Reproductive biology of *Benthosema pterotum* (Myctophidae) in the shelf region of the East China Sea

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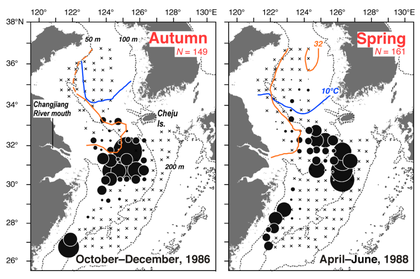
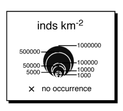
1. Introduction – biology of *B. pterotum*

Distribution and biomass

Myctophid fishes are one of the most abundant and widespread mesopelagic fish groups in the world oceans, being key species in ecosystems[1]. Of these, some species occur associated with submerged bottom features such as islands, seamounts, and continental edge-slope regions (so-called pseudoceanic species)[1,2].

Benthosema pterotum is a typical pseudoceanic myctophid, and dense distributions were observed in the ECS shelf (mainly 40–90 m depth) in all seasons[2]. The biomass was estimated in the order of several thousands to several tens of thousands of metric tons in the area[2].



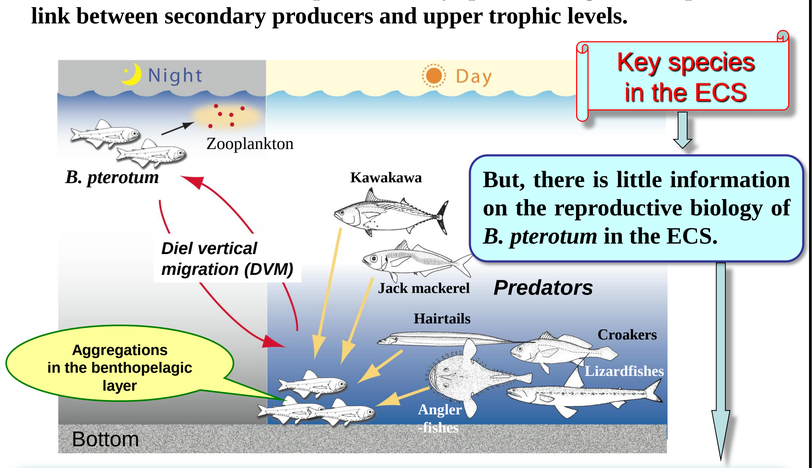


Horizontal distributions of *B. pterotum* in the ECS, based on data from daytime bottom trawl surveys[2].

Trophic position in the food web

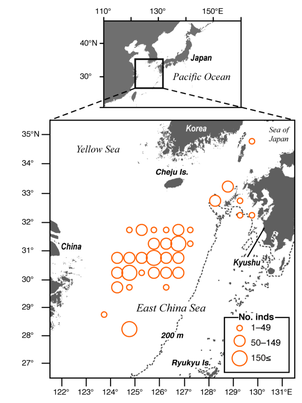
B. pterotum occurs in the epipelagic layer at night, and shifts down to the benthopelagic layer during the daytime to form dense aggregations[2,3]. The prey items of *B. pterotum* are mainly composed of zooplankton[3].

B. pterotum form a major prey item for both pelagic and demersal fishes, including many commercially important species in the shelf region of the ECS[2,3]. Therefore, this species is a key species acting as an important link between secondary producers and upper trophic levels.

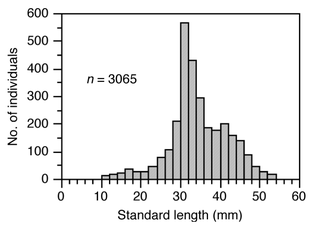


In this study, we examined the sex ratio, sexual maturity, spawning period, oocyte development, and batch fecundity of *B. pterotum* in the ECS.

2. Sample collection & general biological data



B. pterotum were collected during 31 cruises in the shelf region of the ECS and its adjacent area in 1999 and from 2004 to 2009. A total of 3,065 specimens ranging from 10.7 to 54.8 mm standard length (SL) were used in this study.

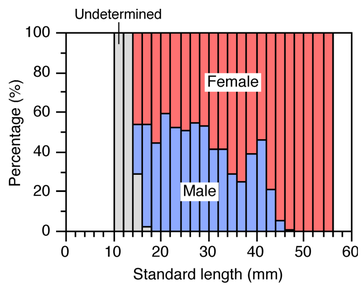


The *SL*, body weight (*BW*), gonadal weight (*GW*) and liver weight (*LW*) were measured and sex was determined for all specimens. Gonadosomatic index (*GSI*) and hepatosomatic index (*HSI*) were calculated using the following equations:

$$GSI = GW/BW \times 100 \qquad HSI = LW/BW \times 100$$

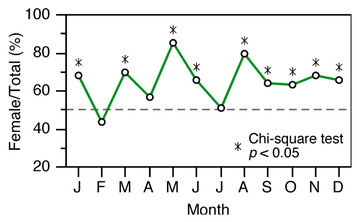
3. Sex ratio

In fish >14 mm SL it was possible to distinguish between the sexes. Between 14 and 30 mm SL, the ratio of females to males was *ca.* 50%, it increased with SL and all individuals ≥46 mm SL were females.



This might relate to sexual differences in growth rate and life span, i.e. faster growth and longer life span in females than those in males. In several myctophid species, females grow faster than males and reach a larger maximum size[4].

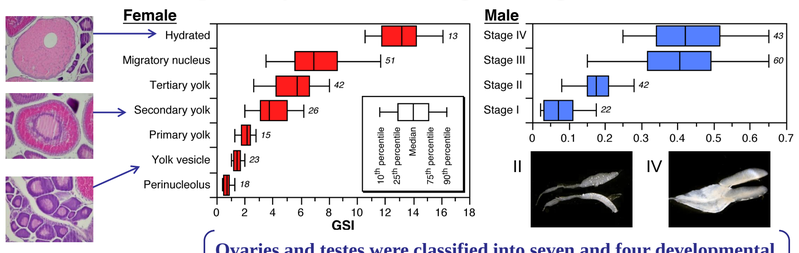
The preponderance of females over males was significant throughout the year, i.e. there were more females than males.



This would result in a greater biomass of mature females than that of males, possibly is an adaptation to maximize the egg-producing biomass.

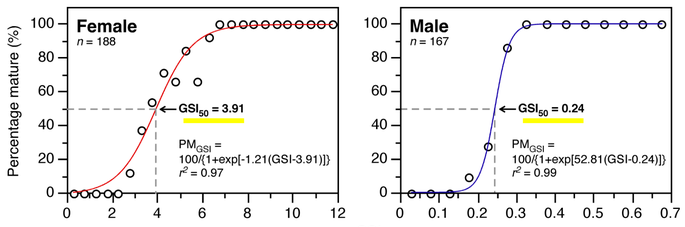
4. GSI *vs.* developmental stages of gonad

[a] The GSI was positively correlated with gonad stages in both sexes.



Ovaries and testes were classified into seven and four developmental stages based on Yamamoto[5] and Dalpadado[6], respectively.

[b] The GSI at 50% sexual maturity (GSI_{50}) of females and males was 3.91 and 0.24, respectively, based on fitting to a logistic function.

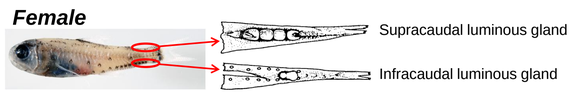


Females with tertiary yolk, migratory nucleus, and hydrated stages and males with stage III and IV were considered reproductively mature[6].

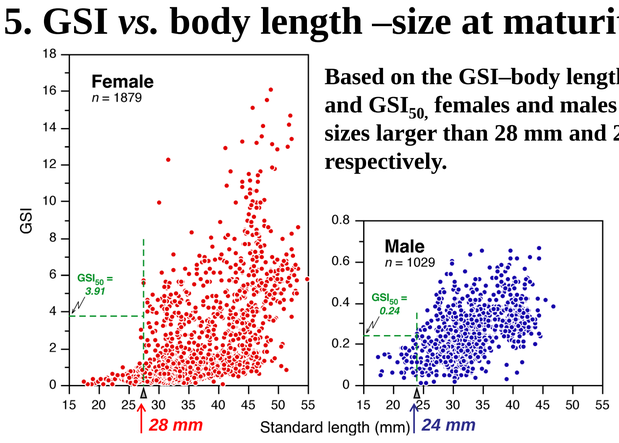
[c] The GSI in males was much lower than females, as reported for several other myctophid species[7].

Generally, in pelagic fishes that release eggs and sperm into the pelagic layer, males show comparable GSI values to those of females, thus *the low GSI of male B. pterotum suggests that there is a mechanism related to efficient mating and fertilization.*

Since sexual dimorphism in luminous organs is known in *B. pterotum*, as in most myctophids[8], bioluminescent sexual signaling might be used to facilitate communication between sexes at night, and this possibly is related to efficient mating?



5. GSI *vs.* body length –size at maturity–



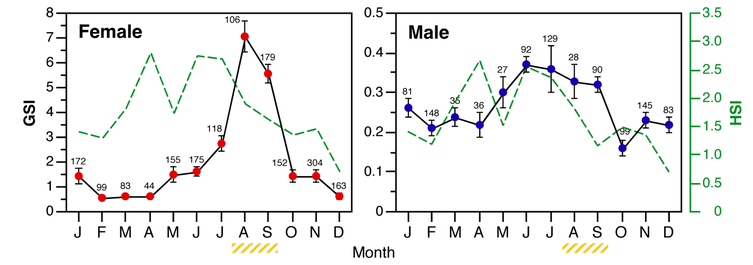
Based on the GSI–body length relationships and GSI_{50}, females and males can mature at sizes larger than 28 mm and 24 mm SL, respectively.

Males mature at smaller sizes than females, as in some other reported myctophid species[7,9].

6. Monthly changes in GSI and HSI

Mean GSI of females (≥28 mm SL) peaked sharply during August to September. Mean GSI of males (≥24 mm SL) was high during May to September, showing an earlier and longer peak than that of females.

In both sexes, mean HSI peaked during April to July, and declined during August to September, indicating storage of energy for reproduction.



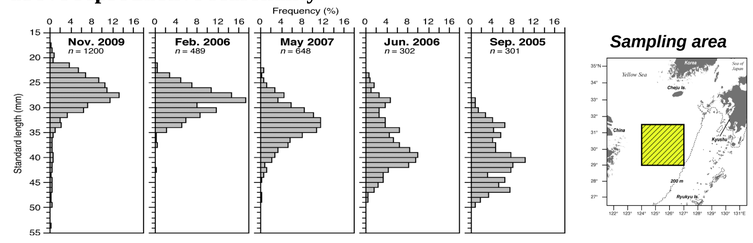
The primary spawning period was during August to September.

In the sampling area,

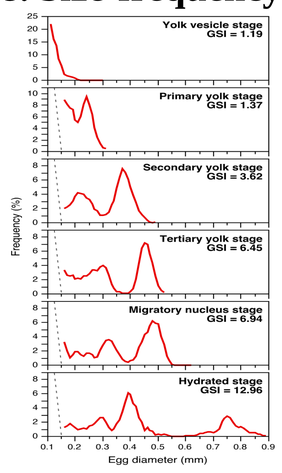
- Water temperature during August to September is the highest of the year, with a mean SST of *ca.* 23–29˚C[2].
- *B. pterotum* larvae occur abundantly during late summer to autumn[3], corresponding with the present results.

7. Seasonal change of body size distribution

Based on data from seasonal bottom trawl surveys, small individuals of *B. pterotum* began to occur abundantly in autumn, and modal body lengths increased progressively during spring–summer, corresponding with the above reproductive seasonality.



8. Size-frequency distribution of oocytes

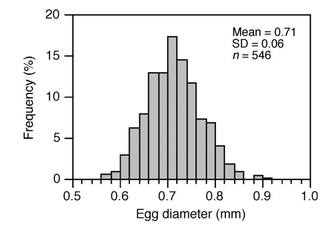


The size of all the oocytes in a cohort gradually increased in synchrony with ovarian development. As an advanced group of the oocytes reached the secondary yolk stage, they form a clear separate mode that is distinct from adjacent groups of smaller oocytes.

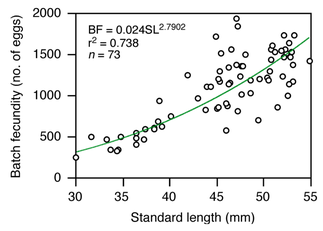
This multi-modal oocyte size frequency showed that *B. pterotum* are multiple spawners within a spawning season.

Two to four modes of oocyte size frequencies have been reported in some other myctophids[7,9], corresponding with our results.

9. Egg size and batch fecundity (BF)



Egg size of *B. pterotum* at the hydration stage ranged from 0.55 to 0.85 mm. In many other myctophids, the egg size ranges from 0.45 to 0.8 mm[7,9], i.e. that of *B. pterotum* appears to be slightly larger than these reports.



BF was positively correlated with SL, ranging from 253–1,942 eggs in fish from 30.1–54.8 mm SL. This fell within the reported ranges on other myctophids of similar-sized species[7,9].

To determine BF, specimens having ovaries containing tertiary yolk, migratory nucleus, and hydrated oocytes were used. We counted the number of oocytes in the most advanced mode.

Considering that *B. pterotum* produce slightly larger and a similar number of eggs compared to other myctophids, they might have higher energetic costs for reproduction.

10. Conclusions

- There were more females than males, and the ratio of females to males increased with SL.
- The GSI_{50} of females and males was 3.91 and 0.24, respectively, and the GSI in males was much lower than females.
- Females and males can mature larger than 28 mm and 24 mm SL, respectively.
- *B. pterotum* are multiple spawner within a spawning season, and the primary spawning period is during August to September.
- Egg size ranged from 0.55–0.85 mm and batch fecundity ranged from 253–1,942 eggs.

References

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