# Dynamic Linkage between Epipelagic and Mesopelagic Ecosystems by Horizontal and Vertical Migrations of Myctophids

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DEEP
Deep-Sea Ecosystem and Exploitation Programme
-Interaction between Epipelagic and Mesopelagic Ecosystems-
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# Marine Ecosystem beneath the Euphotic Layer

## *Epipelagic Ecosystem*

**Ecosystem components**

**Biomass of each component**

**Ecosystem dynamics**

## *Twilight Zone Ecosystem*

# Mesopelagic Ecosystem

No phototrouphs (heterotrophic ecosystem)

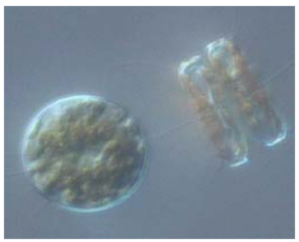
Dependent on export production from the EZ

Passive sinking particles are one of the drivers

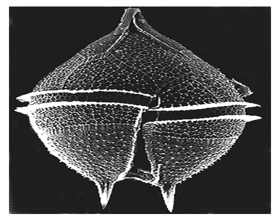
# Passive Sinking Particles

## Large particles, aggregates

Diatom/Phaeocystis

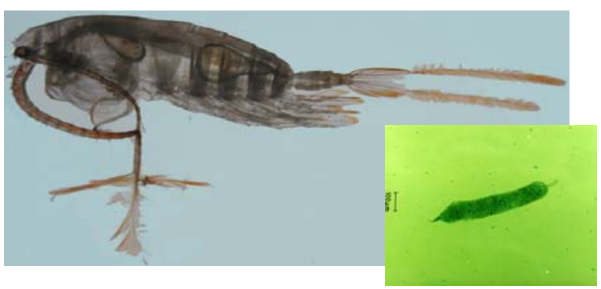


Heterotrophic dinoflagellate

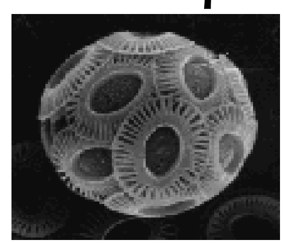


Tunicate/Appendicularian

Faecal pellet of macrozooplankton

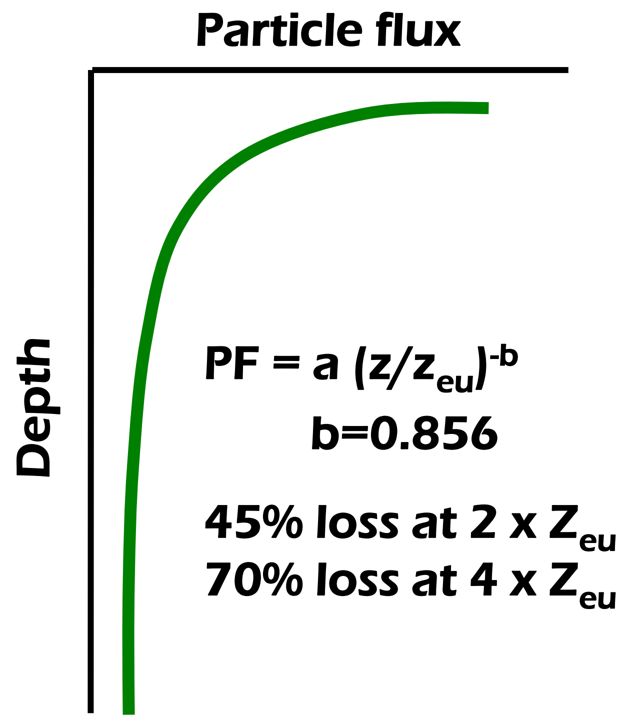


Coccolithophore



# Mesopelagic Ecosystem

## Passive sinking particles: rapidly decreasing with depth



# Mesopelagic Ecosystems

Nutrient max. ~ 1000 m

↓

Most particles are remineralized by bacteria and other organisims by reaching to 1000 m

# Faecal Pellets

Faeces of zooplankton (copepod, krill, salp, etc)
Packed in polysaccharide pellicles
Fast sinking particle (15-500 m $d^{-1}$)

Vertical flux of copepod faecal pellets gradually decreases with depth instead of fast sinking speed (Viitasalo et al. 1999)

Fecal pellet production and sedimentation are not well correlated (Svensen & Nejstgaard, 2003)

Vertical flux of faecal pellets comprise a minor fraction of sedimental material (Turner 2002, review)

Various organisms feed on sinking particle including faecal pellets. Most sinking particles are swiftly detected by mesopelagic organisms and fed, fractionated and/or repackaged, and finally remineralized by reaching ～by 1000 m

# Coupling of Epi- and Mesopelagic Ecosystems

Direct coupling between these ecosystems by sinking particles mostly occurs upper 1000 m

Bathypelagic ecosystem is connected to the epipelagic ecosystem by exceptionally large particles which occasionally sink to the bathypelagic layer, e.g., spring bloom diatoms, salp faecal pellets at salp-bloom, whale corpse, etc.

# Mesopelagic Ecosystem

**Dependent on export production from the EZ**

Passive sinking

Waiting for passively sinking particles
e.g., bacteria, detritivorous copepods, etc.

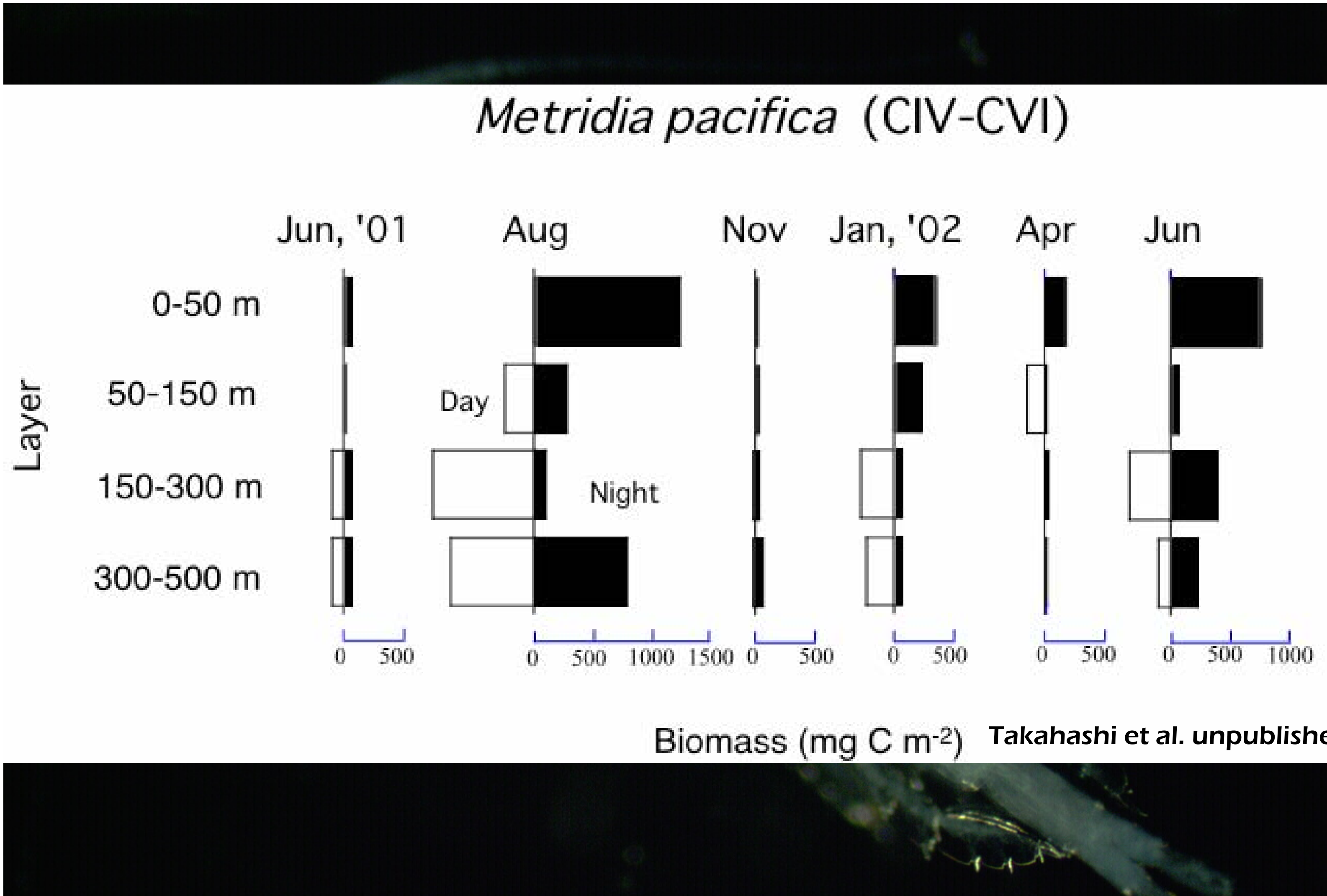
Vertical migration

Migrating to the euphotic zone and feed on EZ prey
e.g., mesopelagic copepods, pelagic decapods, micronekton

Migrating down to the mesopelagic layer from EZ and egest feces, being predated, respire.
e.g., ontogenetic migrating copepods, ommastrophid squids, marlins, sperm whales, etc.

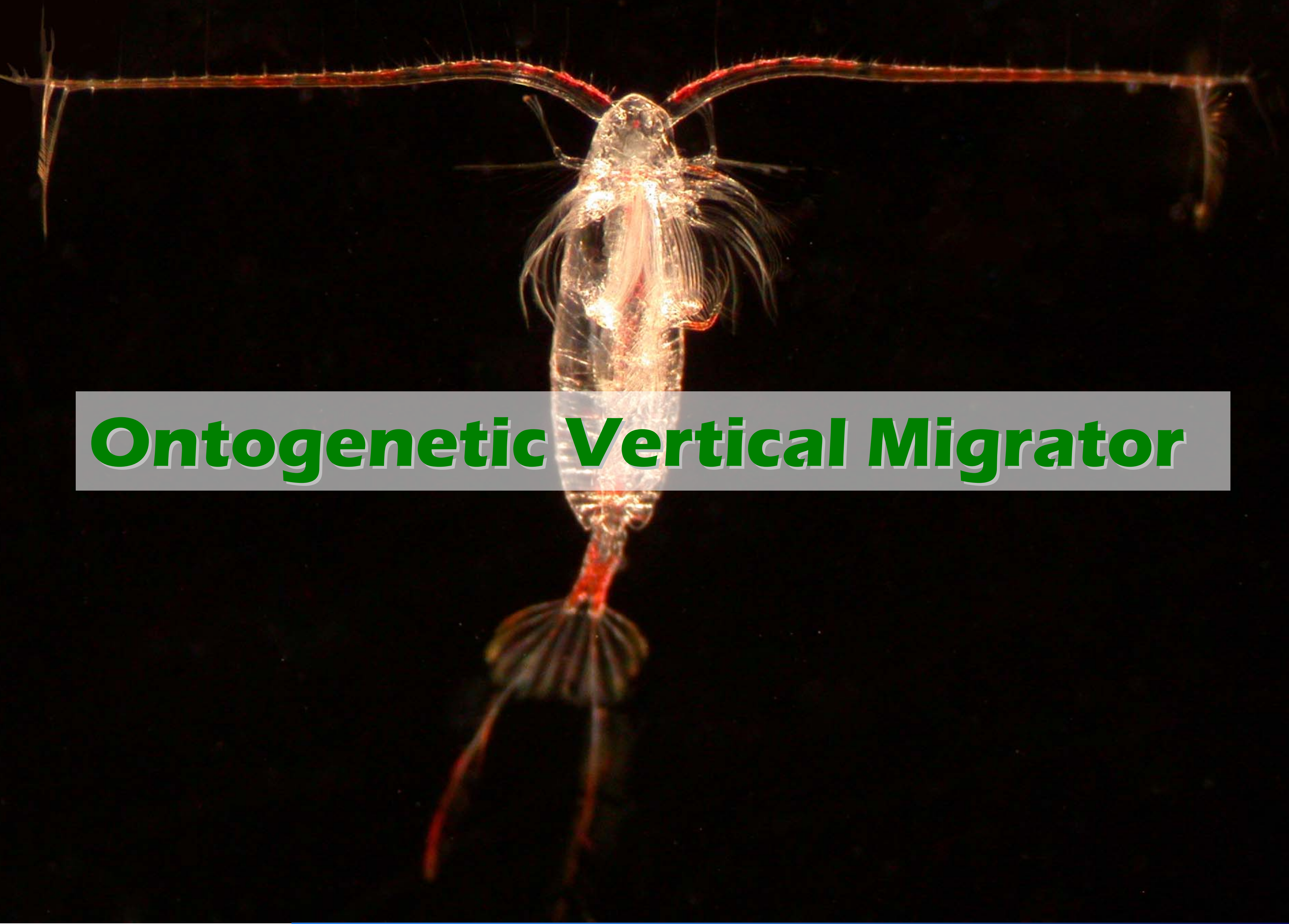
# Diel Vertical Migrator from EZ

# Diel Vertical Migrator

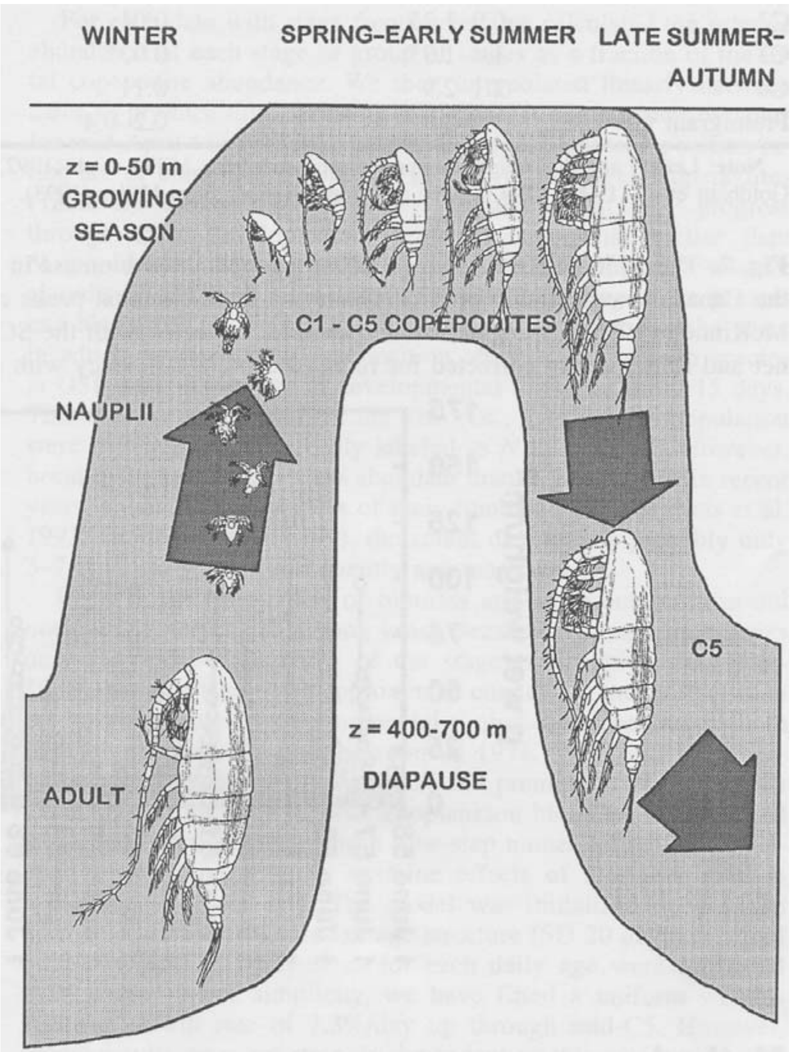



**Takahashi et al. unpublished**

# Ontogenetic Vertical Migrator

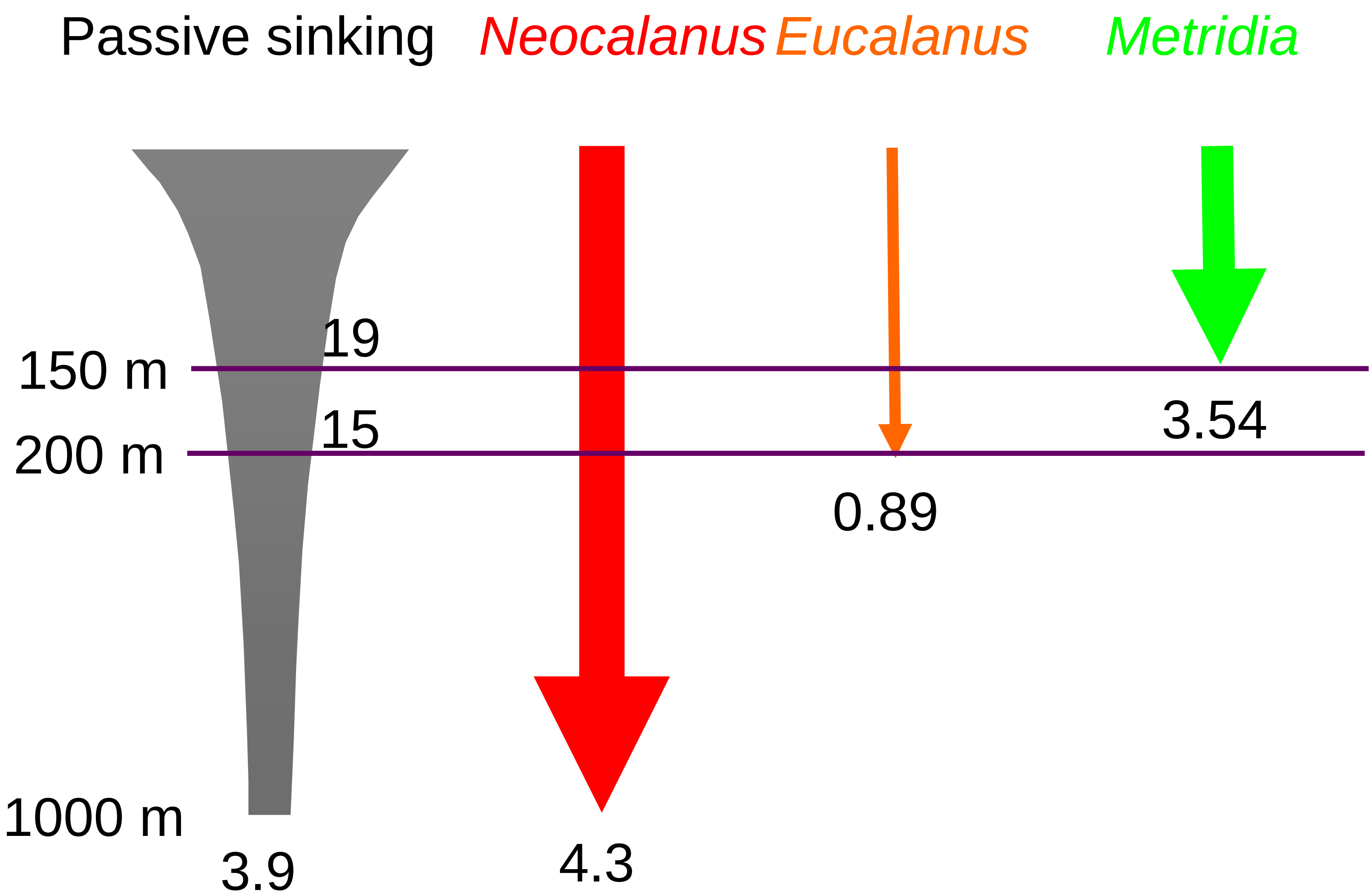


# Ontogenetic Vertical Migration

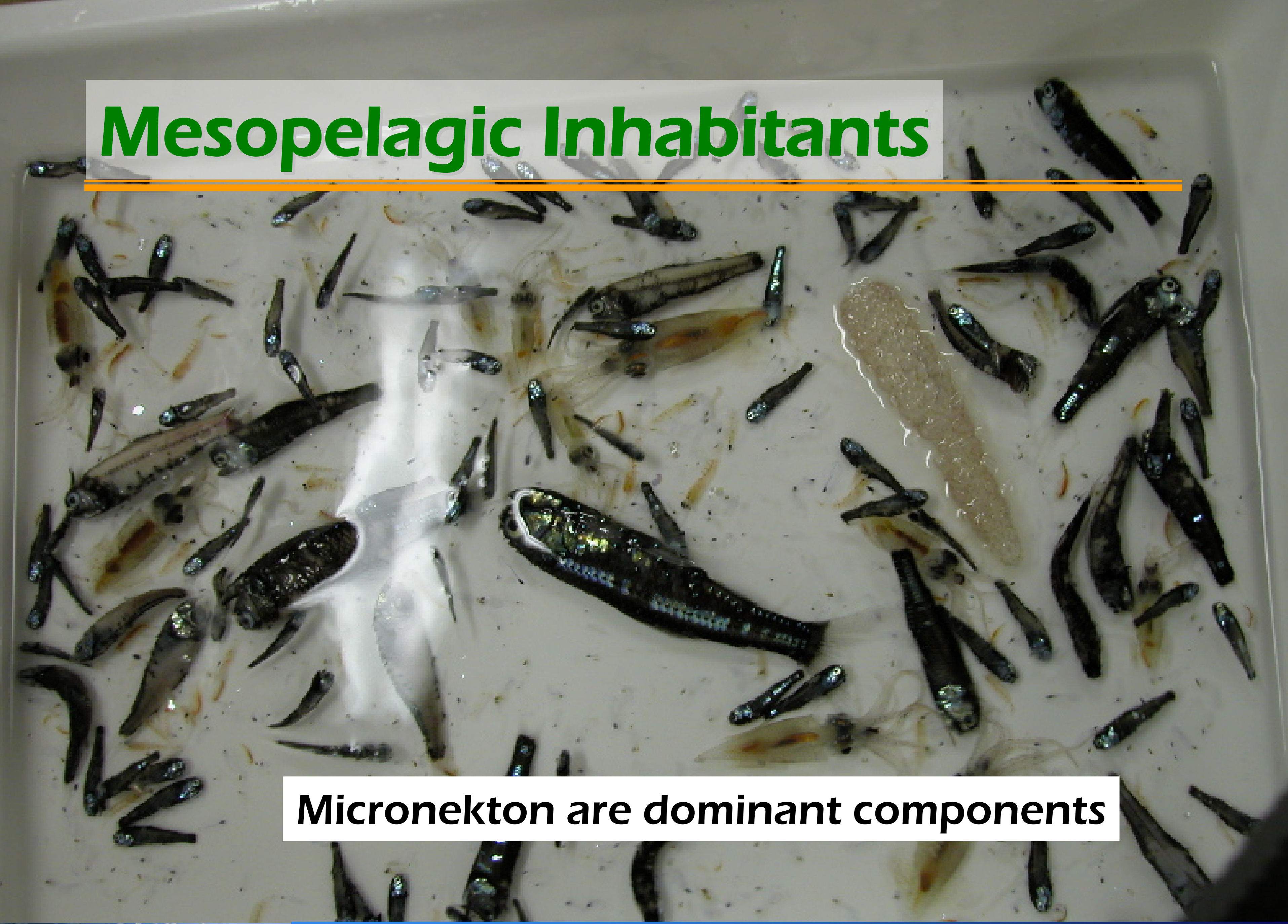



- *Neocalanus* spp. & *Eucalanus bungii*
- Feeding and growing in the epipelagic layer
- Overwinter at 300-2000m
- Reproduce using reserves w/o feeding *(Neocalanus)*
- Predation mortality is a main loss term

# C Transport by VM (gC $m^{-2}$ $y^{-1}$)



# Mesopelagic Inhabitants

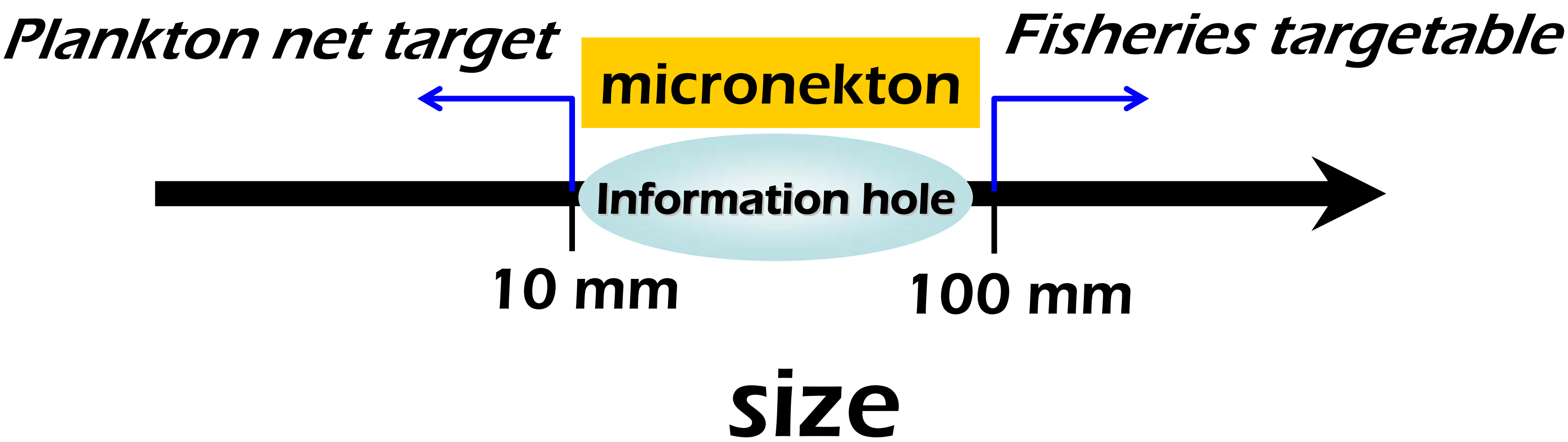


Micronekton are dominant components

# Overlooked Dominance

## Micronekton

Too fast for plankton nets
No fisheries
Costly sampling (gears, ship-time)



# Overlooked Dominance

**Myctophid:**

**$10^8$ ton in Northern N. Pac**

**Mesopelagic cephalopods:**

**Sperm whale feed on**

**$0.8\text{-}2 \times 10^8$ ton year$^{-1}$**

| | |
|---|---|
| Global fish landings: | $8 \times 10^7$ ton year$^{-1}$ |
| N. Pac salmon biomass: | $2\text{-}5 \times 10^6$ ton |
| Japanese sardine max. biomass | $1.8 \times 10^7$ ton |

# MOCNESS

MOHT

~5 knot

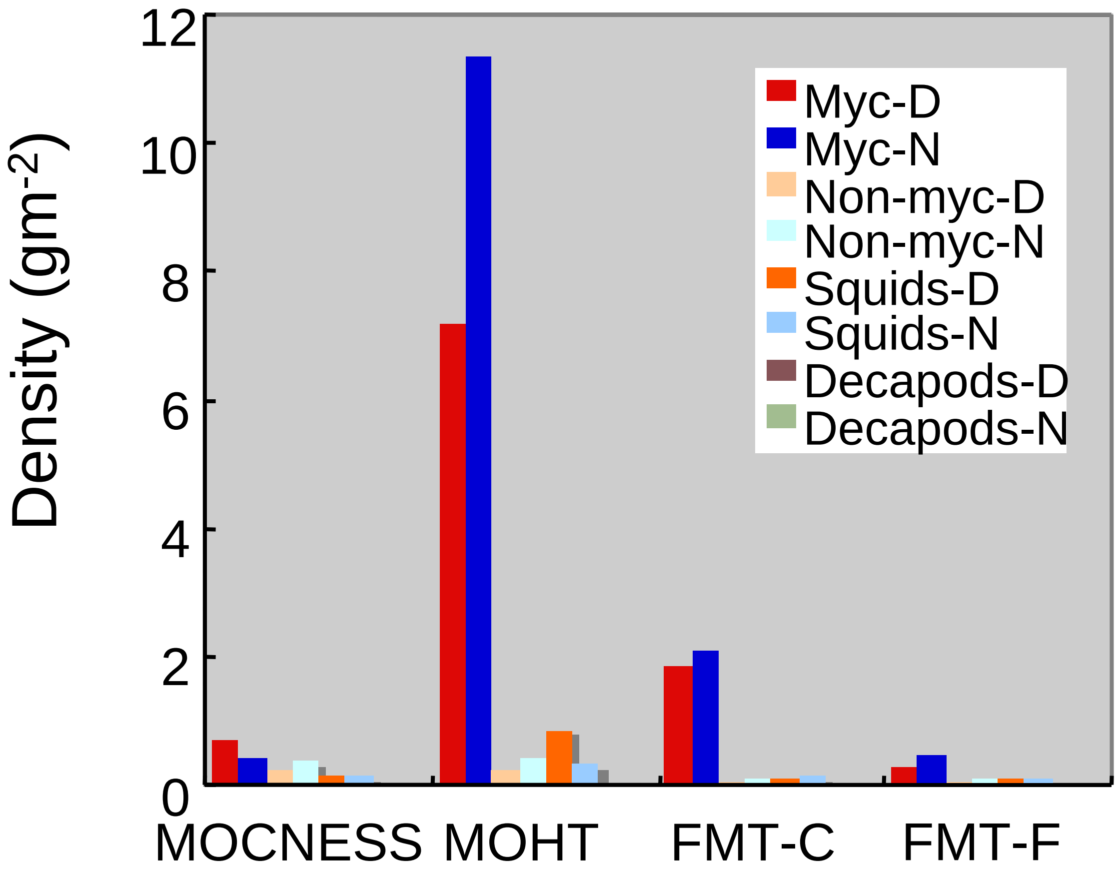
Unity mesh size


Frame trawl

# Midwater trawl

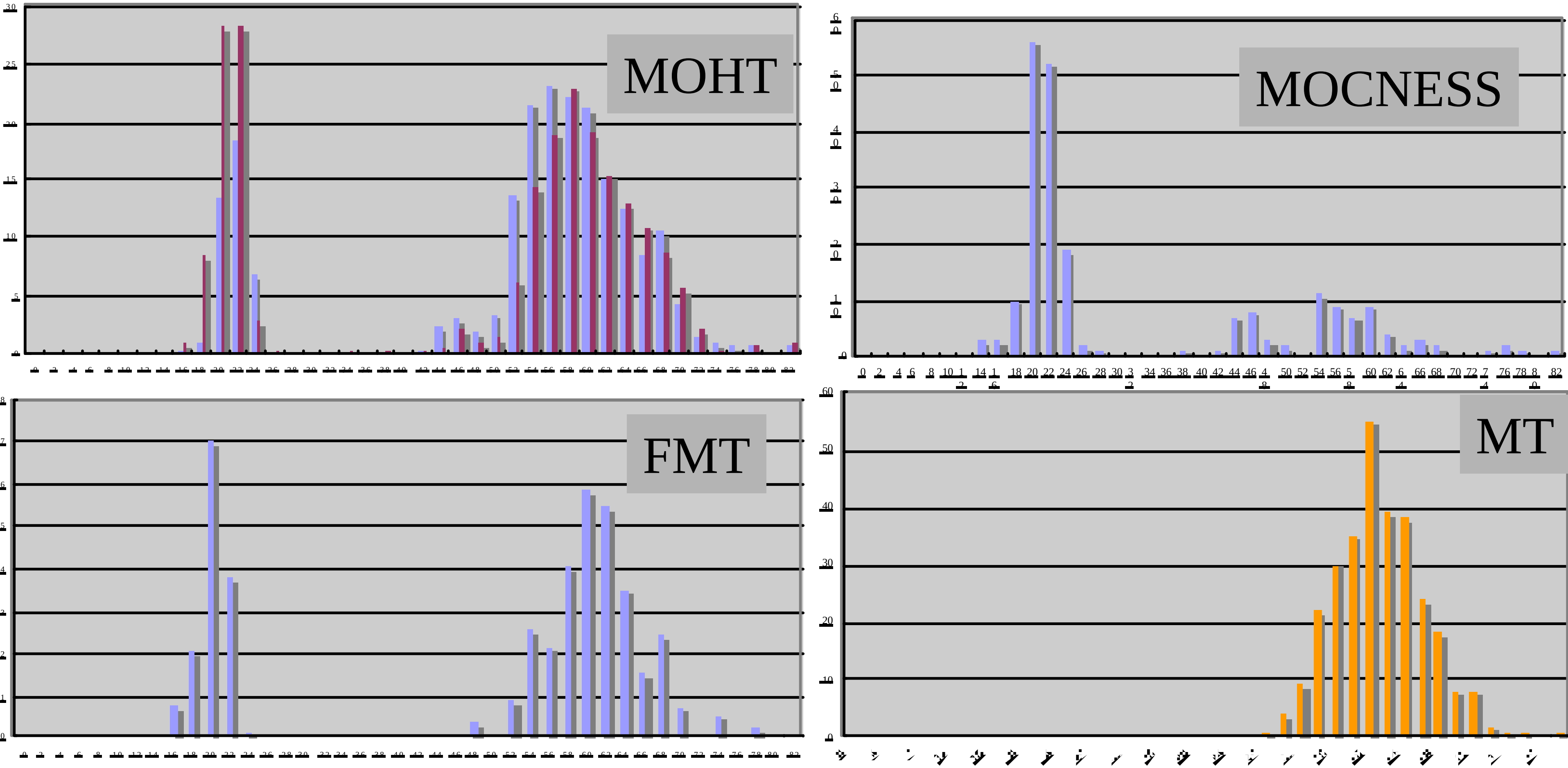

Multi-codend for midwater trawl

# Different Sampling Efficiency




**Yamamaura et al. W9-3193**

# Different Sampling Efficiency




size

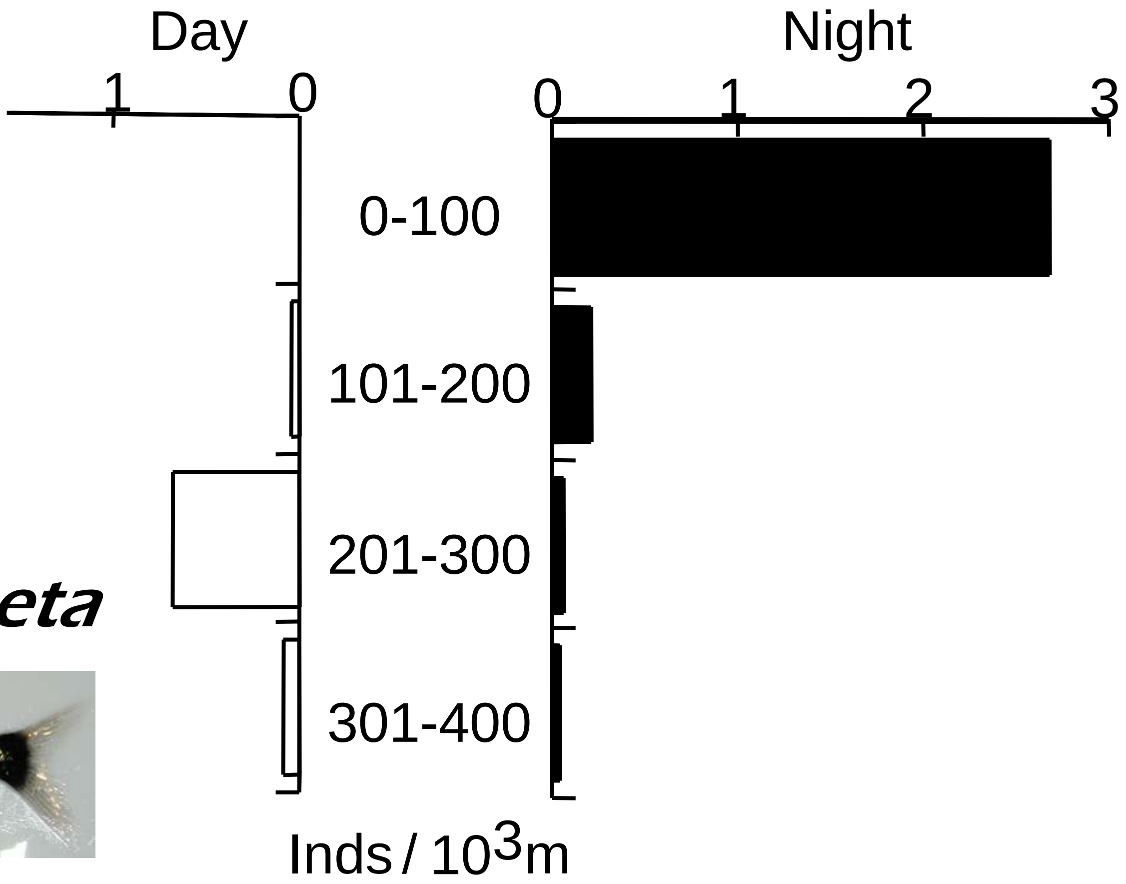
Yamamaura et al. W9-3193

# Biomass of myctophids

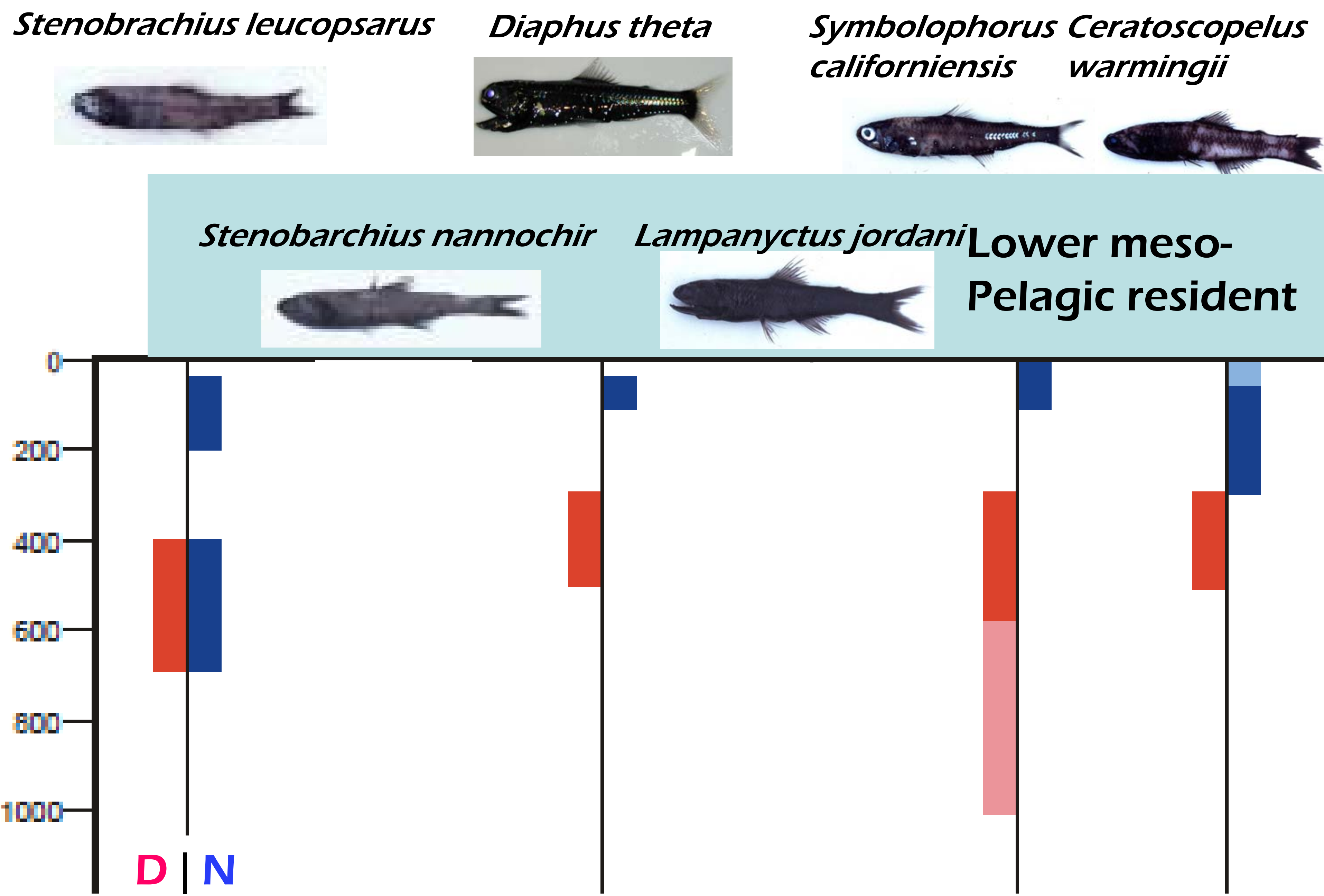
Acoustic surveys determined that myctophids biomass is >4 times of one estimated from MOHT net sampling and >10 times of MOCNESS sampling (Yasuma, Miyashita, Yamamura, W9)

Gjisaeter & Kawaguchi (1980) estimated myctophid biomass in the northern NP as $10^9$ ton using a factor of 10 from one obtained by various net samplings.

# Diel Vertical Migration

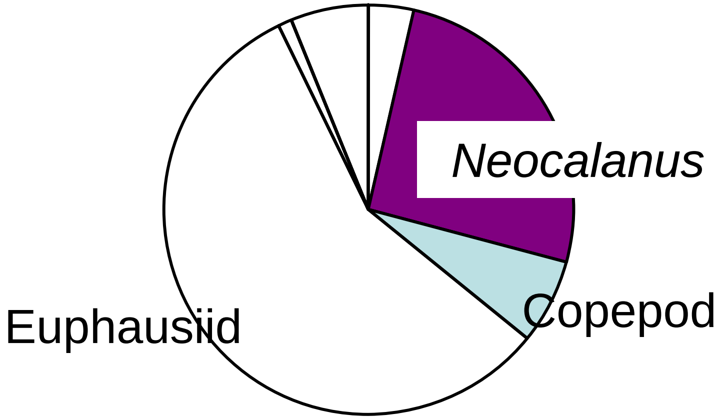



*Diaphus theta*

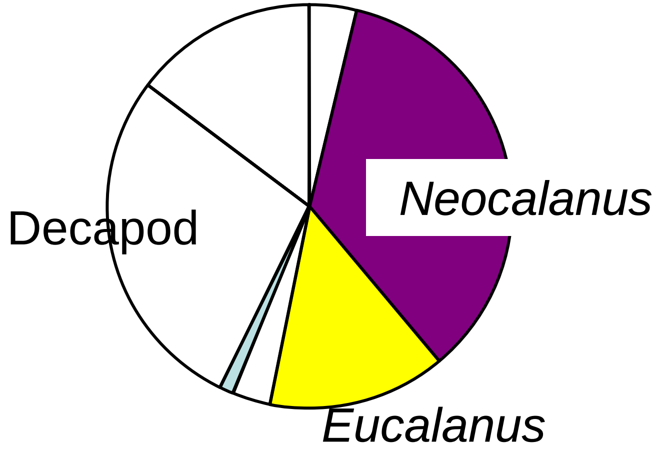

Stenobrachius leucopsarus
Diaphus theta
Symbolophorus californiensis
Ceratoscopelus warmingii
Stenobarchius nannochir
Lampanyctus jordani
Lower meso-Pelagic resident
0
200
400
600
800
1000
D | N

# Myctophids Prey (July)

**Vertical migrator**
**(*Diaphus theta*)**




**Lower mesopelagic resident**
**(*Stenobarchius nannochir*)**




**Sugisaki et al. S5-2985**

# Myctophid Predation

Biomass of *S. leucopsarus* 2.1 x $10^7$ tonnes (ww)
(Beamish et al., 1999)

Their daily ration is 3.0 % (Moku et al., 2000)

Annual Feeding 7.1 x $10^7$ tonnes (DW)

fraction of *Neocalanus* in prey during summer is 10-20 % (Moku et al., 2000) or higher (Sugisaki et al, W5).

Daily *Neocalanus* predation

5.5 - 11 x $10^{12}$ N. cristatus C5

or 32 - 64 x $10^{12}$ N. plumchrus C5

# Myctophid Predation

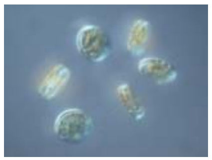
*S. nannochir* (non-migratory mesopelagic resident)

Their vertical distribution (mainly 500-700 m) is overlapped with the dormant depths of *Neocalanus*.

The daily ration of *S. nannochir* is estimated as 0.33 %, largely dependent on *Neocalanus* (>50 %, Beamish et al., 1999)

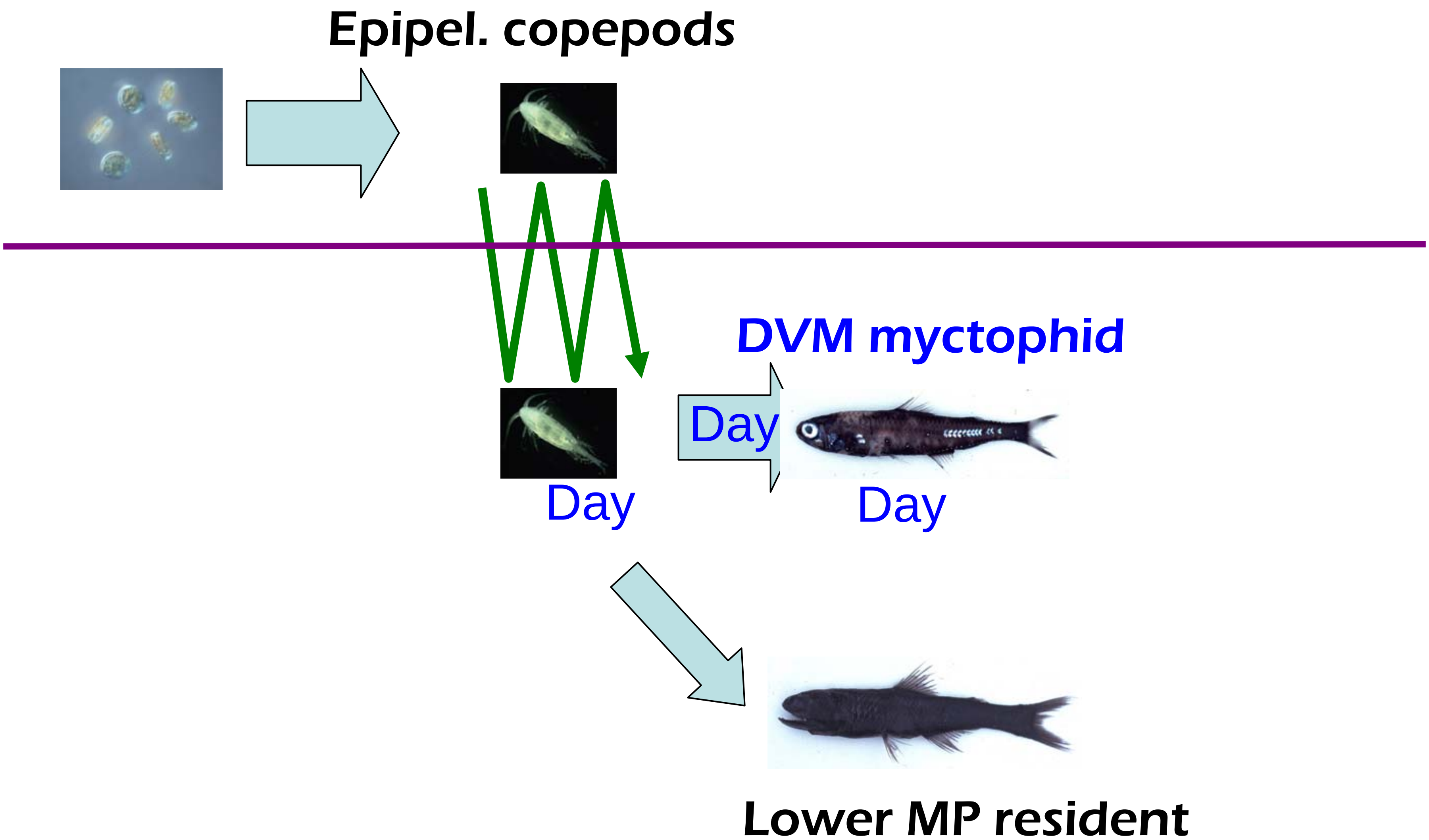
Their biomass is, unfortunately, unknown. It is estimated that their predation pressure is one of the important loss factors of *Neocalanus* during dormant and reproduction.

# Epi- and Mesopelagic Coupling



**Detritivors**
**Bacteria**

# Epi- and Mesopelagic Coupling



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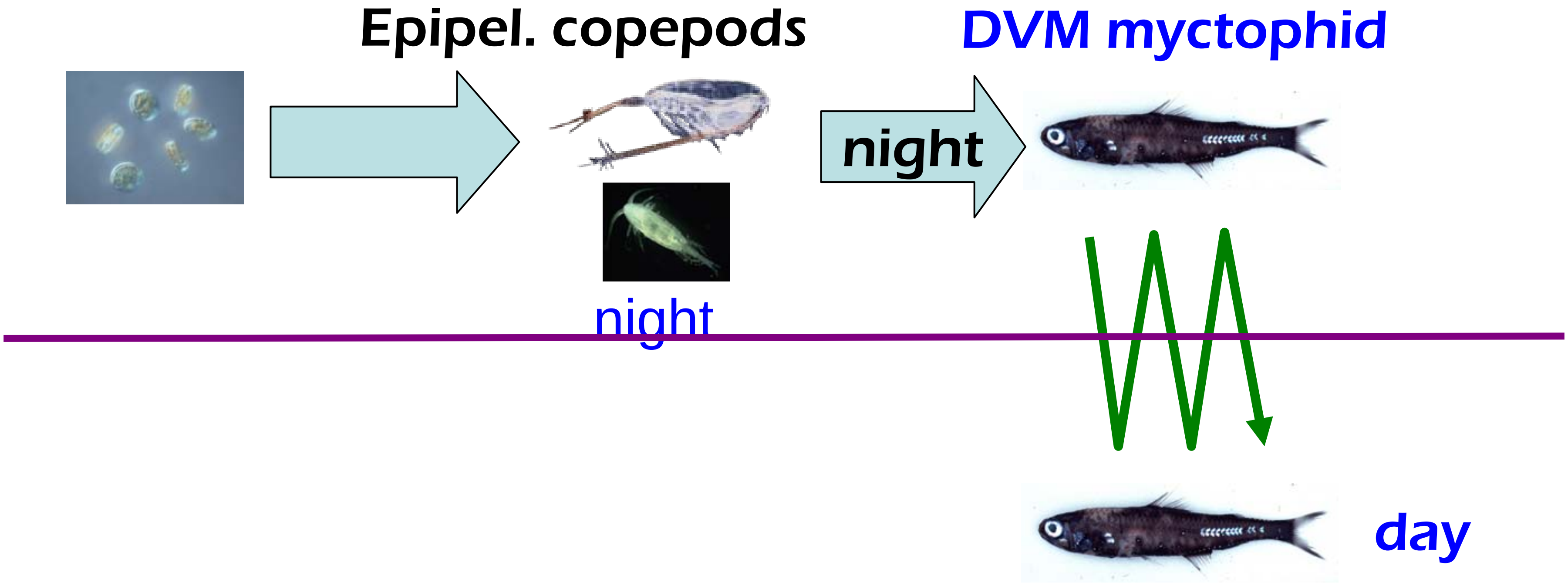

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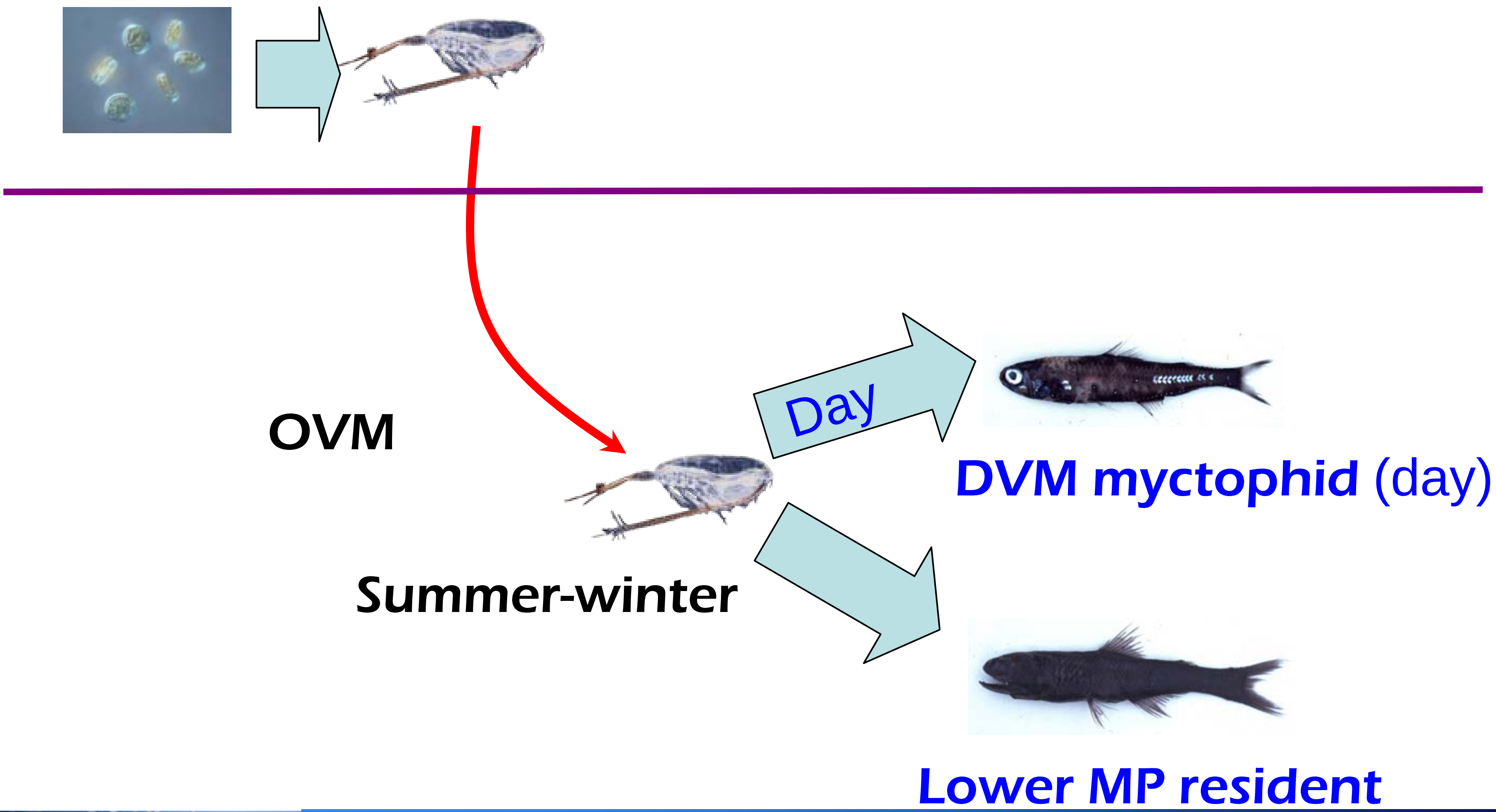

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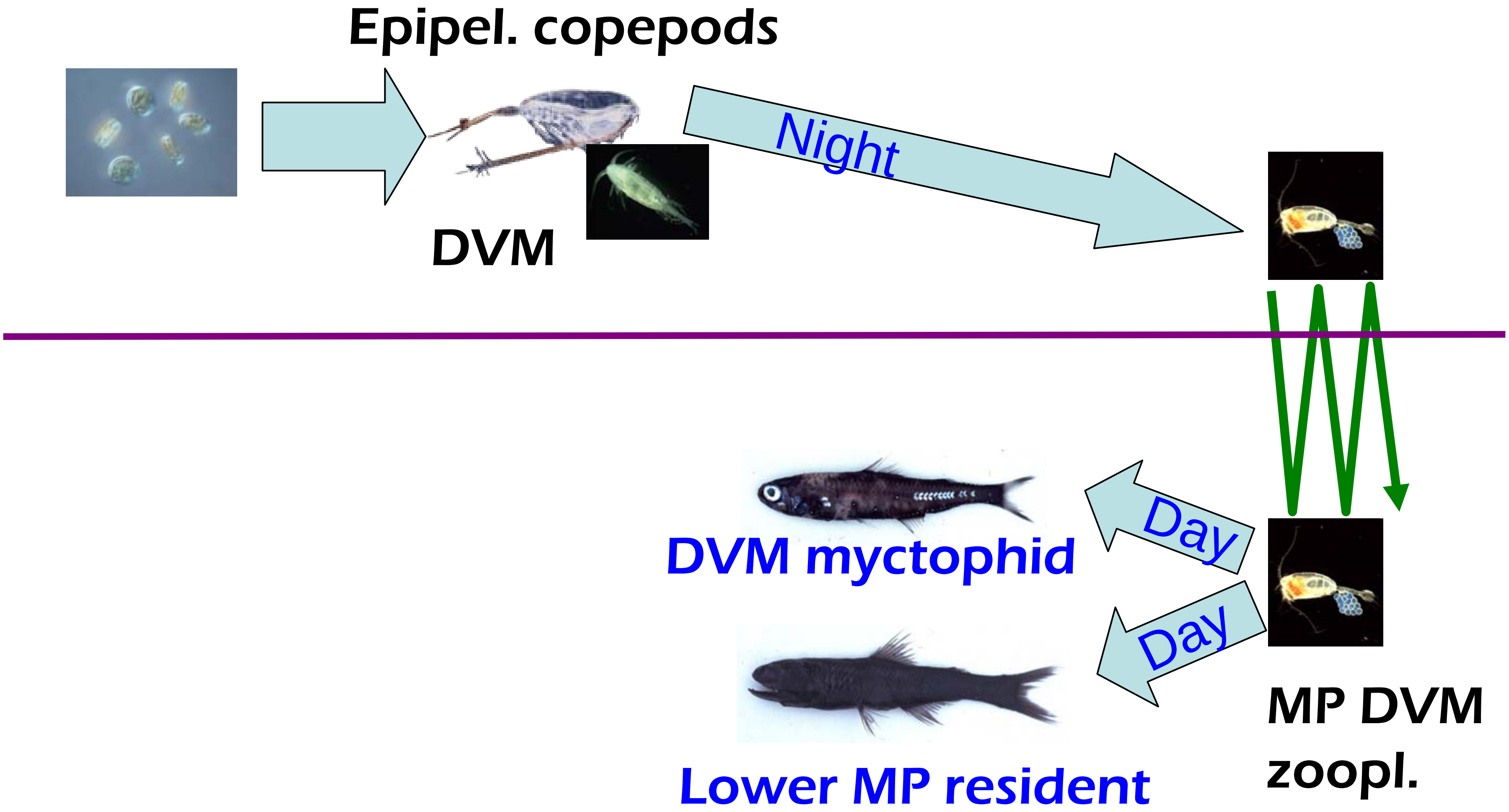

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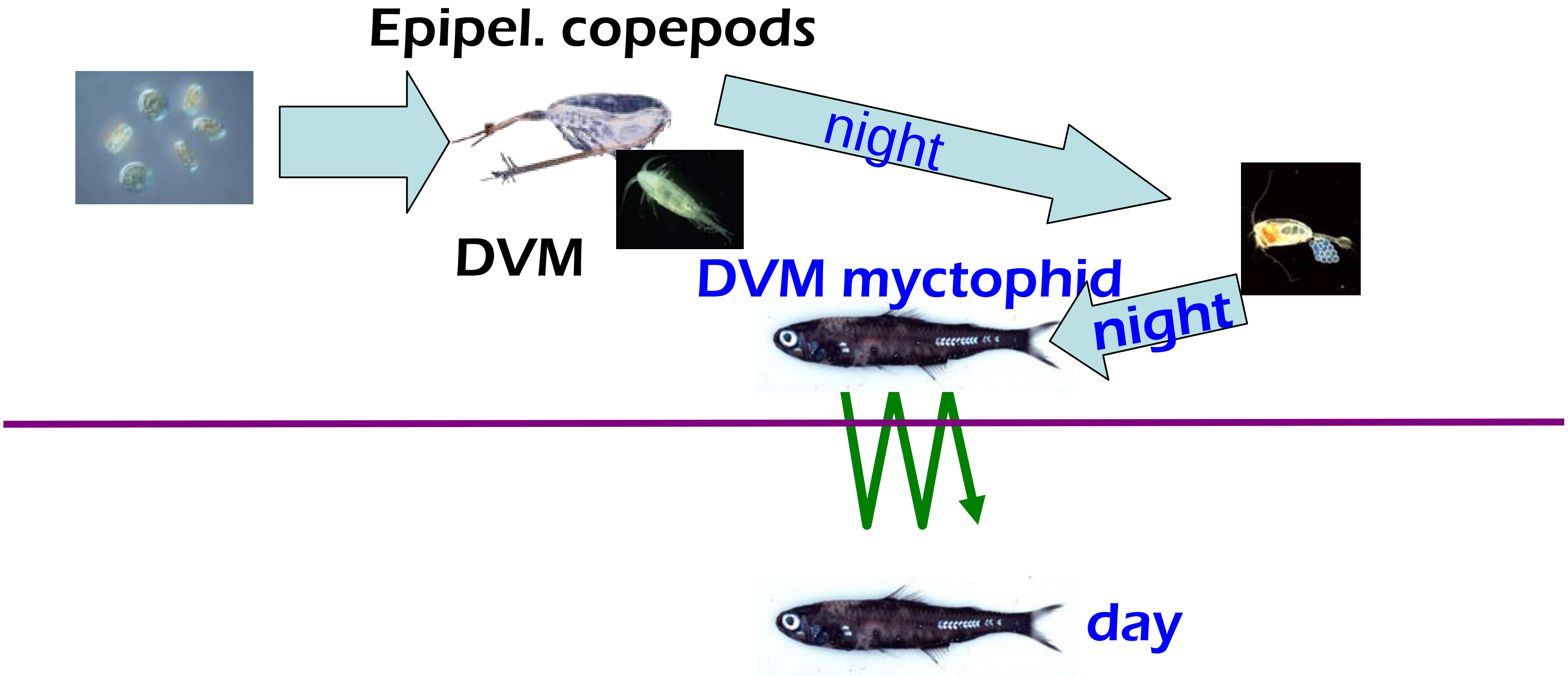


# Myctophids

Upper Mesopelagic

- Diel vertical migrators
- Feed on epipelagic zoopl. and upward-migrating mesopelagic zooplankton in night
- Feed on mesopelagic zoopl. & down-migrating epipelagic zoopl. during the daytime
- Active tranporter

Lower Mesopelagic

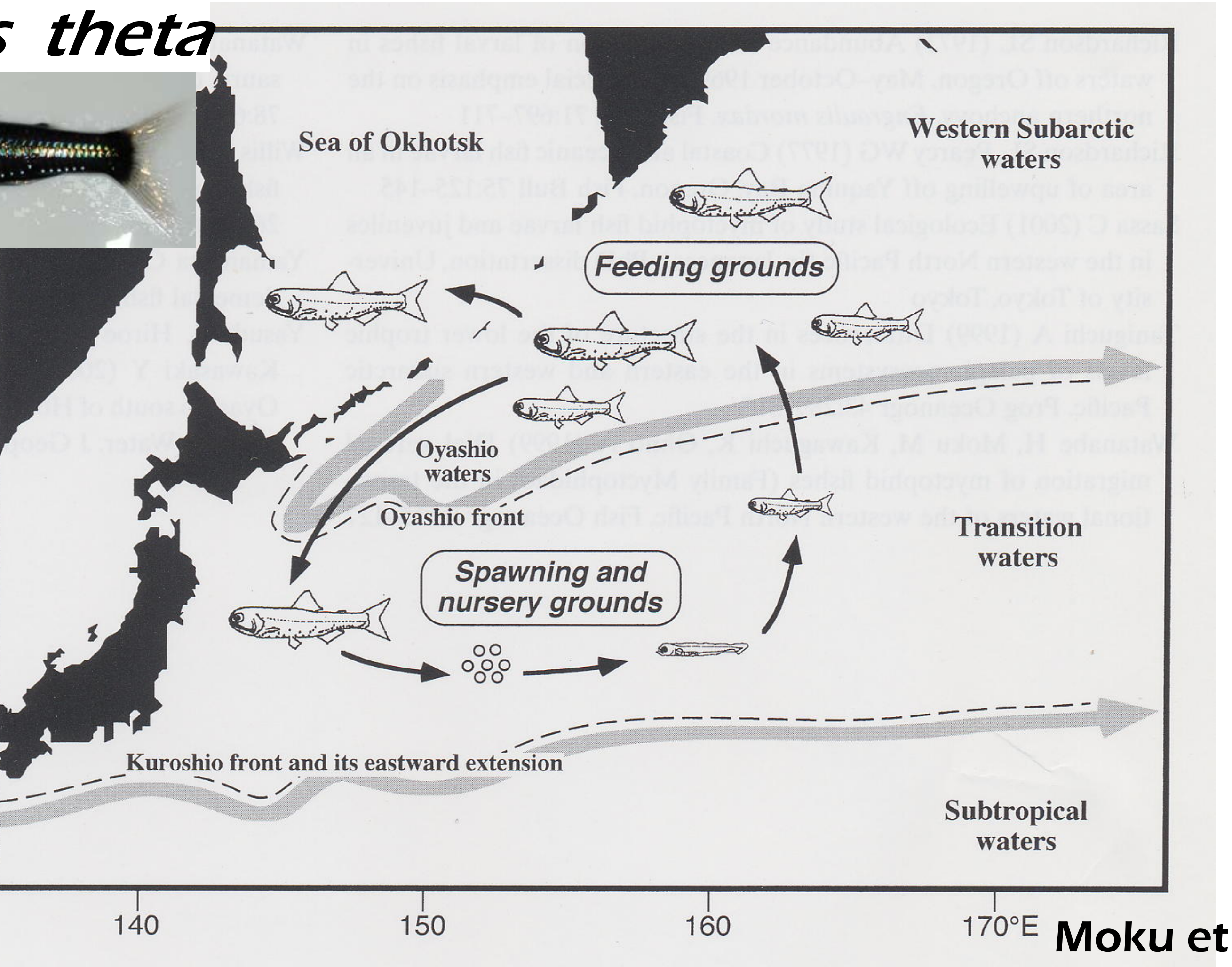
- Mesopelagic residents
- Feed on mesopelagic zoopl. & down-migrating epipelagic zoopl.

# Foraging Migration

All the myctophids in the subarctic Pacific are foraging migrators from south. They reproduce in the Kuroshio-Oyashio Interfrontal Zone or subtropical regions where sea water temperature is higher and expected to be higher growth rate of their larvae.

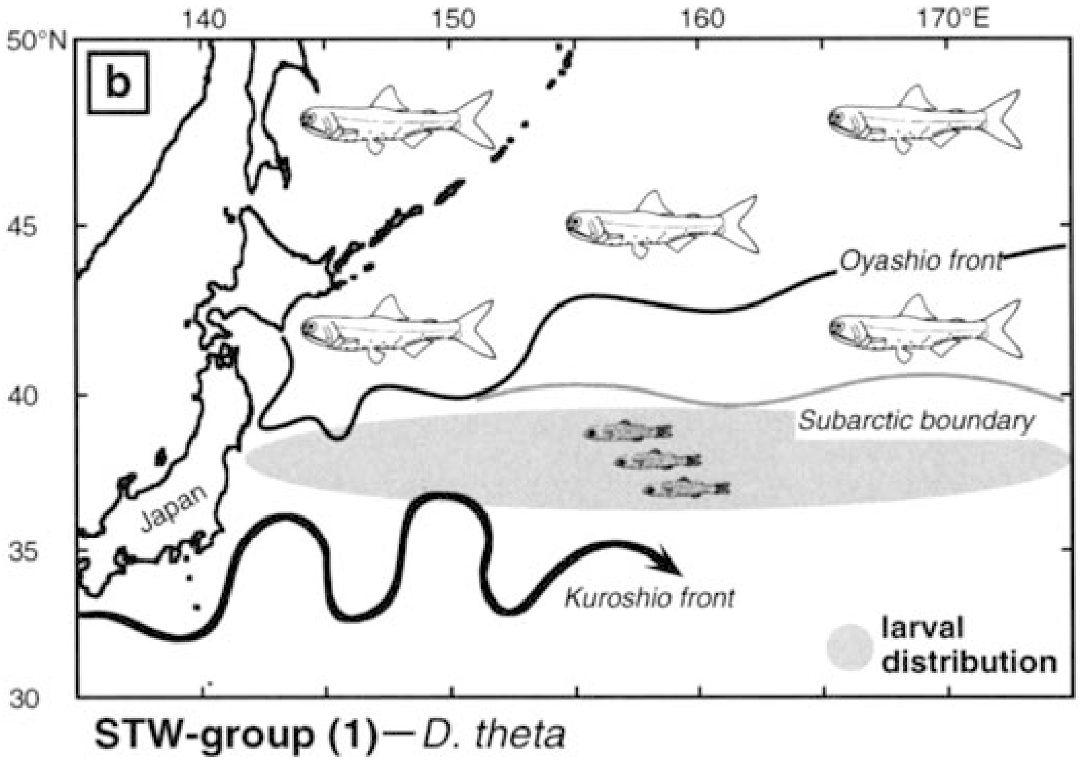
# Foraging Migration

*Diaphus theta*




Moku et al. 2003

# Foraging Migration




Sassa et al 2000

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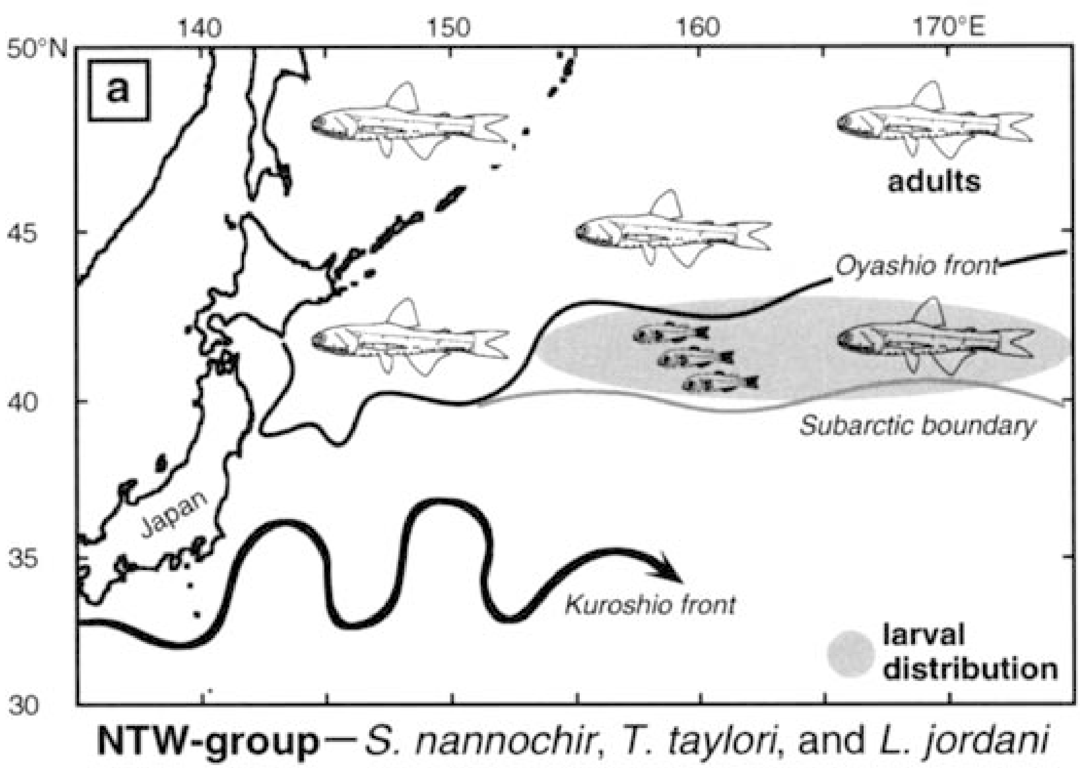
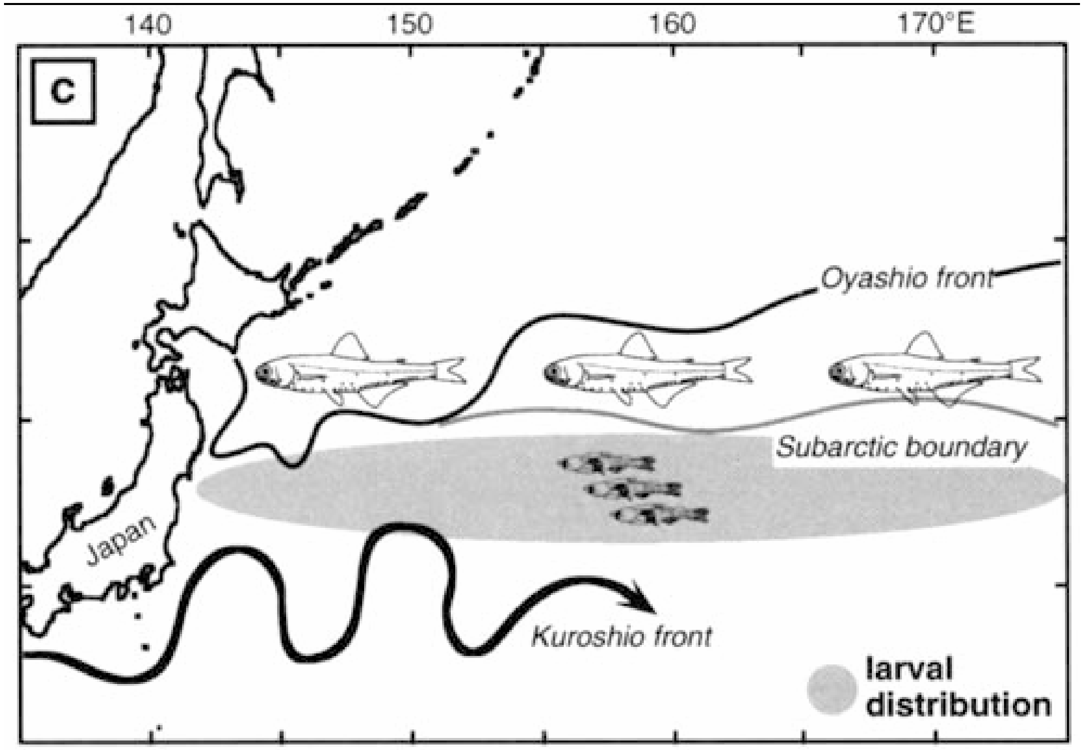



**Sassa et al 2000**

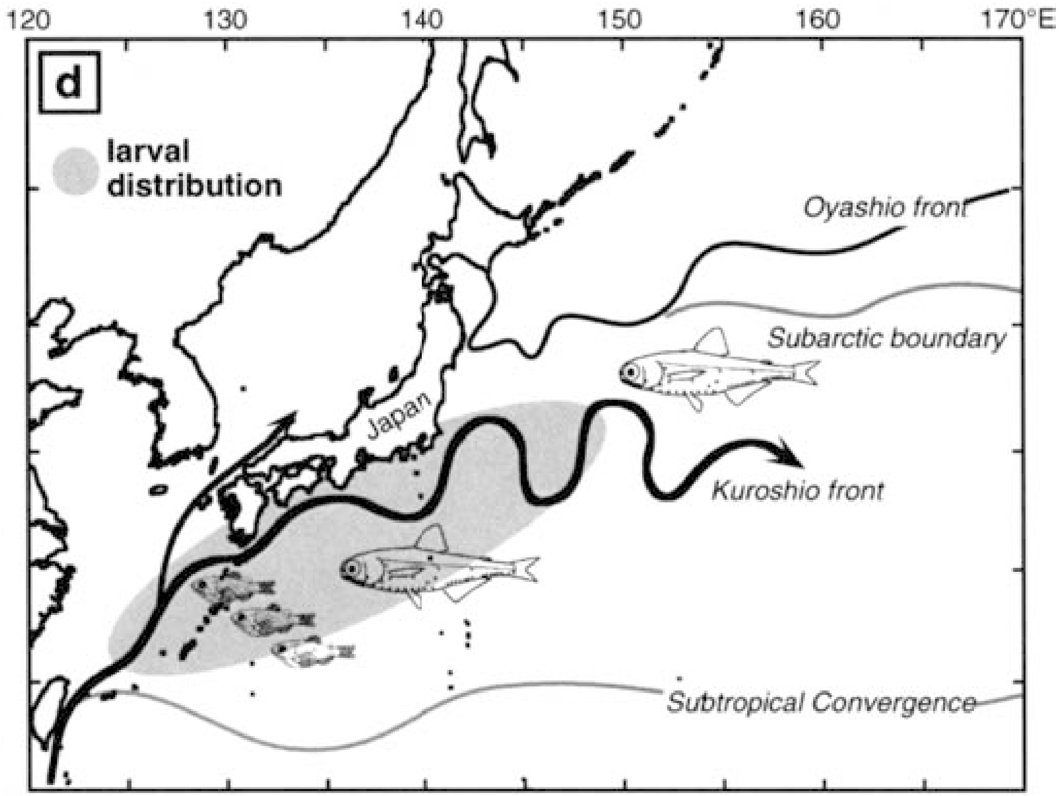
# Foraging Migration




STW-group (2)—*S. californiensis*

**Sassa et al 2000**

# Foraging Migration




Kuroshio-group—*M. asperum* and *D. garmani*

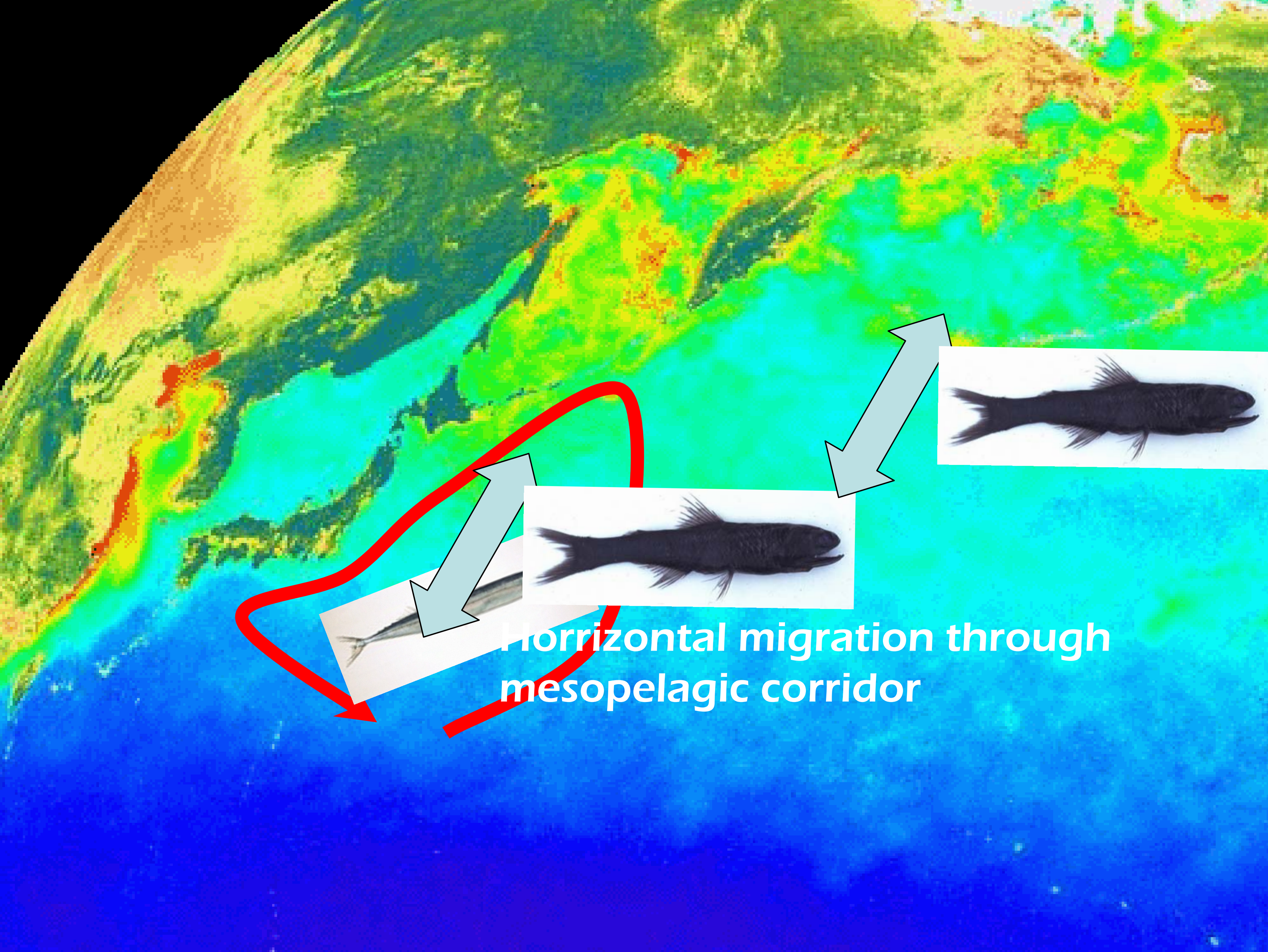
**Sassa et al 2000**

# Foraging Migration

**Although other mesopelagic fish and demersal fish carry out foraging migration across the boudaries, it is limitedly understood their migration range, migration biomass, etc.**

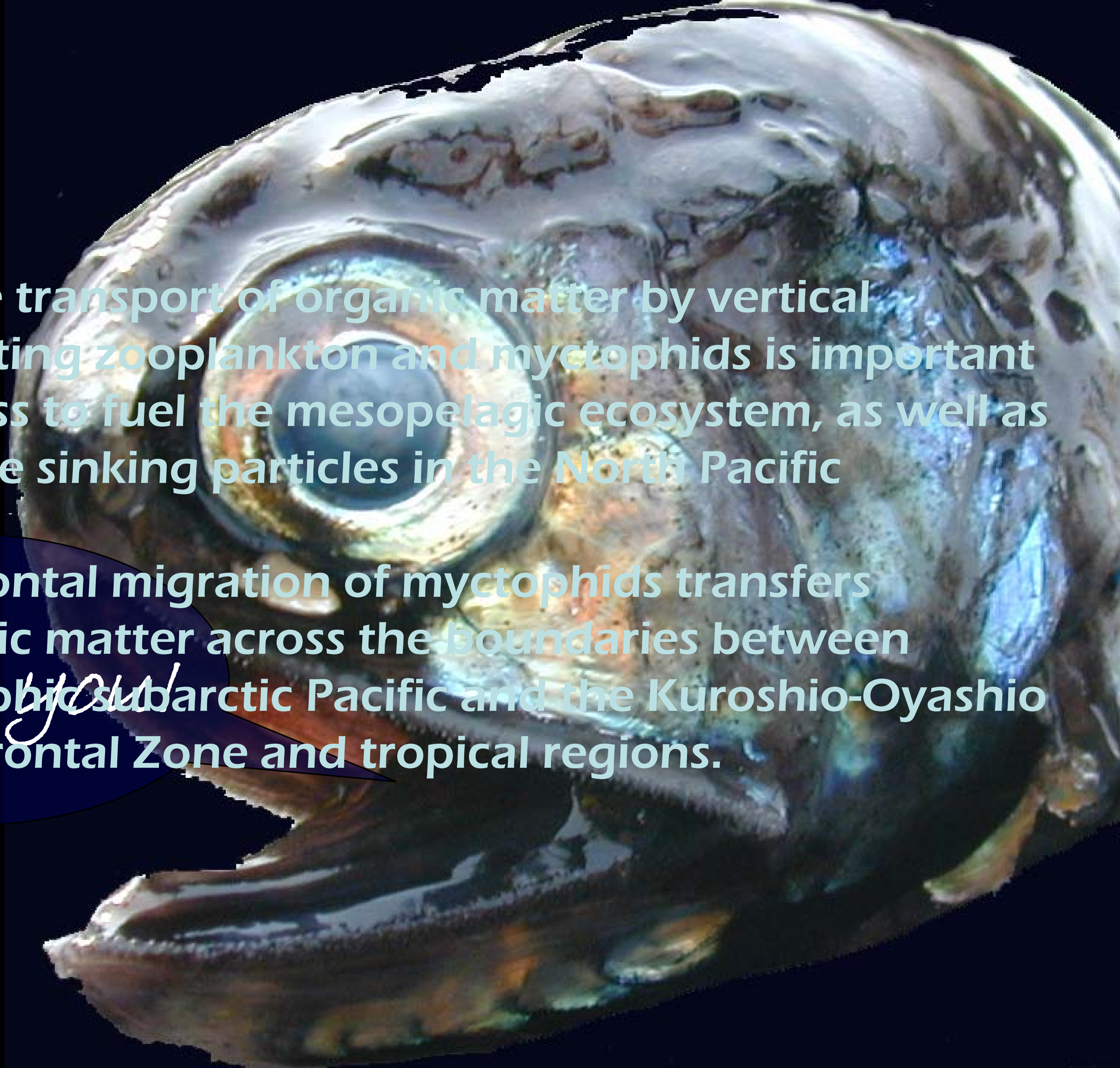
*Buffalo's migration in the North America, a legend.*
*0.5 ton/ind. x 1-4(?) x$10^6$ ind.*

**For reproduction, 10's million tons of myctophids migrate back to the K-O Interfrontal Zone and subtropical region.**
**It's not a legend, occurring every year!**


Horrizontal migration through
mesopelagic corridor

# Foraging Migration

Nutrients supplied to the euphotic layer in the subarctic Pacific by winter mixing and upwelling are organized by phytoplankton, and partly transported to the less eutrophic K-O Interfrontal Zone and subtropical region by active transport processes of myctophid vertical and horizontal migration through mesopellagic corridors.



Active transport of organic matter by vertical migrating zooplankton and myctophids is important process to fuel the mesopelagic ecosystem, as well as passive sinking particles in the North Pacific

Horizontal migration of myctophids transfers organic matter across the boundaries between eutrophic subarctic Pacific and the Kuroshio-Oyashio Interfrontal Zone and tropical regions.

Thank you!