Seasonal occurrence of mesopelagic fish larvae on the onshore side of the Kuroshio off southern Japan

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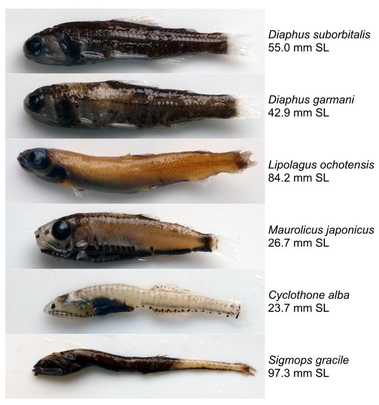
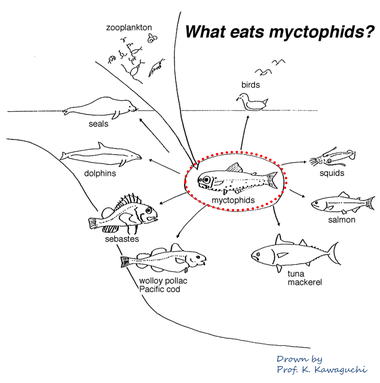
SKED — The Study of Kuroshio Ecosystem Dynamics for Sustainable Fisheries

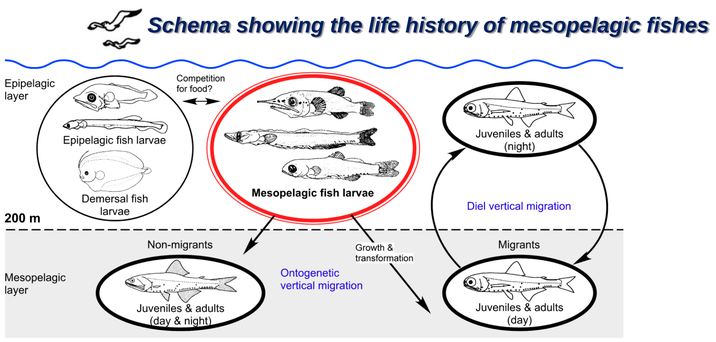
1. Introduction

Mesopelagic fishes (1) occur in all the world's oceans, (2) have high species diversity, (3) numerically dominate in the oceanic fish assemblage, (4) have high biomass – global estimate of 10^{10} t, and (5) act as an important link between secondary producers and upper trophic levels in the ecosystem[1)]. Thus, mesopelagic fishes are a key component of oceanic ecosystems.





Most mesopelagic fishes spend their larval stages in the productive epipelagic zone of the upper 200 m layer, and move to the mesopelagic zone when they begin transformation from larval to juvenile stages[2)]. Recent studies shows that the Kuroshio region is an important spawning ground for various species of mesopelagic fishes[3)]. However, information on the annual reproductive cycle of mesopelagic fishes has been limited in this region.

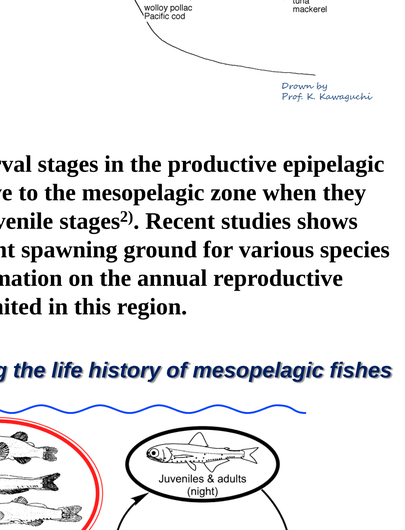


In this study, to describe the reproductive seasonality, we examined the seasonal occurrence patterns of the mesopelagic fish larvae in Tosa Bay which is strongly influenced by the Kuroshio.

2. Sample collection

Samplings were carried out at monthly intervals during the daytime at a fixed station on the continental slope in Tosa Bay, from January 2001 to December 2004. A double-oblique tow of a Bongo net (70-cm mouth diameter and 0.34-mm mesh) was conducted from the surface down to 500 m depth each month. Total number of net tows was 54. A 0–500 m CTD cast was conducted each month.

RV Kotaka-Maru (59 t)

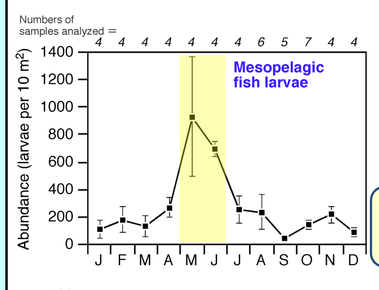


3. Oceanographic conditions

The position of the Kuroshio axis is represented by the 16.5˚C isotherm at 200 m depth[4)]. Temperature at 200 m depth ranged from 9.6 to 15.5˚C throughout the sampling period, thus, *our sampling station was concluded to be located on the onshore side of the Kuroshio axis*.

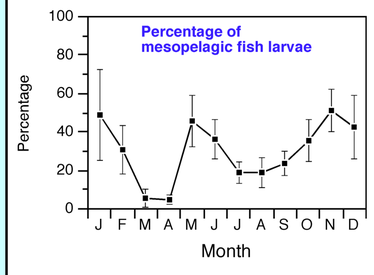
Mean temperature over the 0–100 m ($T_{0–100}$) during January to March was lowest of the year, and began to increase from April. $T_{0–100}$ showed peak values between August and October, and then declined during November to December. Mean salinity over the 0–100 m ($S_{0–100}$) declined from June and showed the lowest values between August and October, due to increase of inflows of freshwater. The water column was vertically well mixed during January to March, and the seasonal thermocline occurred during May to September.

4. Monthly changes in larval abundance



In total, 2,558 mesopelagic fish larvae occurred, with a peak abundance during May to June. This peak was due to extremely high abundance of *Diaphus* stubby spp.

This peak corresponded with the peak in zooplankton biomass with a 1–2 month lag.



The mean percentage of mesopelagic fish larvae to total abundance of fish larvae (including epipelagic and demersal fishes) ranged from 19.2 to 51.3%, except for March to April. The mean percentage was <5% during March to April due to extremely high abundance of the Japanese anchovy (*Engraulis japonicus*) larvae.

5. Species composition

Larvae of the dominant families Myctophidae, Sternoptychidae, Gonostomatidae, Bathylagidae, and Phosichthyidae were represented by 26 species (or types) belonging to 18 genera.

Taxon	No. of individuals	%	Rank
Bathylagidae			
Lipolagus ochotensis	85	3.33	6
Gonostomatidae			
Cyclothone spp.	56	2.19	10
Sigmops elongatum	1	0.04	22
S. gracile	211	8.26	4
Sternoptychidae			
Argyropelecus spp.	13	0.51	14
Maurolicus japonicus	264	10.33	2
Phosichthyidae			
Vinciguerria nimbaria	65	2.54	9
Myctophidae			
Benthosema pterotum	1	0.04	22
B. suborbitale	7	0.27	17
Ceratoscopelus warmingi	1	0.04	22
Diaphus slender type	82	3.21	7
Diaphus stubby type	1200	46.97	1
Diogenichthys atlanticus	28	1.10	12
Hygophum proximum	1	0.04	22
H. reinhardtii	4	0.16	18
Lampadena luminosa	19	0.74	13
Lampanyctus sp. A	48	1.88	11
Lampanyctus spp.	12	0.47	15
Lobianchia gemellarii	3	0.12	19
Myctophum asperum	231	9.04	3
M. nitidulum	9	0.35	16
M. orientale	2	0.08	20
Notolychnus valdiviae	1	0.04	22
Notoscopelus caudispinosus	2	0.08	20
N. japonicus	136	5.32	5
Symbolophorus evermanni	73	2.86	8

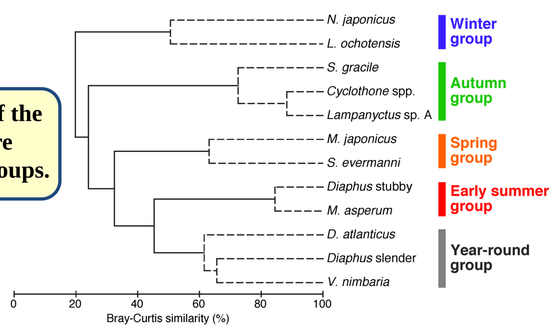
%, percent of the total mesopelagic fish catch.

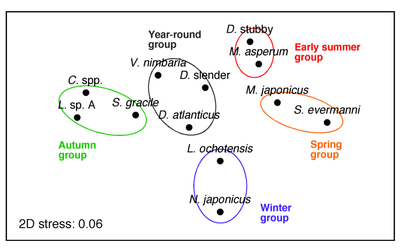
Twelve most abundant taxa accounted for 96.9% of the total mesopelagic fish catch.

6. Grouping of seasonal occurrence

In the larvae of the 12 dominant mesopelagic fish species, mean abundances in each month for the four years were standardized as a percentage of summed mean abundance over 12 months. The Bray-Curtis similarity index was adopted to distinguish the seasonal occurrence patterns of the larvae. Clustering by the group average was used to construct similarity matrices. The non-metric multidimensional scaling (MDS) ordination was also carried out.

Seasonal occurrences of the 12 species of larvae were categorized into five groups.

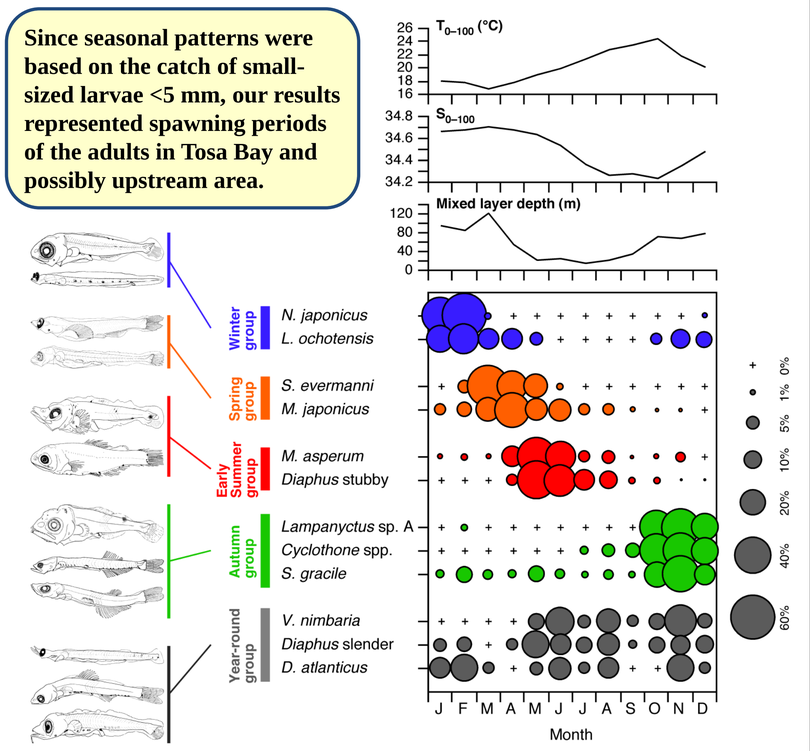




7. Reproductive seasonality

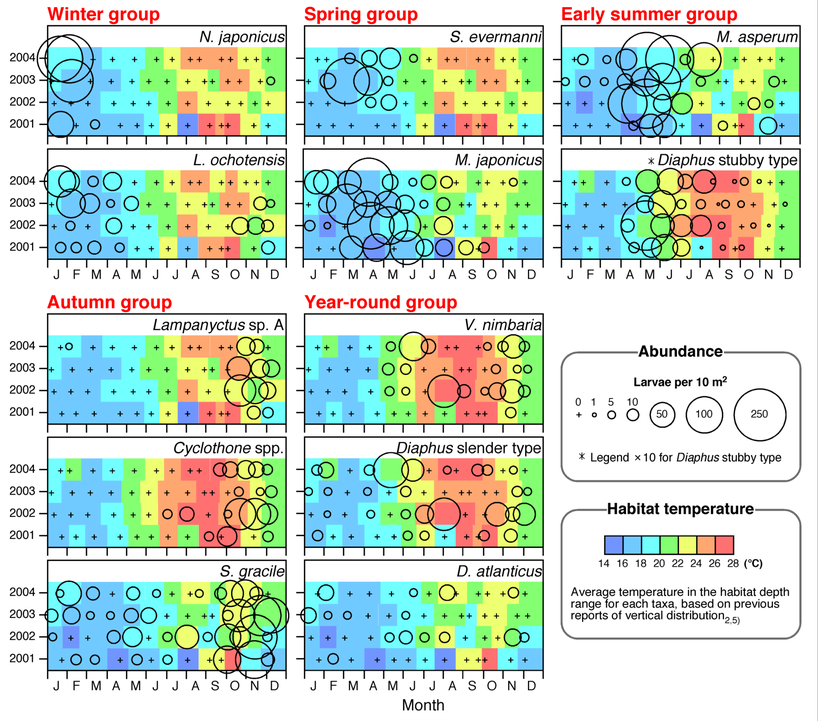
The seasonal occurrence patterns of the larvae were categorized into five groups in accordance with physical properties of the water column: Winter (*Notoscopelus japonicus* and *Lipolagus ochotensis*); Spring (*Symbolophorus evermanni* and *Maurolicus japonicus*); Early summer (*Myctophum asperum* and *Diaphus* stubby type); Autumn (*Lampanyctus* sp. A, *Cyclothone* spp., and *Sigmops gracile*); and Year-round (*Vinciguerria nimbaria*, *Diaphus* slender type, and *Diogenichthys atlanticus*) groups. There were no species that showed peak abundance during August to September.

Since seasonal patterns were based on the catch of small-sized larvae <5 mm, our results represented spawning periods of the adults in Tosa Bay and possibly upstream area.



8. Interannual variations

No significant difference was observed in the months of peak abundances of the dominant 12 mesopelagic fish larvae during 2001 to 2004, suggesting that *each species has a fixed seasonal pattern of reproduction*.



The various patterns of seasonal occurrence would result in seasonal habitat segregation of the larvae among species in the productive epipelagic zone where most of mesopelagic fish larvae develop.

The seasonal habitat segregation as well as the reported species-specific patterns of vertical distribution[2)] and feeding[6,7)] of the mesopelagic fish larvae possibly contributes to reduce intraspecific competition for food resources in the oligotrophic waters of the Kuroshio.

9. Conclusions

- **To describe the reproductive seasonality, we examined the seasonal occurrence patterns of the mesopelagic fish larvae on the onshore side of the Kuroshio off southern Japan, based on monthly samples collected from January 2001 to December 2004.**
- **The samples included 26 mesopelagic fish species or types belonging to 13 genera. A peak abundance of the total mesopelagic fish larvae was during May to June.**
- **The dominant 12 taxa showed marked seasonality with high abundances in one particular period (*i.e.* Winter, Spring, Early summer, and Autumn groups), although year round occurrence was also observed (*i.e.* Year-round group).**
- **No significant difference was observed in the seasonal occurrence patterns, suggesting that each species has a fixed seasonal pattern of reproduction.**

References

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