g. by North and White (1987) and Ekau (1988) show that, except for harpagiferid species of less than 150 mm maximum length, *Pleuragramma antarcticum* has the lowest Index of Growth Performance ("P") within the known range of nototheniids. Its growth parameter "k" is close to that of the largest growing species *Dissostichus mawsoni* and *Notothenia rossii marmorata*, but maximum size is small. This is a peculiarity of the species, as k and L_{inf} (resp. W_{inf}) are usually inversely related in fish (Beverton and Holt 1957; Pauly 1979; North and White 1987).

In species inhabiting a wide geographical area, and hence living at different water temperatures, "k" is positively related with temperature in the range from 5–30 °C, whereas L_{inf} (and "P") follow the opposite trend (Pauly 1979). In the concept of "metabolic cold adaptation" (Wohlschlag 1960; Pauly 1979), it was postulated that this relation was inverted at temperatures below 5 °C, i.e. lower L_{inf} and higher values of "k" would be found in "high polar" species. Wohlschlag's concept has been widely rejected, since it became clear that the basal metabolism of polar species is not elevated to the extent suggested by the early experiments. Lower overall levels of energy and pronounced seasonality of food supply may be more important factors governing slow growth in polar species (Holeton 1974; Clarke 1980, 1983).

Data on growth of fish from the high Antarctic shelves are scarce. A high "k" of 0.3 and low W_{inf} of 300 g were reported for *Pagothenia* (*Trematomus*) *bernacchii* from the Ross Sea by Wohlschlag (1962), and used to support the cold adaptation hypothesis of fish growth. Hureau (1970) determined "k" for the same species as between 0.12 and 0.18 in the East Antarctic, and Ekau (1988) found values of "k" of 0.09, and W_{inf} of 600 g in the Weddell Sea. Other high Antarctic species have low values of "k" and *high* L_{inf} (*Dissostichus mawsoni*; Burchett et al. 1984) or low k and *low* L_{inf} (*Trematomus* spp.; Zurr 1977; Ekau 1988). Thus, there is little evidence for generally increased "k" and reduced infinite size in Antarctic fish from existing growth data, suggesting that the "cold adapted" species do *not* invert the physiological trend set by Krogh's normal curve of temperature dependence.

Latitudinal growth differences in the Antarctic have been investigated by Freytag (1980) for *N. rossii marmorata* from South Georgia and the South Shetland Islands. Slightly slower growth was observed for the southern populations. In the present analysis, growth parameter "k" of *Pleuragramma antarcticum* was slightly higher in the north (0.064, compared to 0.052 in the southern area), and infinite length was smaller (303 mm, compared to 389 mm in the Weddell Sea).

As temperature differences between the two areas are small, and growth parameters may be biased by the different size distributions examined, we thus present a growth estimate for the Weddell Sea population based on both samples, rather than postulating separate stocks with different growth parameters. In any case, even only slightly higher values of "k", indicating increased metabolic activity at lower latitude during the juvenile and pre-adult phase may be an important event in the ontogeny of the species (Hubold 1985b).

Small maximum sizes, accompanied by low "k" factors, are found for a number of bottom living nototheniids on the Weddell Sea shelf (Ekau 1988). This growth pattern may reflect the low energetic level at which these fishes live (Clarke 1983). Even lower values, at the lower limit of Antarctic fish growth, may be an adaptation to the special niche occupied by *Pleuragramma antarcticum. P. antarcticum* are unique among Antarctic fish in their pelagic planktivorous way of life, and in quantitative terms, very successful. Their food comprises copepods, mollusks, and euphausiids, with an emphasis on copepods during the prolonged pre-adult phase (Moreno et al. 1986). Smaller size over a long life span may help to successfully exploit these resources. Furthermore, adaptation to pelagic life of this swimbladderless species posed physical problems to overcome negative buoyancy (Eastman and DeVries 1981). Part of the energy available to the fish is stored in lipid sacs to increase buoyancy, and is not accessible as a normal metabolic energy source. During a juvenile phase of 4–5 years, the species maintains a number of larval characters, which economize weight (retarded development of scales and weak calcification of the skeleton, persisting chorda). Slow growth to moderate size may thus be another facet in the mosaic of adaptations, necessary for the fish to live pelagically in Antarctic shelf waters, where it has occupied a niche which is relatively undisputed by other fish species.

The central position of *P. antarcticum* in the pelagic food web of the high Antarctic shelves is documented both by its dominance in numbers and locally high biomass, and by its importance as prey for virtually all top predators. Investigations on the role of *P. antarcticum* in the diet e.g. of Emperor penguin chicks, and impact of predation on the fish populations, have only just started. Although Antarctic Silverfish have been identified as a potential fishery resource (Lubimova et al. 1973; Kock 1985), high predation pressure, and low growth are convincing arguments against human exploitation of this species. Human exploitation may lead to uncontrollable damage to one of the least investigated, but possibly most sensitive parts of the Antarctic ocean: the high Antarctic shelf ecosystems.

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