# Investigating the number and colour of photophores in *Maurolicus muelleri*

Anette Aune, Adam Haugen Mortensen, Joseph Cormac Lawrence, and Kristian Rørhus Fjeld

Image of fjord bros

## Muller's Pearlside

Mesopelagic fish constitute a large portion of the world's ocean biomass[1]. There is much discussion considering the potential for exploitation in world fisheries, however there are substantial gaps in knowledge concerning the biology of these species.

Mueller's pearlside (*Maurolicus muelleri*) is a cosmopolitan mesopelagic fish and is one of the dominating species in Norwegian fjords[2]. Since pearlside is an important part of the food web of fjords, its ecology is well described[3].

Pearlside has distinct light organs (photophores), and little is known of the relationship between the species' life history traits (body condition, depth preference, and age) and these organs.

Photo by Dr Joan Soto-Angel

## Bioluminescence & Photophores

Bioluminescence is a wide-spread trait in the ocean. It is estimated that ~ 90 % of all fishes have bioluminescence[4]. Pearlside use bioluminescence for counterillumination to hide its silhouette from predators underneath them and therefore has many photophores on its ventral side. Pearlside have usually developed most of their photophores when they're between 5-20 mm[5]. Adult individuals have been consistently observed to have a maximum of 138 photophores[6].

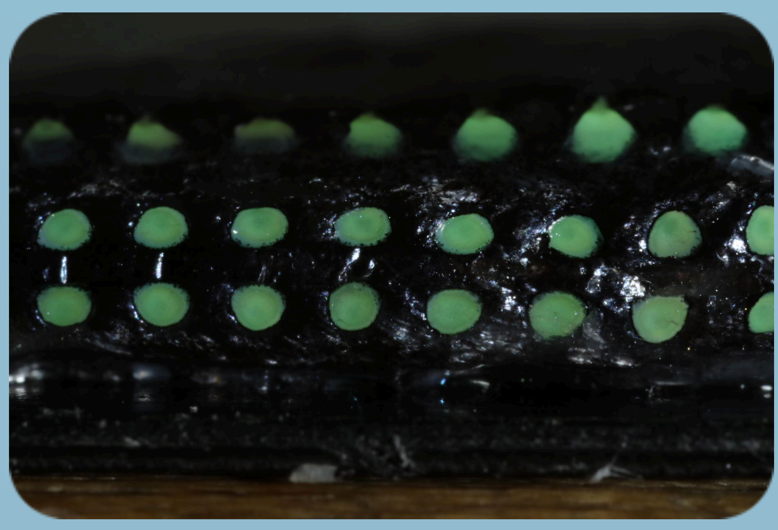


Photo by Dr Joan Soto-Angel

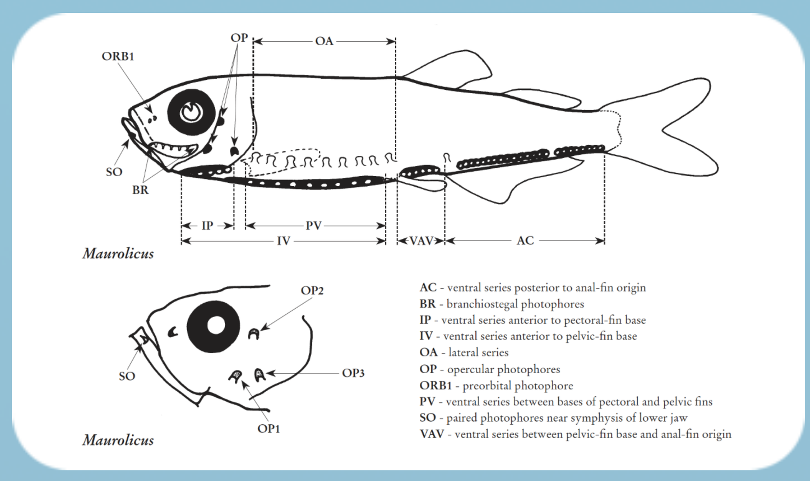


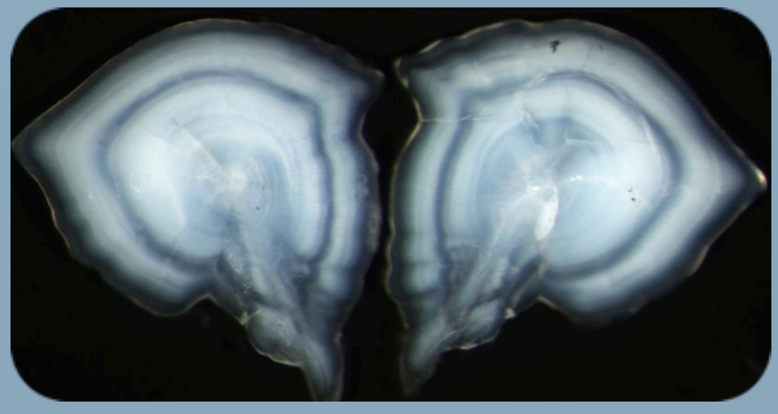

Illustration of photophore distribution in *Maurolicus* genus[7]

Photophore number may be genetically determined, but whether other factors control this is yet to be described. The metabolic cost of producing photophores is unknown in this species[3]. If the cost of photophore development is high, there would be a trade-off between amount of photophores and other life history traits such as body condition, size, and reproductive effort.

## Methods

Study was conducted between 24.-30. Sept 2022 in Masfjorden and Fensfjorden in Norway on research vessel G.O. Sars. A multisampler was used to collect samples at three fixed depths (300-200m, 200-100m, 100-0m).
34 individuals were randomly selected from each depth and bagged. Individuals were length measured using standard length. Photophore colour was recorded for each individual as pink or green.

In the lab, weight was calculated by weighing the individuals and subtracting the bag weight. The number of photophores were counted followed protocol describe by Sutton et al. (2020). To age the fish, the sagittal otoliths were removed from 25 of the 34 individuals.
Body condition was then calculated using Fulton's body condition factor K (Fulton, 1904). Subsequent analysis comparing the photophore number and colour to environmental factors and body condition was conducted in R.



## Our Findings

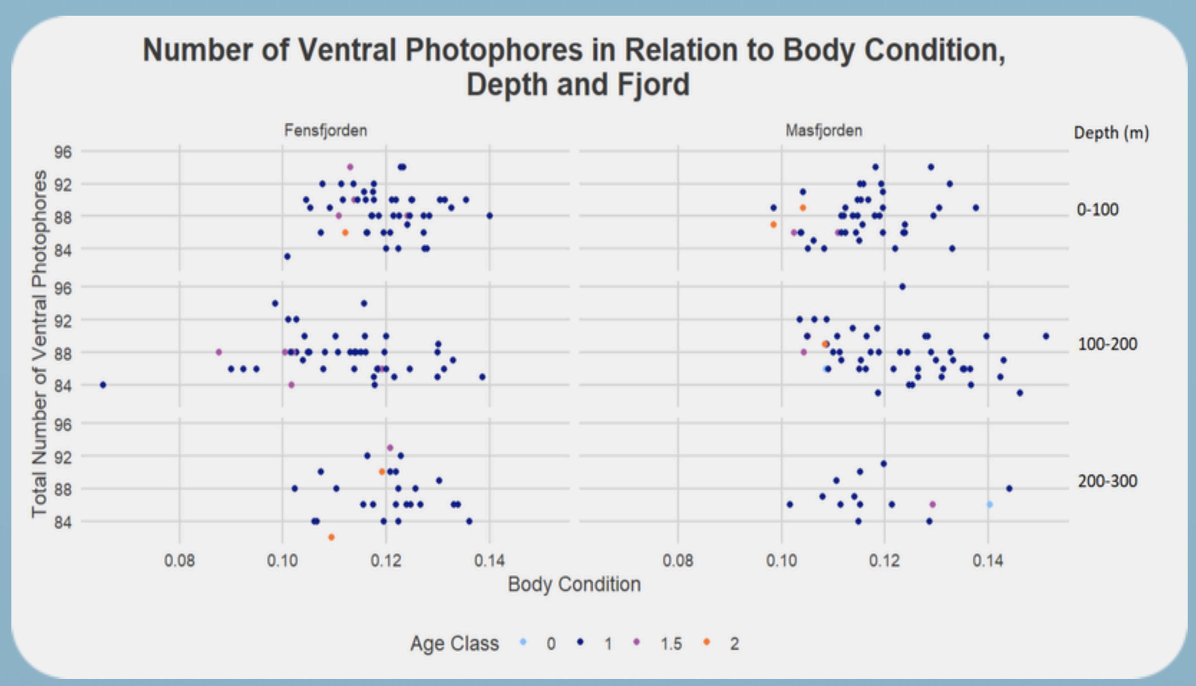



Figure 1: Scatterplot showing the relationship between number of ventral photophores of *Maurolicus muelleri* in relation to body condition, depth, in the two fjords Masfjorden and Fensfjorden

The mean number of ventral photophores was 87.9 ± 2.62. There was no significant relationship in photophore number related to body condition ($p = 0.3269$), between the two fjords ($p = 0.7134$), or with age ($p = 0.6806$).

There was, however, a significant difference in number of photophores in relation to depth ($p = 0.03284$), with the mean number of photophores being: 0-100m = 87.1 ± 2.59, 100-200m = 87.7± 2.50, 200-300m = 88.4 ± 2.67.

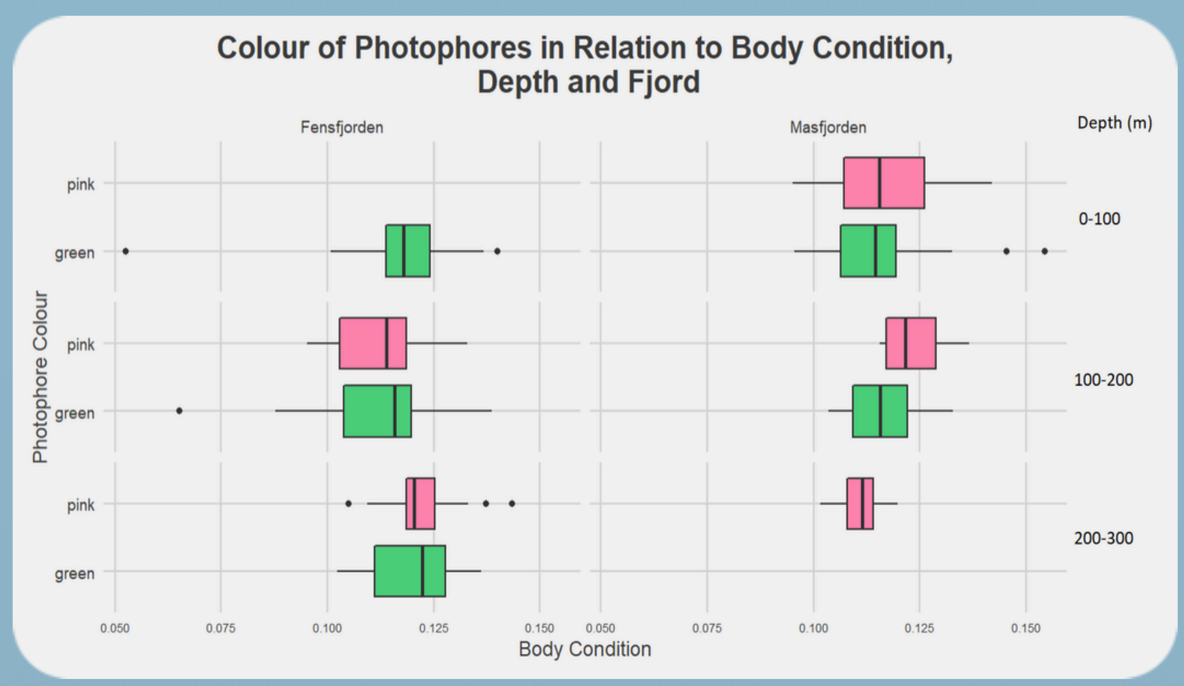



Figure 2: Box-plot showing the relationship between photophore colour of *Maurolicus muelleri* in relation to body condition, depth, in the two fjords Masfjorden and Fensfjorden

In total, 75% had green photophores, 25% had pink. In Fensfjorden, 78% were green and 22% were pink. In Masfjorden there were 69% green and 31% pink.

A three-way ANOVA showed no significant trend in the colour distribution between the fjords ($p = 0.64756$), between the different depth layers ($p = 0.06382$), or the body condition ($p = 0.15487$).

## Discussion

The only significant result seen was between the number of photophores and depth, which showed an increase in total numbers with decreasing depth. However, it is likely this result is unreliable due to a small sample size.

Generally, there was no significant relationships between number or colour of photophores with any life history traits. This, however, could be explained by certain limitations of the project

- Time of trawling: samples were only collected at night
- Age: overwhelming majority of fish were 1 year old
- Trawling method: only using fixed depths

Photophore number and colour could be related to other variables like sex, time of day (diel vertical migrations), or genetics.

The large variation in photophore number could be a result of them being used in species recognition, and as Mueller's pearlside is isolated from other *Maurolicus* species in these fjords there may not be a selection pressure to uphold a distinct number of photophores.

A bigger sample size and samples from both day and night would improve the liability of the results. Targeting echo layers of pearlside would improve the quality of depth data. Sampling pearlsides from other ecosystems such as the open ocean and other fjords could give insight into whether photophore variation only occurs in fjords.

Biochemistry and light emission of the photophores should also be studied, in terms of differences in colour.

Population genetic methods could be used to define the populations within the fjords and between oceanic populations to investigate gene flow and isolation.

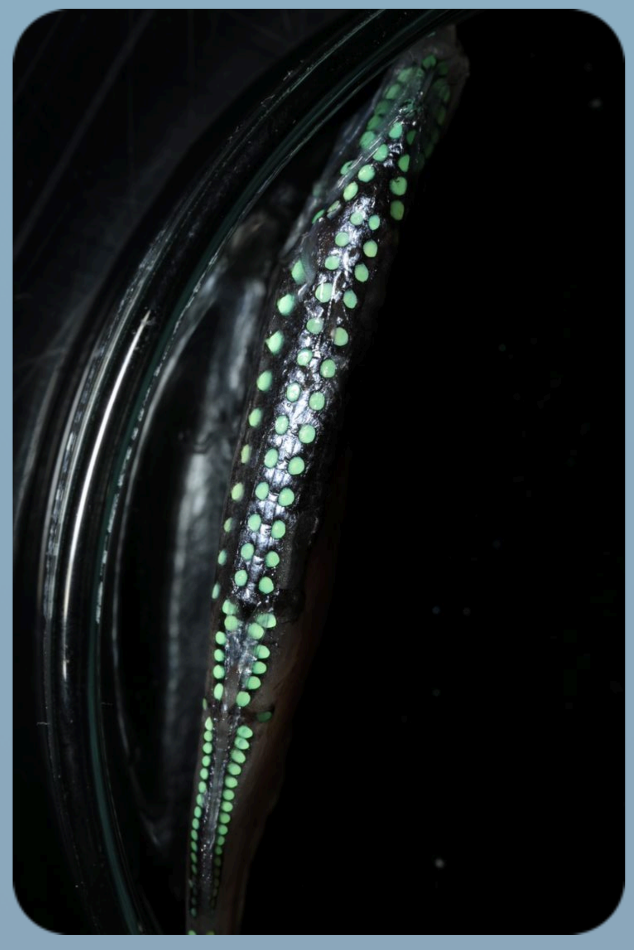


Photo by Dr Joan Soto-Angel

## References

1. Irigoien, X., Klevjer, T., Røstad, A., Martinez, U., Boyra, G., Acuña, J., Bode, A., Echevarria, F., Gonzalez-Gordillo, J., Hernandez-Leon, S., Agusti, S., Aksnes, D., Duarte, C. and Kaartvedt, S. (2011b). Large mesopelagic fishes biomass and trophic efficiency in the open ocean. Nature communications, 5(3271). doi:10.1038/ncomms4271.

2. Staby, A., Srisomwong, J. and Rosland, R. (2013). Variation in DVM behaviour of juvenile and adult pearlside (Maurolicus muelleri) linked to feeding strategies and related predation risk. Fisheries Oceanography, 22(2), pp.90–101. doi:10.1111/fog.12012.

3. Folkvord, A., Gundersen, G., Albretsen, J., Asplin, L., Kaartvedt, S. and Giske, J. (2016). Impact of hatch date on early life growth and survival of Mueller's pearlside (Maurolicus muelleri) larvae and life-history consequences. Canadian Journal of Fisheries and Aquatic Sciences, 73(2), pp.163–176. doi:10.1139/cjfas-2015-0040.

4.Herring, P. (1978). Bioluminescence in action. Academic Press, 1978

5. Rodrigues-Ribeiro, M., Suzuki, K. and Martins, R.S. (2022). Early development of pearlside Maurolicus stehmanni off south-eastern Brazil. Journal of Fish Biology, 100(2), pp.519–531. doi:10.1111/jfb.14962.

6. Cavallaro, M., Mammola, C.L. and Verdiglione, R. (2004). Structural and ultrastructural comparison of photophores of two species of deep-sea fishes: Argyropelecus hemigymnus and Maurolicus muelleri. Journal of Fish Biology, 64(6), pp.1552–1567. doi:10.1111/j.0022-1112.2004.00410.x.

7. Sutton, T.T., Hulley, P.A., Wienerroither, R., Zaera-Perez, D. and J.R. Paxton. 2020. Identification guide to the mesopelagic fishes of the central and south east Atlantic Ocean. FAO Species Identification Guide for Fishery Purposes. Rome, FAO. 2020. https://doi.org/10.4060/cb0365en

8. Fulton, T.W., 1904. The rate of growth of fishes. Fisheries Board of Scotland, Annual Report 22 part 3, pp. 141–241

UNIVERSITAS BERGENSIS