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Spawning Pattern of a Mesopelagic Micronektonic Fish, *Diaphus suborbitalis*, in Suruga Bay, Japan

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日本 駿河灣産 中·深層性 魚類 micronekton, *Diaphus suborbitalis*의 産卵樣式

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本 硏究에서는 日本 駿河灣에 있어서 中·深層性 魚類 micronekton의 주요종인 *Diaphus suborbitalis*의 成熟과 産卵 및 産卵期의 移動樣式을 밝혔다.

組織學的 觀察에 의한 生殖巢의 月別熟度變化의 결과, 精巢에서는 精子의 出現盛期가 7~9月이어서 精巢의 성숙도로부터 추정되는 産卵期는 夏季~秋季였다. 한편 雌의 試料에서는 年間을 통하여 成熟한 개체가 出現치 않고, 가장 성숙도가 높은 개체에서도 成熟段階 初期에 相當하는 周邊仁期의 卵母細胞가 觀察될 뿐이었다. 本硏究에서 사용한 試料의 대부분이 日周垂直移動에 의해 夜間 100m 以淺에 上昇한 個體인 것임을 고려하면, 산란기에는 成熟雌가 日周垂直移動을 하지 않고 夜間에도 100m 以深에 머물러 있음을 暗示하고 있다.

生殖巢의 組織學的 觀察 및 耳石에 의한 年令査定의 결과에 의하면, 雄은 만 1歲에서 성숙하고, 그 生物學的 最小形은 약 50mm였다.

Introduction

Myctophids are one of the dominant groups of mesopelagic fish both in numbers of species and individuals, and their roles in the open ecosystem are generally thought to be important. The most part of early work in lanternfish, including *Diaphus suborbitalis*, was concerned primarily with taxonomy and distribution, and admirable studies have been published recently(Nafpaktitis, 1968, 1978; Wisner, 1976; Kawaguchi and Shimizu, 1978). However, there are numerous problems in our knowledge of the ecology of this ubiquitous fish.

Diaphus suborbitalis occurs over deep water near the continental slope in Suruga Bay, on the Pacific side of central Japan. The zoogeographic range of the species known throughout the world extends from the eastern Indian and southeast Asian Seas. The present study describes the time of the spawning and the migrating characteristic of the species at that time.

Materials and Methods

Samples were collected in Suruga Bay by the *R/V Tansei Maru*, Ocean Research Institute, University

of Tokyo, the commercial shrimp fisheries boat, and the bottom trawl, from May 1973 to April 1977. The gears used are 6-ft Isaacs Kidd midwater trawl and commercial nets. Although these materials include collections over several years, the samples were gathered from March to December, except January and February.

Table 1. Number of individuals examined for the gonad of *Diaphus suborbitalis* in Suruga Bay

Date	No. of fish examined	Male	Female
Mar. 16, 1975	4	1	3
Apr. 21, 1977	18	3	15
May 12, 1973	24	9	15
June 12, 1974	11	3	8
July 26, 1975	30	6	24
Aug. 31, 1976	12	5	7
Sep. 21, 1976	13	9	4
Oct. 14. 1976	23	10	13
Nov. 16, 1974	19	1	18
Dec. 15, 1976	20	3	17
Total	174	50	124

Fifty males and 124 males over 45㎜ SL were examined to determine the time of spawning(Table 1). The gonads of these materials were used for sectioning and staining with haematoxylin and eosin.

Results

Histological observation of gonad

In histological appearance, no mature ovary was found in any season as shown in Plate 1. Histological appearance presented that female *Diaphus suborbitalis* in this area had only oogonia and oocytes, and oocytes of peri-nucleous were only found in individuals to be in high maturity stage of materials examined. The oocytes appeared to be normal, but had not undergone vitellogenesis.

Table 2. Conditions of testis of *Diaphus suborbitalis* in Suruga Bay

Date	No. of fish examined	No existence of spermatozoa	Existence of spermatozoa
Mar. 16, 1975	1	1	
Apr. 21, 1977	3	3	
May 12, 1973	9	5	4
June 12, 1974	3	1	2
July 26, 1975	6	2	4
Aug. 31, 1976	5	1	4
Sep. 21, 1974	9	2	7
Oct. 14, 1976	10	2	8
Nov. 16, 1974	1	1	
Dec. 15, 1976	3	2	1
Total	50	20	30

The results of observation in testes are presented in Table 2. Males collected in March and April had immature testis(Plate 2-A), and some spermatozoa were found in four of nine individuals examined in May(Plate 2-B). In June two of three males had a similar condition to May(Plate 2-C). Testes in July had plenty of spermatozoa(Plate 2-D), and in August testes, being in the fully matured stage, appeared(Plate 2-E). A lot of spermatozoa in testes in September were found. Although males captured in October had some spermatozoa, the number of spermatozoa were less in number than those in August and September(Plate 2-F), so these suggest that the males in October are the individuals having spent spermatozoa. In December a negligible number of spermatozoa appeared in only one of three males.

These data seem to show that the testes of the species mature from May to December, and the season of high maturity stage is from June to September. If the season of maturity stage in male is consistent with that in female, the main breeding season of the species is from summer to autumn.

Seasonal changes in sex ratio

Table 3. Monthly sex ratio of *Diaphus suborbitalis* in Suruga Bay

Month	No. of fish examained	Male	Female	Ratio(F/M)
Apr. 1977	63	31	32	1.03
May 1973	72	39	33	0.85
June 1974	67	36	31	0.86
July 1974	63	35	28	0.80
Sep. 1974	44	25	19	0.76
Oct. 1976	77	42	35	0.83
Dec. 1976	66	35	31	0.89
Total	452	243	209	0.86

Monthly sex ratio(Female/Male) of the species over 40㎜ SL sampled at random are compared in Table 3. It is worth notice that the month when the number of females are more numerous than male is only April, and in other seasons males are abundant. Especially, sex ratios in July and September estimated at breeding season were very low, and 0.80 and 0.76 in turn.

The bulk of material under study was collected at night when the species ascended in the upper 100㎡ depth. The estimates that the the mature female does not undertake diel vertical migration and stays in the waters deeper than a depth of 100㎡, may be derived from the fact that mature female among samples collected does not appear throughout the year.

Although expatriation of the mature female on account of spawning outside this bay may be considered, the possibility will diminish because the species from open sea have not been collected, and a lot of mature males and juveniles less than 20㎜ SL were collected in the bay.

Age and length of maturity

After histological observation and age determination by otolith (see Go *et al*, 1977a), males come to maturity at one year from hatching. Though in the female mature age does not come to a conclusion from the histological examination, it seems to show that its mature age is the same as male judging

from the seasonal size frequency distribution of the species(see Go *et al*, 1977b). Biological minimum size is about 50mm SL in the male, but indistinct in the female.

Discussion

The breeding season of *Diaphus suborbitalis* is estimated from summer to autumn. Within the family Myctophidae, comparisions of breeding season between the result under study and other reports are shown in Table 4. The bulk of species spawns from spring to summer, or summer to autumn. This suggests that increasing plankton in spring and autumn encourages the larvae to grow well.

Table 4. Comparision on the spawning season of the myctophid fishes

Species	Main spawning season	Area	author
Benthosema glaciale	Spring	N. W. Atlantic	HALLIDAY (1970)
Myctophum selenoides		Off Hawaii	CLARKE (1973)
Ceratoscopelus warmingi		Off Hawaii	CLARKE (1973)
Myctophum nitidulum	Spring to summer	Off Japan	ODATE *et al.* (1961)
Hygophum proximum		Off Hawaii	CLARKE (1973)
Diaphus schmidti		Off Hawaii	CLARKE (1973)
Lampanyctus steinbecki		Off Hawaii	CLARKE (1973)
Triphoturus nigrescens		Off Hawaii	CLARKE (1973)
Bolinichthys supralateraris		Off Hawaii	CLARKE (1973)
Diaphus holti	Summer	Mediterranean	TANING (1918)
Ceratoscopelus maderensis		Mediterranean	TANING (1918)
Triphoturus mexicanus		Off S. California	PAXTON (1967)
Diaphus flagilis		Off Hawaii	CLARKE (1973)
D. elucens		Off Hawaii	CLARKE (1973)
D. brachycephalus		Off Hawaii	CLARKE (1973)
D. adenomus		Off Hawaii	CLARKE (1973)
Diaphus holti	Summer to autumn	N. Atlantic	NAFPAKTITIS (1968)
Bolinichthys supralateralis		Off Hawaii	CLAEKE (1973)
Diaphus suborbitalis		Suruga Bay	Present study
Diaphus brachcephalus	Winter	N. Atlantic	NAFPAKTITIS (1968)
D. subtilis		N. Atlantic	NAFPAKTITIS (1968)
Lobianchia dofleini		N. W. Atlantic	KARNELLA and GIBBS(1975)
Stenobrachius leucopsarus	Winter to spring	Off S. California	PAXTON (1967)
Lampanyctusniger		Off Hawaii	CLARKE (1973)

In the subarctic area *Stenobrachius leucopsarus* spawns from winter to spring(Paxton, 1967). It seems to be fit that environment, if special regard will be paid to the fact that the development rate of eggs and larvae is slow because of low temperature. It has been reported that some species of the genera *Diaphus* and *Lobianchia* spawn in winter, and it indicates the possibility that the eggs and larvae of those species are distributed at low temperature layer of the mesopelagic zone. Although the egg of the only species *Lampanyctodes hectoris* of the familly Myctophidae was identified as yet (Roberston, 1977), the possibility described above is no more than speculation at the present stage of study.

It is indicated under study that the mature female of *Diaphus suborbitalis* does not undertake diel vertical migration. Nafpaktitis(1968) who studied taxonomy and distributon of the genera *Lobianchia*

and *Diaphus*, has reported a result similar to that of the present study. Mature females were very low in his samples, and he states the reasons : Very low collecting rate by non vertical migration, and increasing escape rate due to large size of the fish. Though the actual proofs that maure female is seperated from migrants at night and stays at deep layer have not been reported, it cannot be known until further study is done. Since salmon and trout do not feed in breeding season, and one of the causes of the vertical migration is regarded as an adaptation to feed at the upper layer where food organisms are abundant, non vertical migration of mature female in breeding season does not seem to be a strange phenomenon. Consequently, it is difficult to think that *Diaphus suborbitalis* in Suruga Bay is as expatriated as the two species of *Lobianchia* in the North Atlantic (O'Day and Nafpaktitis, 1967) and *Myctophum punctatum* in the Northwest Atlantic (Zurbrigg and Scott, 1972).

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Abstract

Breeding season and vertical migrating difference between mature male and female of the abundant myctophid fish, *Diaphus suborbitalis*, in Suruga Bay, are described. Season of high maturity stage in testis is from June to September. Females possess only oogonia or oocytes of peri-nucleous throughout the year. On the bases of maturity stage of male and seasonal changes in size composition, it is shown that main breeding season of the species is from summer to autumn.

Mature female probably does not undertake diel vertical migration and stays in the waters deeper than 100m depth, indicating no expatriation outside the bay. Males mature at one year from hatching. Biological minimum size is about 50mm SL in male, but obscure in female.

References

Clarke, T. A. (1973): Some aspects of the ecology of lanternfishes(Myctophidae) in the Pacific Ocean near Hawaii. Fish. Bull, 71(2), 401 ~433.

Go, Y. B., K. Kawaguchi and T. Kusaka(1977a): Ecologic study on *Diaphus suborbitalis* WEBER(Pisces, Myctophidae) in Suruga Bay, Japan- I . Method of aging and its life span. Bull. Japan. Soc. Sci. Fish., 43(8), 913~ 919.

Go, Y. B., K. Kawaguchi and T. Kusaka(1977b): Ecologic study on *Diaphus suborbitalis* WEBER(Pisces, Myctophidae) in Suruga Bay, Japan- II . Growth pattern. Bull. Japan. Soc. Sci. Fish., 43(12), 1411~1416.

Halliday, R. G. (1970): Growth and vertical distribution of the glacier lantern fish, *Benthosema glaciale*, in the northwestern Atlantic. J. Fish. Res. Bd. Can., 27(1), 105~116.

Karnella, C. and R. H. Gibbs, Jr. (1975): The lanternfish *Lobianchia dofleini*: An example of the importance of ife-history information in prediction of oceanic sound scattering. Pro. ONR Working Symposium on the Prediction of Sound Scattering in the Oceans

11-14, November, Asilomar, pacific grove, California.

Kawaguchi, K. and H. Shimizu(1978): Taxonomy and distribution of the lantern fishes genus *Diaphus*(Pisces, Myctophidae) in the western Pacific, eastern Indian and the southeast Asian Seas. Bull. Ocean Res. Inst., Univ. Tokyo. 10, 1~145.

Nafpaktitis, B. G. (1968): Taxonomy and distribution of the lanternfishes, genera *Lobianchia* and *Diaphus*, in the North Atlantic. Dana-Rep., 73, 1~131.

Nafpaktitis, B. G. (1978): Systematics and distribution of lanternfishes of the genera *Lobianchia* and *Diapahus* (Myctophidae) in the Indian Ocean. Nat. Hist. Mus. Los Ang. Country, Sci. Bull., 30, 92 p.

Odate, S. and T. Ogawa(1961): Study on the fishes of the family Myctophidae in the north-eastern Sea Area along the Pacific coast of Japan. Part-Ⅱ. Susuki-hadaka, *Myctophum affine* TEMMINCK et SCHLEGEL. Bull. Tohoku Reg. Fish. Res. Lab., 19, 90~97. (in Japanese).

O'Day, W. T. and B. Nafpaktitis. (1967): A study of the effects of expatriations on the gonads of two myctophid fishes in the North Atlantic Ocean. Bull. Mus. Comp. Zool. Harvard Univ., 136(5), 77~89.

Paxton, J. R. (1967): Biological notes on southern California lanternfishes(family Myctophidae) Calif. Fish Game., 53, 214~217.

Roberston, D. A. (1977): Planktonic eggs of the lanternfish, *Lamphanyctodes hectoris*(family Myctophidae). Deep-Sea Res., 24, 849~852.

Taning, A. V. (1918): Mediterranean Scopelidae (*Sarus, Aulops, Chloropthalmus* and *Myctophum*). Rep. Danish Oceanogra. Exped. Medit., Ⅱ. Biol. A., 7, 1~154.

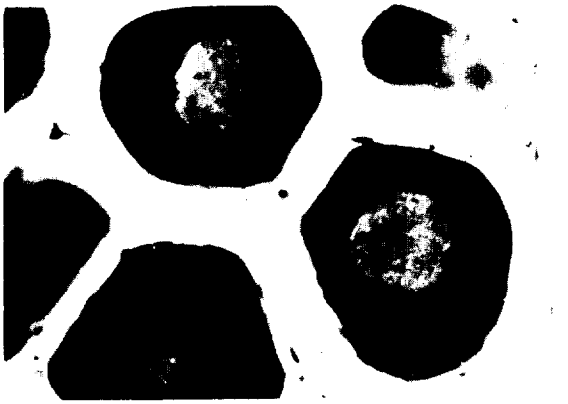
Wisner, R. L. (1976): The taxonomy and distribution of lanternfishes(family Myctophidae) of the eastern Pacific Ocean. Navy Ocean Research and Development Activity(NORDA) Rep., -3, 1~229.

Zurbrigg, R. E. and W. B. Scott(1972): Evidence for expatriate population of the lanternfish *Myctophum punctatum* in the northwest Atlantic. J. Fish. Res. Bd. Can., 27(7), 1265~1275.

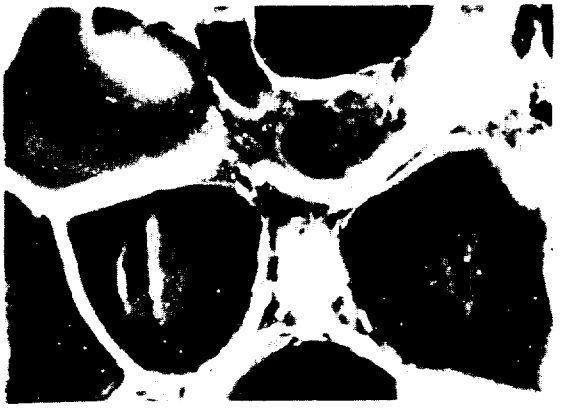
Plate 1. Ovarian sections of *Diaphus Suborbitalis*

A. The oocytes at peri-nucleolus stage in a 51mm SL specimen collected in Apr. 21, 1977 (X400).

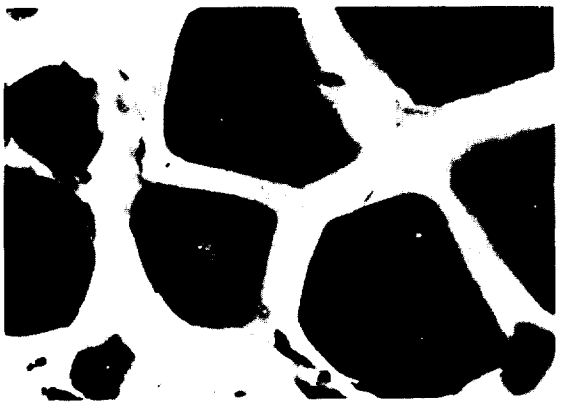
B. The oocytes at peri-nucleolus stage, 51.3mm SL, May 12, 1973 (X400).



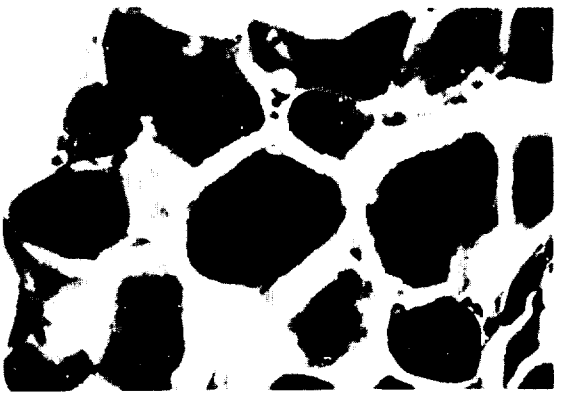
C. The oocytes at peri-nucleolus stage, 56.0mm SL, July 26, 1975 (X400).



D. The oocytes of peri-nucleolus stage, 57.0mm SL, Aug. 31, 1976 (X400).

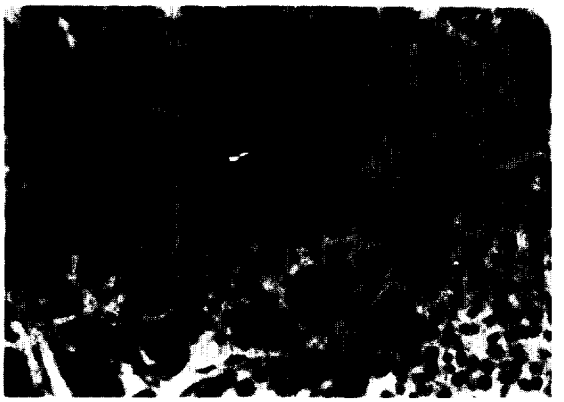


E. The oocytes of peri-nucleolus stage, 61.0mm SL, Oct. 14, 1976(X400).

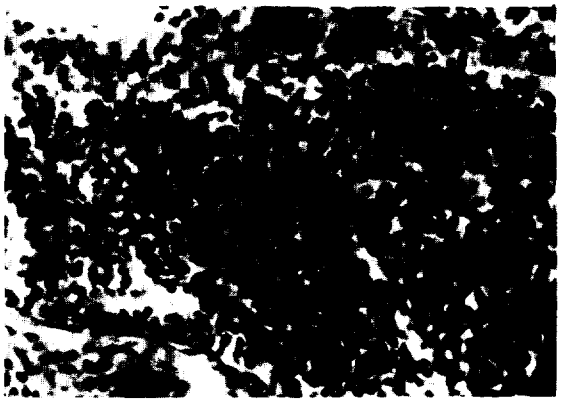


F. The oocytes of peri-nucleolus stage, 57.0mm SL, Dec. 15, 1976 (X400).

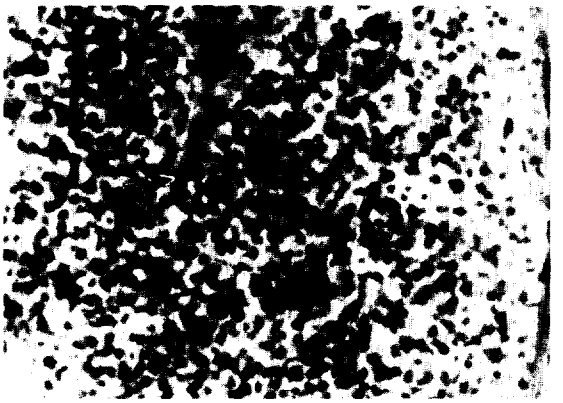
Plate 2. Testicular sections of *Diaphus Suborbitalis* at different maturity stages



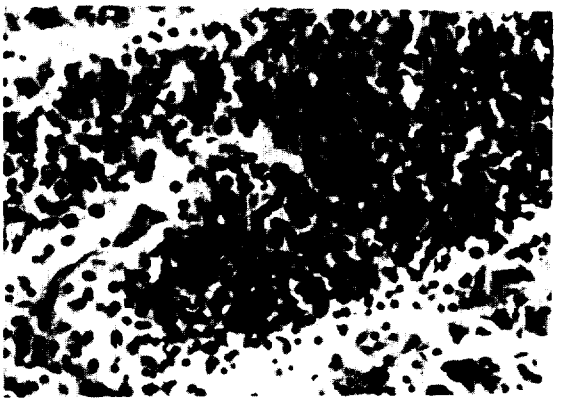
A. Immature testis showing no occurrence of spermatozoa in a 45.4mm specimen collected in Apr. 21, 1977 (X400).



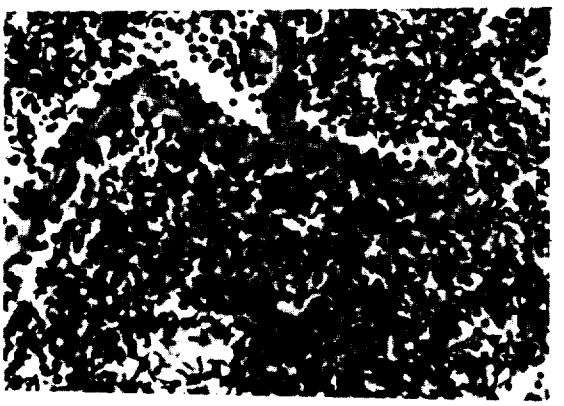
B. Maturing testis showing the occurrence of a few spermatozoa in a 48.5mm specimen in May 12, 1973 (X400).



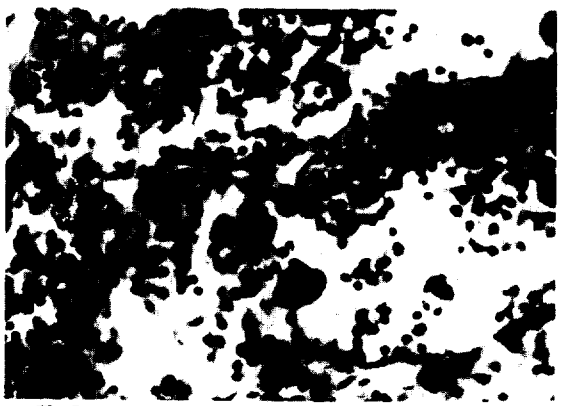
C. Testis in the same condition as above in a 51.4mm specimen in June 12, 1974 (X400).



D. Mature testis showing occurrence of many spermatozoa, in a 59.5mm SL specimen in July 26, 1975 (X400).



E. Mature testis showing the occurrence of very numerous spermatozoa in a 58.0mm specimen in Aug. 31, 1976 (X400).



F. Spent testis showing the occurrence of a few spermatozoa remained in a 52.5mm specimen in Oct. 14, 1976 (X400).