Proc. NIPR Symp. Polar Biol., 5, 90–97, 1992

NOTES ON SOME FISHES ASSOCIATED WITH THE ANTARCTIC KRILL. III. *ANOTOPTERUS PHARAO* ZUGMAYER (FAMILY ANOTOPTERIDAE)

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Abstract: Morphological and ecological studies are given for a total of twelve specimens of *Anotopterus pharao* ZUGMAYER caught along with the Antarctic krill. Among over fifty fish species recorded as a by-catch in krill fisheries in the Antarctic Ocean, *A. pharao* is known as one of the rarest species and its ecology and biology are still obscure. Morphometric and meristic data, except for the number of vertebrae, of the present specimens mostly agree with those of fishes collected from the Northern Hemisphere. *A. pharao* from the Antarctic waters has greater number of vertebrae (usually more than 83) than those from the North Atlantic and North Pacific (usually less than 81). The condition of hermaphroditism is histologically confirmed for the first time. All specimens histologically examined are not fully matured. Developmental stage of oocytes varies among individuals even of nearly the same size. Stomachs are mostly vacant in nine specimens, and those of the other three contain the Antarctic krill. One of the three also contains one specimen of *Notolepis coatsi* DOLLO of partly digested. The distribution pattern of the Antarctic *A. pharao* seems to be circumpolar. *A. pharao* is found in more than 10% of the net hauls of the Antarctic krill fisheries in the Scotia Sea region.

1. Introduction

The first record of *A. pharao* in the Antarctic Ocean was presented by REGAN (1913). Based on a head part trawled in the Weddell Sea, REGAN (1913) described *Eugnathosaurus vorax* as a new genus and species of the Alepisauridae without making mention of *A. pharao*. NYBELIN (1946) revised the Anotopteridae and concluded that genus *Eugnathosaurus* is a junior synonym of *Anotopterus* based on its distinctive features of jaws and teeth. NYBELIN (1946) also described additional two species, *A. antarcticus* and *A. arcticus*. *A. antarcticus*, found in the stomach of a fin whale captured in the Weddell Sea, was the second species from the Antarctic Ocean. NYBELIN (1946) distinguished them on the basis of the size attained, the number, arrangement and attitude of teeth, and the proportions. HUBBS *et al.* (1953) studied more specimens from various localities and found much irregular variation in the number, size, and arrangement of teeth. They also recognized that differences in the size attained and the proportion were not valuable for separating species. Then they suggested *Anotopterus pharao* as an only species referable to the Anotopteridae.

This conclusion was followed by MARSHALL (1955), ROFEN (1966), TEMPLEMAN (1970) and others.

A. pharao is relatively rare especially in the North Atlantic and North Pacific Ocean (ABE, 1952; HUBBS *et al.*, 1953; TEMPLEMAN, 1970). Also in the Antarctic Ocean, not many specimens were caught along with the Antarctic krill (CHŁAPOWSKI and KRZEPTOWSKI, 1978; REMBISZEWSKI *et al.*, 1978; REMBISZEWSKI, 1981). During the Japanese exploratory and commercial fishing of the Antarctic krill, twelve specimens of *A. pharao* were collected and brought back to Laboratory of Biology, Tokyo Kasei Gakuin University in good condition. Lack of samples to be examined prevents us from increasing our knowledge on their biology, biogeography and also taxonomy. Under these circumstances, it is worth describing our specimens of *A. pharao*. In this paper, some information on morphology, reproduction and distribution of the Antarctic *A. pharao* are given.

2. Materials and Methods

A total of twelve specimens of *Anotopterus pharao* are examined. Catch data of these specimens are shown in Table 1.

All the specimens examined were frozen at about −40°C on board the krill fishing vessels and stored at about −20°C. After thawing in running water in the laboratory, the specimens were fixed in 10% formalin. All these specimens are deposited at the Department of Zoology, National Science Museum (Nat. Hist.), Tokyo (NSMT-P).

Methods for taking measurements and counts follow those given by HUBBS and LAGLER (1958). Radiographs were used for counting vertebrae and fin rays. All vertebral centra were counted, including the compound element supporting the parhypural and hypurals. Gonad samples for histological observation were taken from the fixed specimens. Gonads were dehydrated with ethanol-xylol series and embedded in paraffin. They were serially sectioned 8 μm thick. The sections were stained with MAYER's hematoxylin and eosin for the microscopic examination to confirm hermaphroditism and the developmental stage of gonad.

Table 1. Collecting data of Anotopterus pharao *used in the present study.*

Cat. No.	DATE	LOCALITY	DEPTH	VESSEL
NSMT-P 34977	January 3, 1982	60°32′S, 55°08′W	40 m	Yoshino-maru
NSMT-P 34978	December 15, 1981	62°22′S, 61°55′W	70 m	Yoshino-maru
NSMT-P 34979	December 15, 1981	62°22′S, 61°55′W	70 m	Yoshino-maru
NSMT-P 34980	January 16, 1982	60°04′S, 53°19′W	30 m	Yoshino-maru
NSMT-P 34981	January 16, 1982	60°04′S, 53°19′W	30 m	Yoshino-maru
NSMT-P 34982	January 16, 1982	60°04′S, 53°19′W	30 m	Yoshino-maru
NSMT-P 34983	January 21, 1991	61°10′S, 56°57′W	40 m	Niitaka-maru
NSMT-P 34984	March 6, 1991	62°37′S, 61°34′W	50 m	Daisan Chiyou-maru
NSMT-P 34985	February 7, 1983	60°26′S, 44°27′W	50 m	Yoshino-maru
NSMT-P 34986	February 5, 1983	59°52′S, 43°00′W	60 m	Yoshino-maru
NSMT-P 34987	January 15, 1991	61°44′S, 59°54′W	40 m	Aso-maru
NSMT-P 34988	December 29, 1990	61°52′S, 59°16′W	50 m	Daigo Chiyou-maru

3. Results and Discussion

3.1. Morphometric and meristic characters

Morphometric and meristic data are shown in Table 2. There is no important difference between the morphometric data of the present specimens and those of the other Antarctic specimens appearing in the previous works (TEMPLEMAN, 1970; REMBISZEWSKI, 1981). As suggested by the previous works (HUBBS *et al.*, 1953; MARSHALL, 1955; TEMPLEMAN, 1970; REMBISZEWSKI, 1981), body proportions of the Antarctic specimens do not differ noticeably from specimens taken from the other areas (Table 2).

The range of the fin ray counts of the present specimens is within the range of specimens collected from the different localities. The only valuable difference is found in the number of vertebrae (Table 2). The number of vertebrae of the Antarctic specimens was 82–85. The average of the vertebral numbers of the Ant-

Table 2. Morphometric and meristic characteristics of Anotopterus pharao *examined in percentages of the standard length (SL). Hyphens in the table show the parts that*

	NSMT-P 34977	NSMT-P 34978	NSMT-P 34979	NSMT-P 34980	NSMT-P 34981	NSMT-P 34982
SL (in mm)	—	—	858	845	774	770
Head length	—	—	22.3	21.8	22.0	21.6
Snout length	—	—	13.1	12.8	13.4	13.2
Orbit diameter	—	—	1.8	1.8	1.8	1.7
Interorbital width	—	—	1.2	1.3	1.3	1.3
Snout tip to nostril	—	—	12.1	11.5	12.2	11.5
Postorbital length	—	—	7.6	7.2	6.8	7.1
Length of caudal peduncle	—	—	3.8	4.5	4.1	—
Depth of caudal peduncle	—	—	1.9	1.8	1.6	—
Body depth at anal fin origin	—	—	3.7	3.8	3.1	3.1
Snout tip to anal fin origin	—	—	88.0	89.3	89.0	88.7
Snout tip to pectoral fin	—	—	21.6	19.9	21.4	20.9
Snout tip to ventral fin	—	—	56.3	58.8	57.8	58.7
Snout tip to adipose fin	—	—	91.8	91.6	88.8	89.6
Anal fin base length	—	—	6.8	5.7	5.9	6.4
Pectoral fin length	—	—	6.0	6.2	6.0	6.2
Ventral fin length	—	—	3.9	2.9	3.2	3.9
Anal fin rays	—	—	16	13	14	14
Pectoral fin rays						
left side	14	14	13	14	12	14
right side	14	14	14	13	12	14
Ventral fin rays						
left side	10	—	—	9	8	9
right side	9	—	—	9	8	9
Branchiostegal rays						
left side	7	—	7	7	7	7
right side	7	—	7	7	7	7
No. of functional fixed palatine teeth	10	8	10	9	10	8
No. of vertebrae	—	—	84	84	84	85

arctic specimens shown by TEMPLEMAN (1970) and of the present study is 83.4 (14 specimens). On the contrary, the range of the vertebral counts of 19 specimens taken from the North and Central Atlantic and North Pacific is from 78 to 82, with average value of 79.4 (TEMPLEMAN, 1970). TEMPLEMAN (1970) also showed the vertebral number of three South Atlantic specimens, and the count ranged from 81 to 83 with average value of 82.

The inverse correlation between the water temperature during development and the number of meristic elements is pointed out by JOHNSON (1974) for scopelarchid fishes. In the Scopelarchidae, meristic counts including the vertebral number of specimens from high latitudes are more than those of fishes from the temperate seas. The number of vertebrae of *A. pharao* from the Central Atlantic (5 specimens) ranges from 78 to 81 (average value 79.8), and that of North Atlantic specimens (9 specimens) varies from 78 to 82 (average value 78.9) (TEMPLEMAN, 1970). There is no valuable difference in the number of vertebrae between the two regions; therefore, the inverse

compared with those from other areas cited from TEMPLEMAN (1970). All body parts are expressed were not measured or counted.

NSMT-P 34983	NSMT-P 34984	NSMT-P 34985	NSMT-P 34986	NSMT-P 34987	NSMT-P 34988	TEMPLEMAN (1970)
850	833	723	724	1040	873	244–867
22.1	23.2	21.0	21.5	21.3	22.4	20.0–26.8
13.6	13.6	12.7	13.3	13.2	13.2	11.8–15.9
1.7	1.8	1.9	1.9	1.6	1.7	1.8–3.0
1.5	1.5	1.3	1.2	1.3	1.5	1.3–2.3
12.3	12.3	11.1	11.8	11.9	11.5	—
7.1	7.7	6.7	6.6	6.3	7.4	6.6–9.2
5.1	3.9	4.5	4.6	5.1	4.6	—
1.5	1.5	1.4	1.4	1.7	1.6	1.4–2.1
3.3	3.1	2.6	3.8	3.6	4.1	—
90.8	92.8	90.0	89.5	89.6	91.1	—
21.8	23.0	21.3	20.4	21.7	22.2	—
59.6	60.9	58.4	—	58.4	57.6	—
91.8	93.5	92.3	91.7	91.2	91.9	—
5.4	5.0	5.6	5.7	5.5	—	5.0–7.6
5.2	6.7	6.8	6.4	—	7.3	4.5–7.1
3.5	3.1	2.8	—	—	3.4	2.6–4.7
15	13	14	14	14	14	12–17
						10–15
14	14	12	13	14	14	
14	13	12	12	14	14	
						9–11
9	8	7	—	9	9	
9	8	7	—	9	8	
						6–7
7	8	7	7	7	7	
7	7	—	—	7	7	
10	10	10	10	7	10	4–14
85	83	83	83	84	84	78–82

correlation rule cannot be adopted to explain the relatively higher vertebral number of the Antarctic specimens. The other meristic counts and body proportions of the Antarctic specimens completely overlap with those of fishes from other regions (Table 2). Based on the present morphological study, the Antarctic *Anotopterus* was identified as *A. pharao* as hitherto, and the relatively higher vertebral number was confirmed to *A. pharao* from the Antarctic Ocean.

3.2. *Gonad*

The gonads of ten specimens of *A. pharao* were histologically examined. The gonad of *A. pharao* is a paired long and relatively flat tubular organ extending along the dorsal wall of the elongated body cavity. In the present specimens the gonads were not expanded and filled with eggs or cellular tissues. These fishes were easily recognized as immature. Using the dissecting microscope, small "eggs" (ca. 0.1–0.8 mm in diameter) were found in the gonads. It may be supposed that these specimens are females as reported by TEMPLEMAN (1970) and REMBISZEWSKI (1981). But histological examination clearly shows that their gonads are hermaphroditic as suggested by MAUL (1971). Testicular tissue is found at the dorso-medial corner of the gonad and is relatively small in comparison with the size of the ovary (Fig. 1). The structure is moderately similar to that of *Benthalbella linguidens* (MEAD and BÖHLKE) of the Scopelarchidae (IWAMI and ABE, 1980). Some previous works (POSTLAKY, 1962; ROFEN, 1966) identified their examined specimens as males, though the testis is never larger than the ovary and is hard to identify with the naked eye. Their misidentifications of the sex are probably derived from an oversight of the extremely small eggs in the gonads.

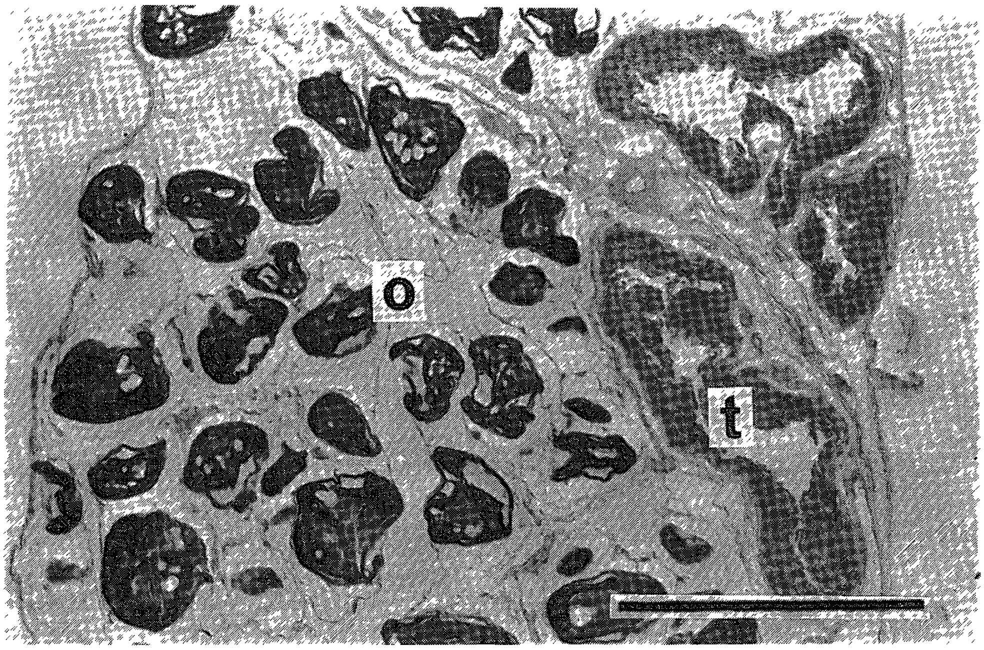

Fig. 1. Transverse section of the gonad of Anotopterus pharao *(NSMT-P 34977) at about the mid-length of the dorsal portion of the gonad. o, ovary; t, testis. The bar represents 0.5 mm.*

Though the gonads are not fixed just after collecting the fishes, the stage of the oogenesis can be determined because of the main structure of the oocytes being preserved. The youngest ovary is found in one specimen (NSMT-P 34983) of 850 mm in SL and is identified as in the intermediate stage between the peri-nucleolus and yolk vesicle stages. The diameter of the largest ten oocytes derived from the youngest ovary is about 0.14 mm. The gonads of the other specimens show mostly the same developmental stage, the primary yolk stage. The average value of the diameter of oocytes is about 0.26 mm. Compared with the data of MAUL (1971), these oocytes are much smaller than those of matured specimen (about 0.76 mm). But most of the Antarctic specimens have more advanced ovaries than those of the large immature specimens (736–965 mm in SL) collected near the Aleutian Islands from June to August. Judging from the sizes of the oocytes, these immature fishes seem to be in the similar developmental stage to the youngest Antarctic specimen.

There is no reliable record of fully matured specimen of *A. pharao* from the Antarctic waters. REMBISZEWSKI *et al.* (1978) reported the catches of "matured" females, but the stage of maturity shown by them do not mean the fully matured stage. No larva or juvenile is also found in the Antarctic Ocean although the extensive surveys for collecting fish larvae have been carried out in that area. The above-mentioned facts show the possibility that *A. pharao* in the Antarctic Ocean migrates to the north of the polar front to spawn eggs. MAUL (1971) also presented the similar idea, but the rare captures of this species in the northern regions prevent us from confirming our ideas.

3.3. Stomach contents

Although all *A. pharao* used in the present study were caught along with the Antarctic krill, the nine of the twelve specimens have no food remains in their stomach. The Antarctic krill *Euphausia superba* DANA is found from the stomachs of the rest three specimens. And the one specimen (NSMT-P 34986) also fed one fish referable to *Notolepis coatsi* DOLLO. The specimen of *Notolepis* is 123 mm in SL and a little digested, therefore, it may be concluded not to be swallowed in the krill net. On the contrary, one *E. superba* found in the other fish stomach is not digested and seems to be fed in the net.

Most of the fishes caught along with the Antarctic krill are supposed to feed mainly on the Antarctic krill (PERMITIN, 1977; ABE and SUZUKI, 1978; REMBISZEWSKI *et al.*, 1978; WILLIAMS, 1985) with a few exceptions; *e.g. Pseudocyttus maculatus* GILCHRIST (=*Xenocyttus nemotoi* ABE) (ABE and SUZUKI, 1981). Relatively high frequency of occurrence of the vacant stomachs in the Antarctic *A. pharao* was also reported by REMBISZEWSKI *et al.* (1978). One of the possibilities shown by the above mentioned facts that they throw up the stomach contents in the net. MAUL (1971) examined one matured and toothless specimen of *A. pharao* and he suggested that this species stops to feed in face of spawning. Antarctic *A. pharao* has strong and sharp teeth and probably need more days to be matured because of its small size of gonad, therefore, the stomach condition found in the Antarctic specimens seems not to have resulted from maturation.

3.4. Distribution

Most of the published records of *A. pharao* in the Antarctic waters are from the Scotia Sea and Weddell Sea (REMBISZEWSKI *et al*, 1978; KOCK, 1982, HEEMSTRA, 1990) and the present materials are also collected from the Scotia Sea region. There are a few records of *A pharao* from the East Antarctic region; from the Ross Sea (69°S, 170°E) (MARSHALL, 1955) and from off the Wilkes Land (64°58′S, 109°45′E) (ABE, pers commun) In spite of the interrupted localities of collecting records as mentioned above, *A pharao* is thought to distribute widely in the Antarctic Ocean as shown by the other mesopelagic fishes (ANDRIASHEV, 1965, BUSSING and BUSSING, 1966; POST, 1978, 1987, McGINNIS, 1982). At least in the Scotia Sea region, this species is not so quite rare During the exploratory fishing of the Antarctic krill carried out in the vicinity of the South Shetland Islands by Japan Marine Fishery Resource Research Center, *A pharao* were taken from the 14 of the 128 stations The frequency of appearance of this species is more than 10% This high percentage of occurrence in the Scotia Sea region is curious comparing with the number of records in the Northern Hemisphere Studies on the abundance and on the pattern of migration of the Antarctic *A pharao* are needed for understanding the life history and taxonomic status of the Antarctic *Anotopterus pharao*

Acknowledgments

The authors thank the crews of the Yoshino-maru, the Niitaka-maru, the Daisan Chiyou-maru, the Daigo Chiyou-maru and the Aso-maru for collecting specimens for the present study.

The authors also wish to express their thanks to Dr T ABE of Division of Zoology, University Museum, the University of Tokyo, and to Mr H NUMANAMI of the Laboratory of Invertebrate Zoology, Tokyo University of Fisheries, for providing much needed information

Part of this work was financed by the FUJIWARA Foundation for the Advancement of Natural History Studies, helping the senior author.

References

ABE, T (1952) Records of the "Mizu-uo-damashi" (new Japanese name), *Anotopterus pharao*, and a record of the "Etchiopia", *Brama rau*, from near the surface of the north-western Pacific Jpn J Ichthyol , **2**(4/5), 230–238

ABE, T and SUZUKI, M (1978) Notes on some fishes associated with the Antarctic krill I *Neopagetopsis ionah* NYBELIN Antarct Rec , **62**, 23–28

ABE, T and SUZUKI, M (1981) Notes on some fishes associated with the Antarctic krill II On *Xenocyttus nemotoi* ABE, and again on *Neopagetopsis ionah* NYBELIN Antarct Rec , **71**, 121–129

ANDRIASHEV, A P (1965) A general review of the Antarctic fish fauna Monogr Biol , **15**, 491–550

BUSSING, W A and BUSSING, M I (1966) Antarctic Scopelarchidae A new fish of the genus *Benthalbella* and the distribution of *B elongata* (NORMAN) Bull Soc Calif Acad Sci , **65**, 53–61

CHŁAPOWSKI, K and KRZEPTOWSKI, M (1978) On the presence of fishes in Antarctic krill catches

Acta Ichthyol. Piscatoria, **8**, 3–8.

HEEMSTRA, P. C (1990): Anotopteridae. Fishes of the Southern Ocean, ed. by O. GON and P C. HEEMSTRA Grahamstown, J. L. B SMITH Inst. Ichthyology, 142–143.

HUBBS, C L and LAGLER, K. F. (1958): Fishes of the Great Lakes region. Ann Arbor, University of Michigan Press, 213 p.

HUBBS, C. L., MEAD, G. W. and WILIMOVSKY, N J. (1953): The widespread, probably antitropical distribution and the relationship of the bathypelagic iniomous fish *Anotopterus pharao*. Bull. Scrips Inst Oceanogr. Univ. Calif, **6**(5), 173–198.

IWAMI, T and ABE, T. (1980): Records of adults of some scopelarchid fishes from the western North Pacific and the Southern Ocean, with osteological notes on five species of the genus *Benthalbella* UO, **31**, 1–20.

JOHNSON, R. K (1974): A revision of the alepisauroid family Scopelarchidae (Pisces. Myctophiformes) Fieldiana Zool., **66**, 1–249.

KOCK, K H (1982). Fishes from RMT 8- and krill trawl catches during FIBEX 1981. Arch. Fischwiss, **33**, 97–112.

MARSHALL, N. B. (1955): Alepisauroid fishes. Discovery Rep., **27**, 303–336.

MAUL, G. E. (1971): Report on the fishes taken in Madeiran and Canarian waters during the summer-autumn cruise of the "Discovery II" 1959 and 1961. III. Order Iniomi I. On a toothless, sexually mature *Anotopterus* Bocagiana, **28**, 1–15.

MCGINNIS, R. F. (1982): Biogeography of lanternfishes (Myctophidae) south of 30°S. Antarct. Res. Ser., **35**, 1–110.

NYBELIN, O (1946): Sur quelques espèces du genre *Anotopterus* ZUGMAYER et sur la position systématique de la famille des Anotopteridae. Goteborgs Vetensksamh Handl. ser B, **5**, 1–16

PERMITIN, YU. YE. (1977): The consumption of krill by Antarctic fishes. Antarctic Ecology, vol. 1, ed. by M W. HOLDGATE. London, Academic Press, 177–182.

POST, A. P. (1978). Beschreibung zweier *Notolepis* arten, *Notolepis coatsi* DOLLO, 1908 und *N. annulata* sp. n aus der Antarktis (Osteichthyes, Myctophiformes, Paralepididae). Arch. Fischwiss., **29**, 1–22.

POST, A P. (1987): Results of the research cruise of the FRV "Walther Herwig" to South America. LXVII. Revision of the subfamily Paralepidinae (Pisces, Aulopiformes, Alepisauroidei, Paralepididae). I. Taxonomy, morphology and geographical distribution. Arch. Fischwiss., **38**, 75–131.

POSTOLAKY, A. I. (1962): Nakhodka *Anotopterus pharao* ZUGMAYER (Pisces, Scopeliformes) v Severnoy Atlantike (Occurrence of *Anotopterus pharao* ZUGMAYER (Pisces, Scopeliformes) in the North Atlantic). Vopr. Ikhtiol., **2**, 25–28.

REGAN, C. T. (1913): The Antarctic fishes of the Scottish National Antarctic Expedition. Trans. R. Soc. Edinburgh, **49**, 229–292.

REMBISZEWSKI, J. M. (1981): *Pseudoicichthys australis* (HAEDRICH, 1966) and *Anotopterus pharao* ZUGMAYER, 1911, rare fishes from Antarctic waters. Ann. Zool., Warszawa, **36**(12), 241–245.

REMBISZEWSKI, J. M., KRZEPTOWSKI, M. and LINKOWSKI, T. B. (1978): Fishes (Pisces) as by-catch in fisheries of krill *Euphausia superba* DANA (Euphausiacea, Crustacea). Pol Arch. Hydrobiol, **25**(3), 677–695.

ROFEN, R. R. (1966). Family Anotopteridae. Fishes of the western North Atlantic. Mem. Sears Found. Mar. Res., New Haven, **1**(5), 498–510.

TEMPLEMAN, W. (1970). Distribution of *Anotopterus pharao* in the North Atlantic and comparison of specimens of *A. pharao* from the western North Atlantic with those from other areas. J. Fish. Res. Bd. Canada, **27**, 499–512.

WILLIAMS, R. (1985): Trophic relationships between pelagic fish and euphausiids in Antarctic waters. Antarctic Nutrient Cycles and Food Webs, ed. by W. R. SIEGFRIED, P. R. CONDY and R. M. LAWS Berlin, Springer-Verlag, 452–459.

(Received June 3, 1991, Revised munuscript received August 15, 1991)