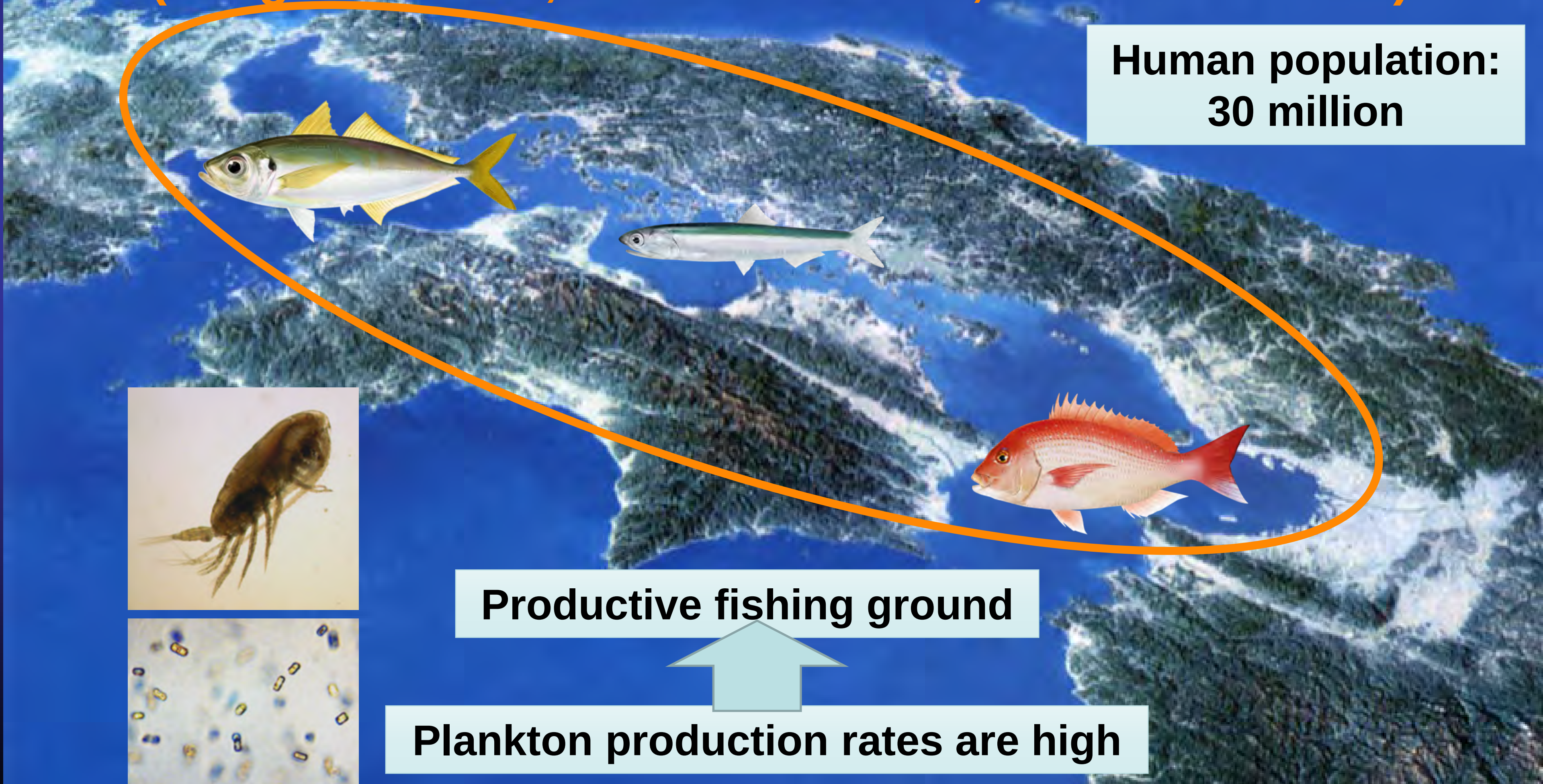
Zooplankton production in temperate coastal waters: from individual to community level

Shin-ichi Uye (Hiroshima University)

Inland Sea of Japan, or Seto Inland Sea

(Length: 500 km, width: 15~50 km, with 600 islands)



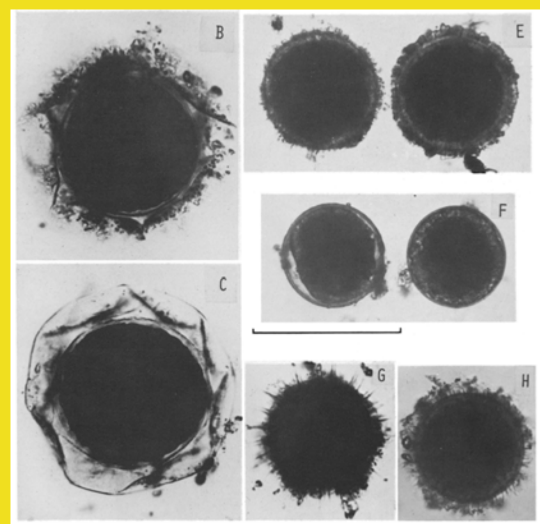
My first copepod works (1973~1977)

In 1974

Mass culture of copepods

Pseudodiaptomus marinus

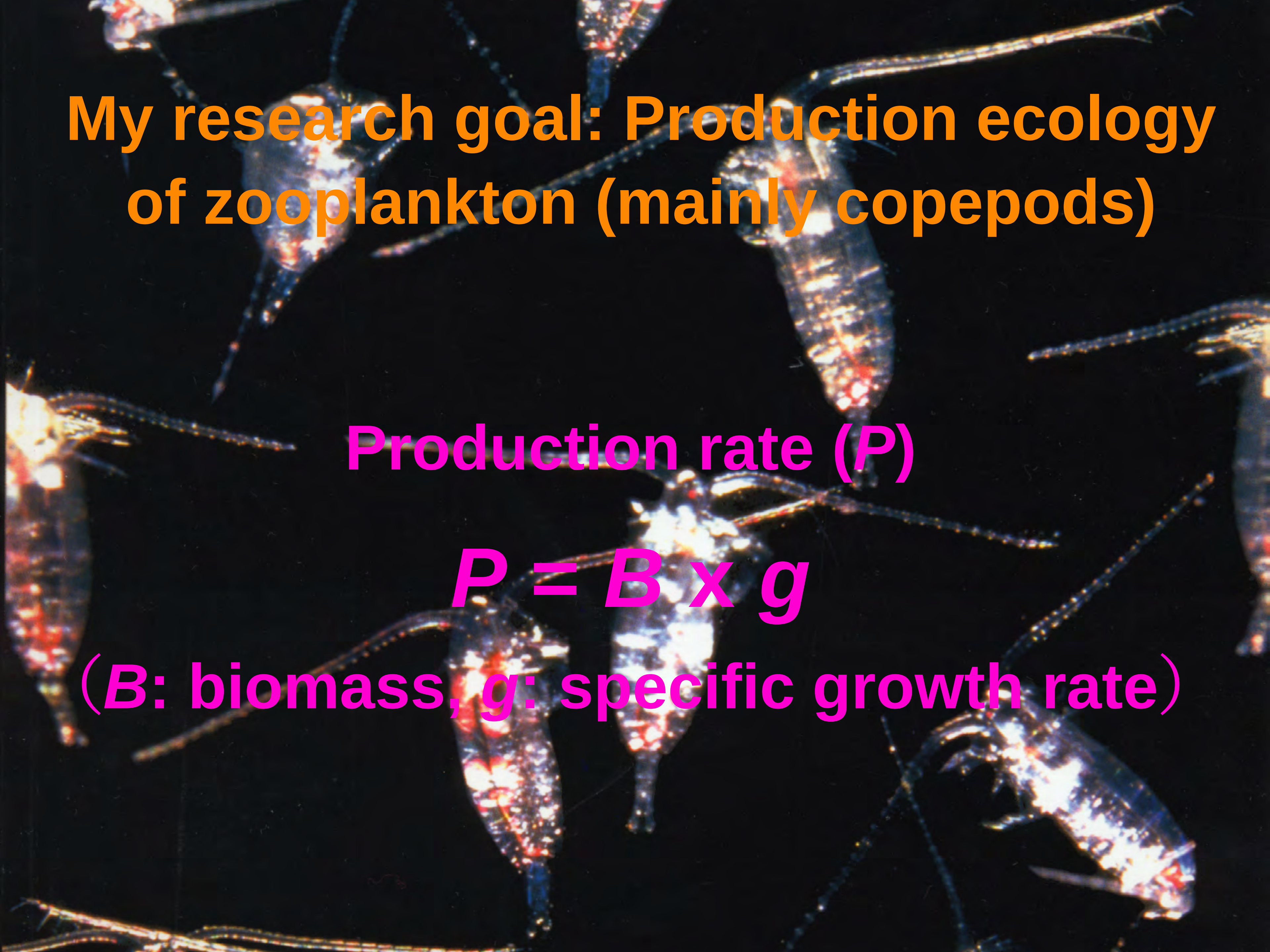
Resting eggs of copepods



(Kasahara et al., 1974)

Study abroad at Scripps Institution of Oceanography, UCSD (1974~1975)

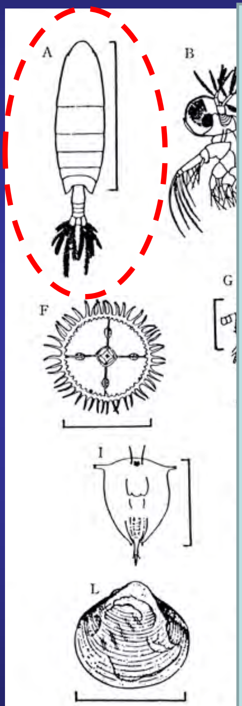
Getting more interested in zooplankton trophodynamics, because of Prof. M. M. Mullin

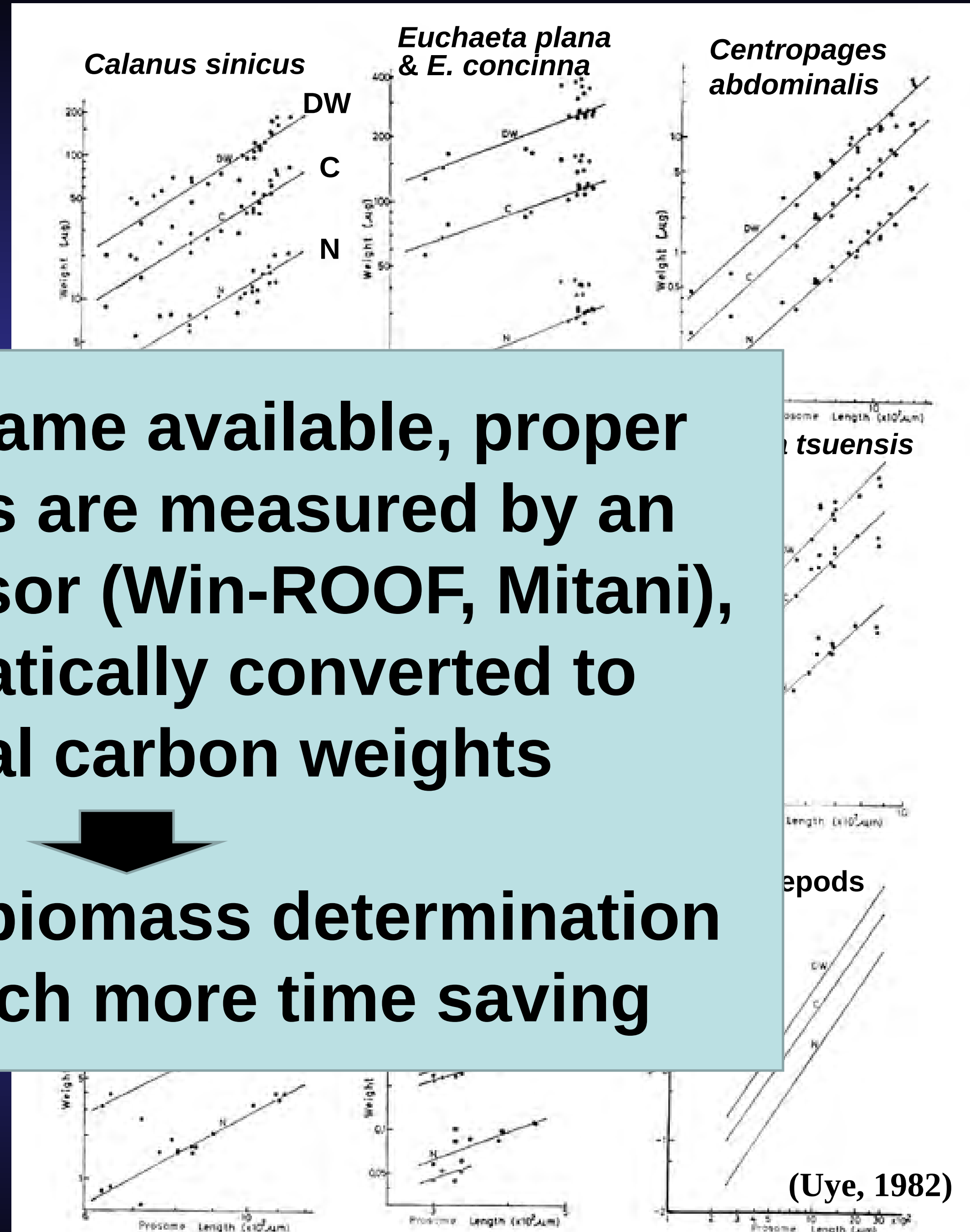

My research goal: Production ecology of zooplankton (mainly copepods)
Production rate (*P*)
$P = B \times g$
（*B*: biomass, *g*: specific growth rate）

Zooplankton biomass

L-C weight relationships

Copepods





After PC became available, proper body lengths are measured by an image processor (Win-ROOF, Mitani), and automatically converted to individual carbon weights

⬇

Zooplankton biomass determination became much more time saving

LogC

C: Carbon weight (μg)

PL: Prosome length (μm)

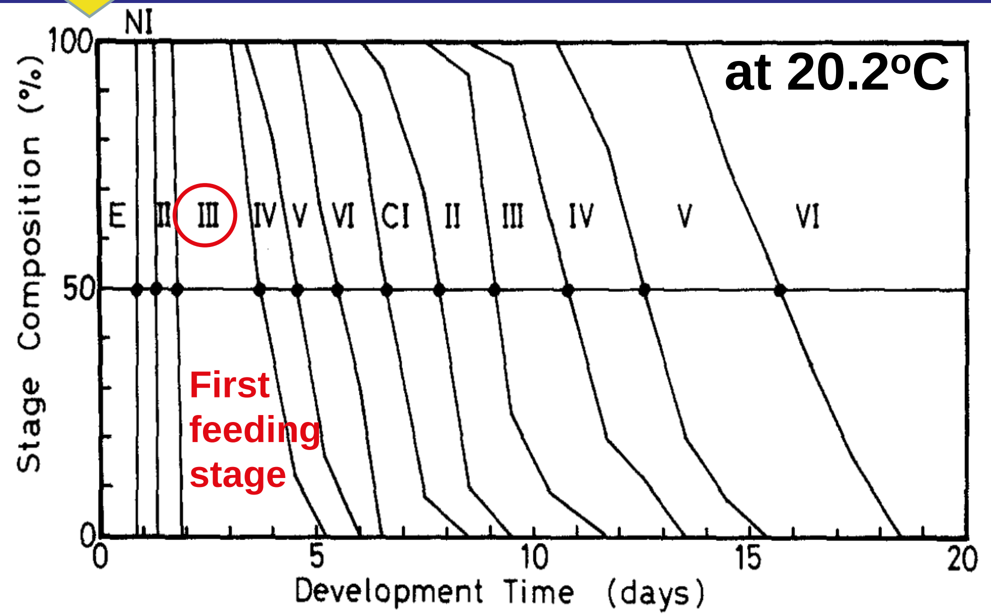
Individual-based production rates

Development times of *Calanus sinicus*

Culture in 2-L glass beakers

About 700 eggs

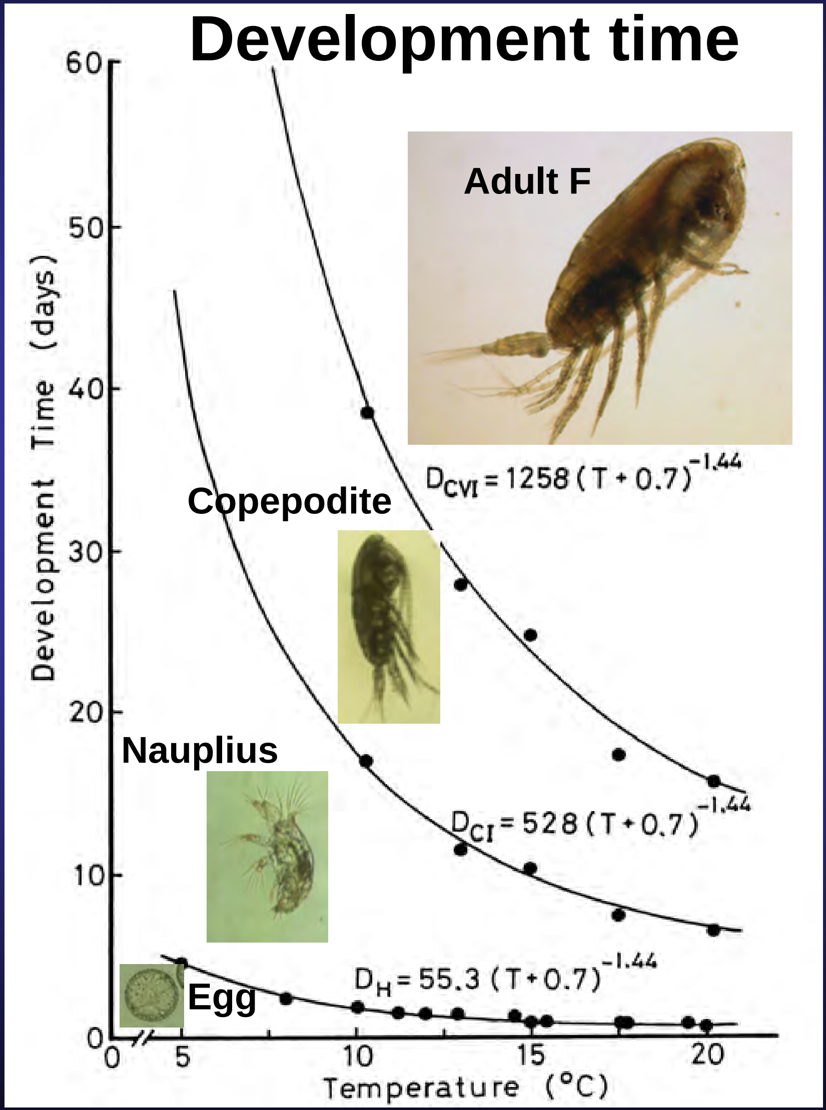
Subsampling of 8-48 specimens



Thalassiossira weissflogii

Prorocentrum micans

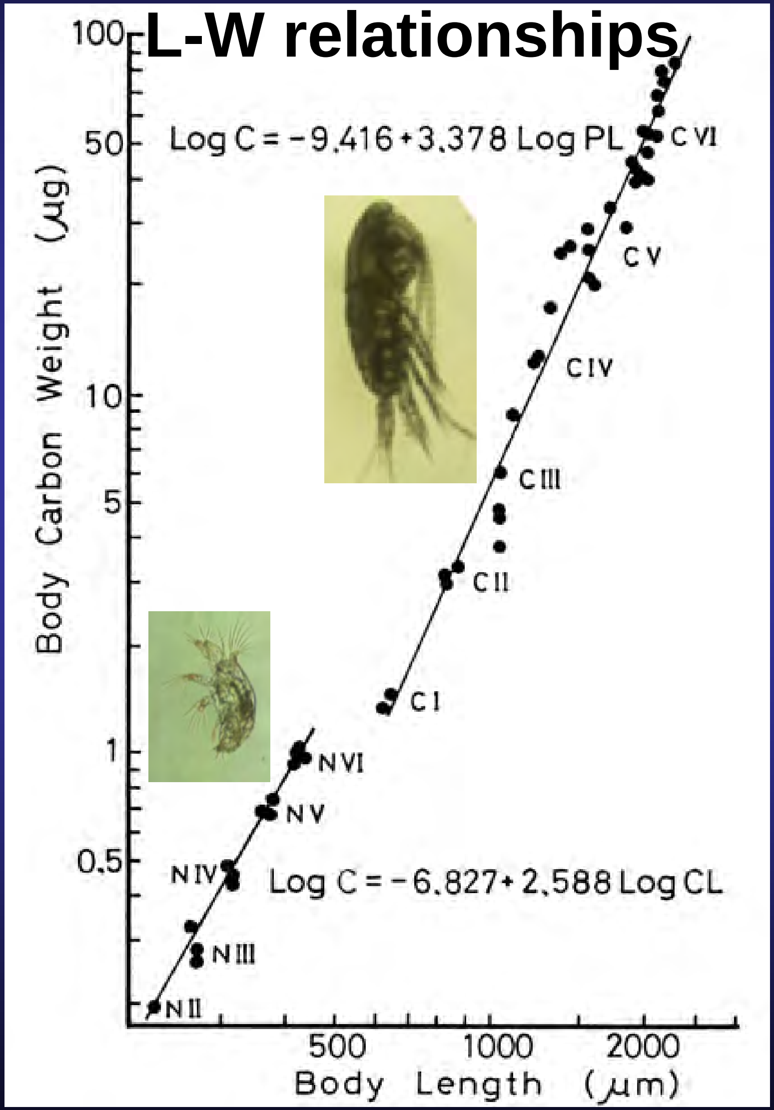
Concentration: >900 µg C L^{-1}

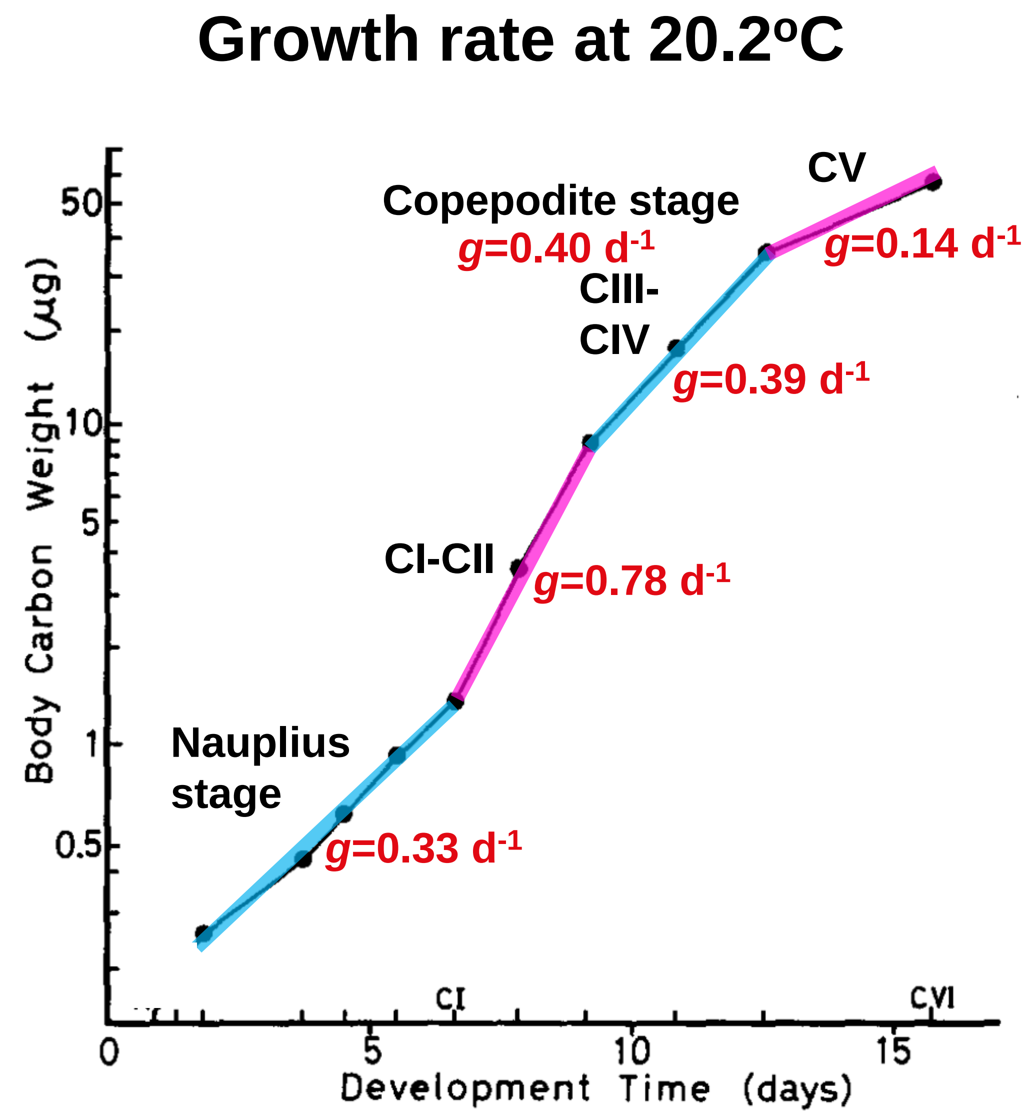


(Uye, 1988)

Individual-based production rates

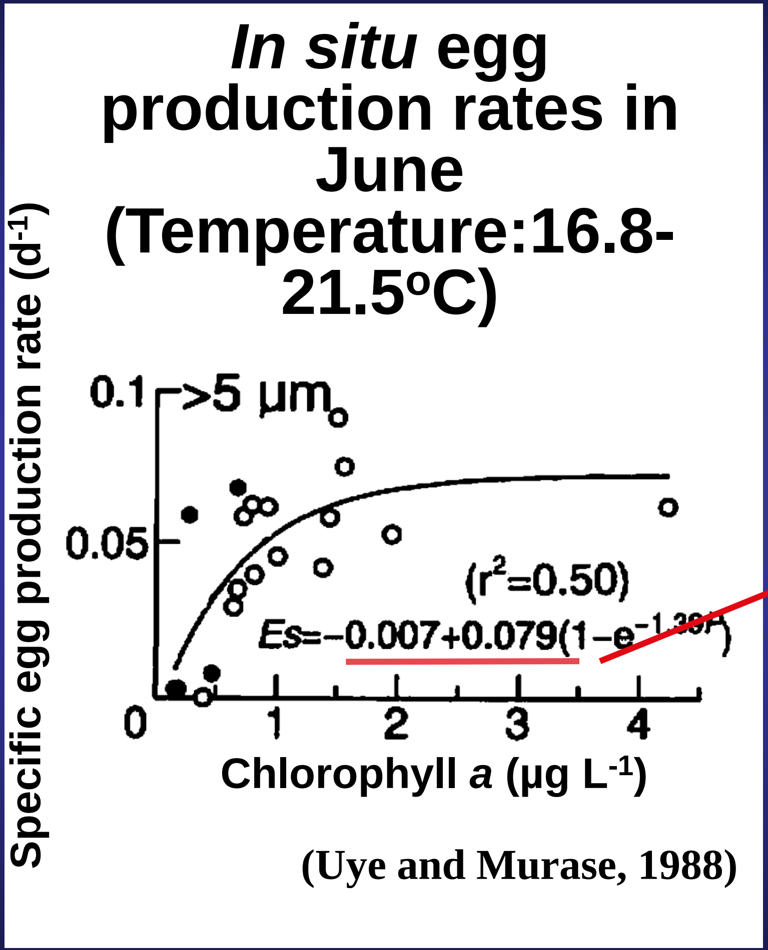
Somatic growth rates of *Calanus sinicus*

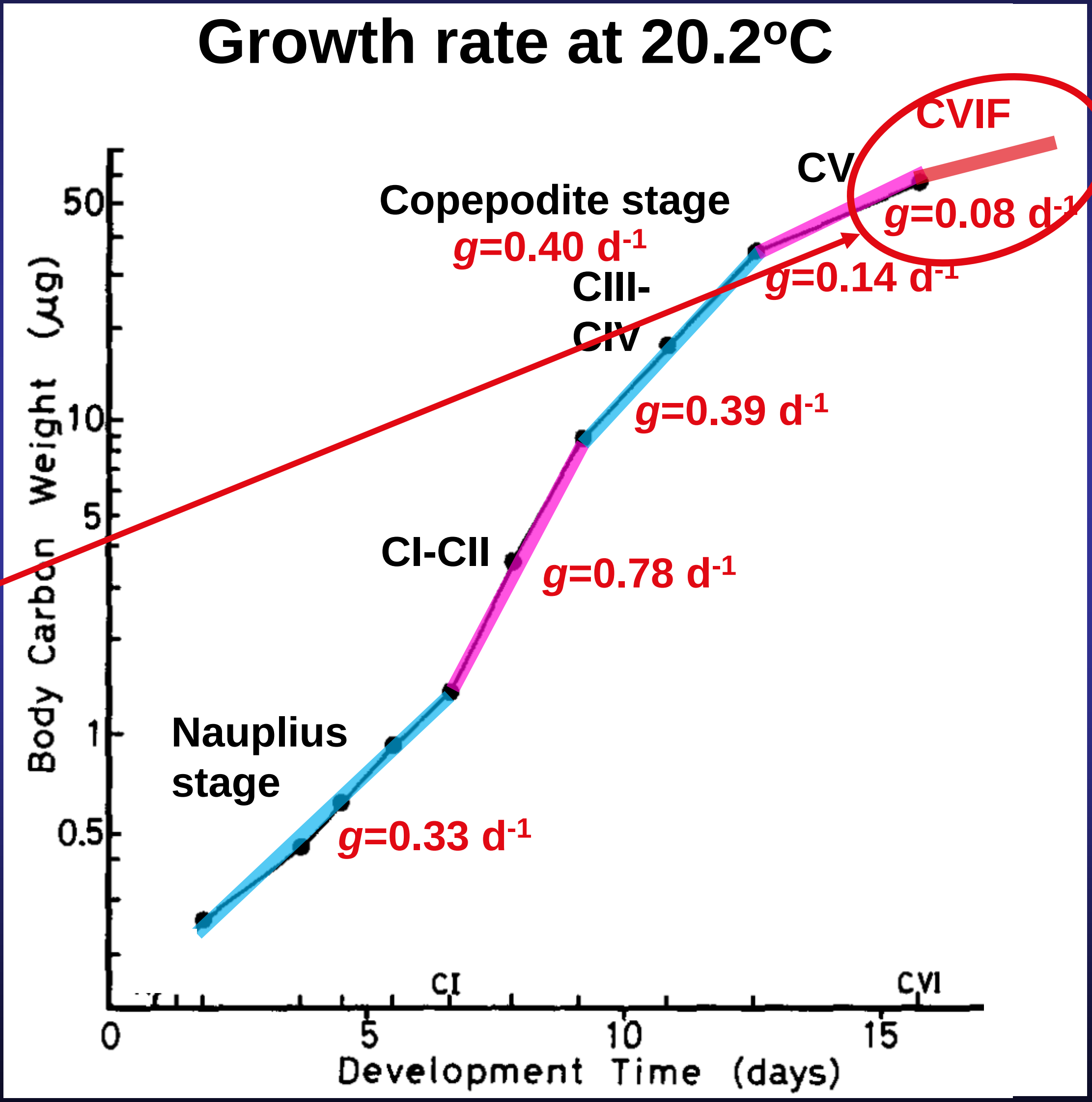




(Uye, 1988)

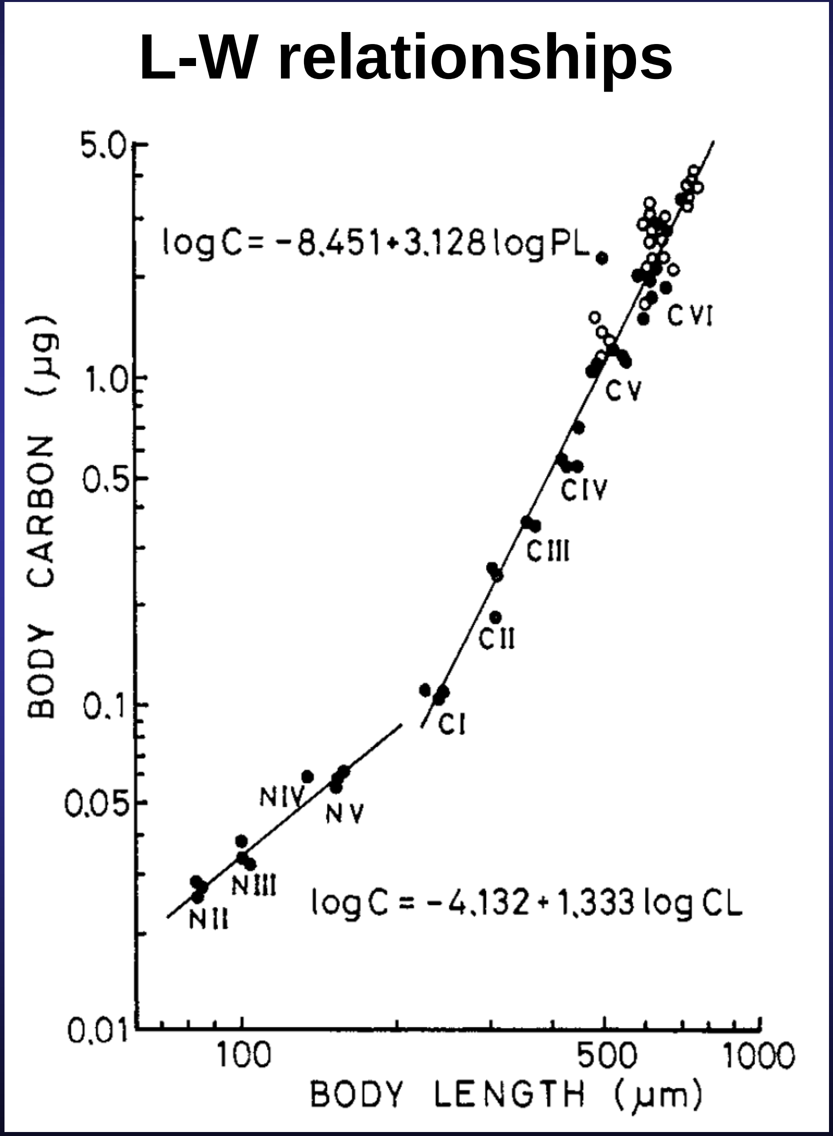
Individual-based production rates
Egg production rates of *Calanus sinicus*

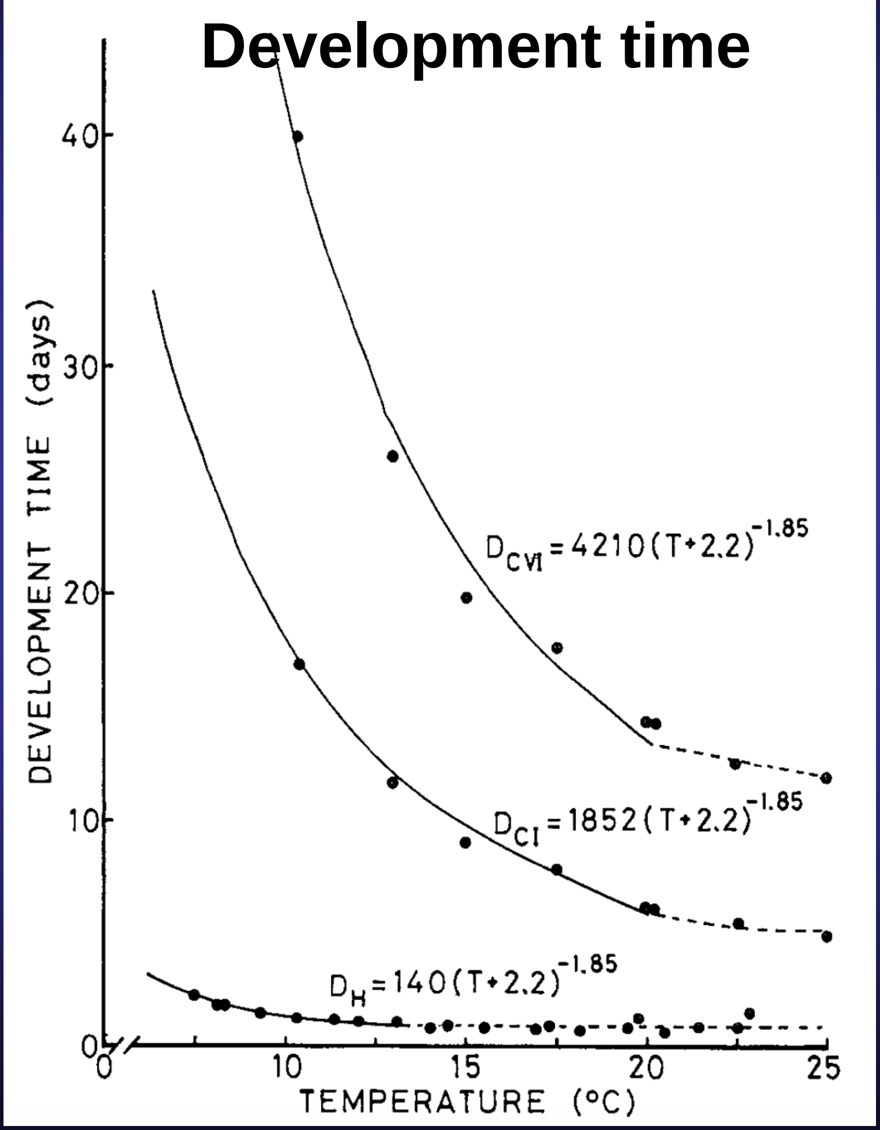




Individual-based production rates

Somatic growth rates of *Paracalanus* sp.

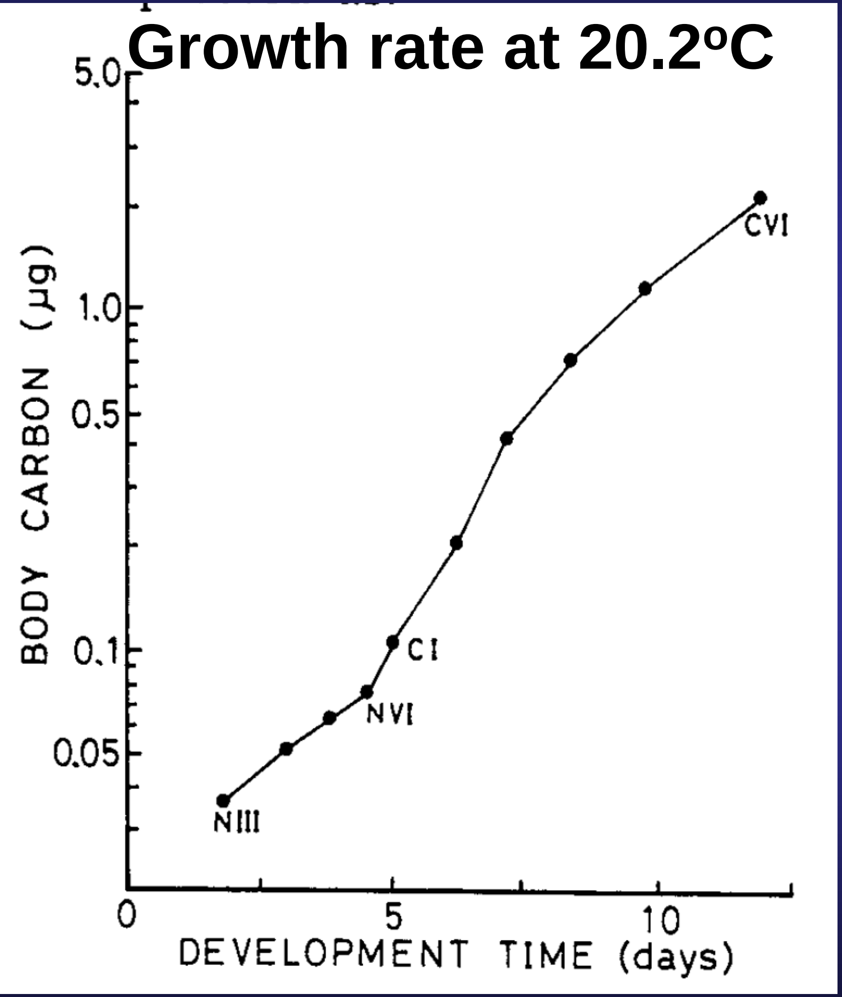


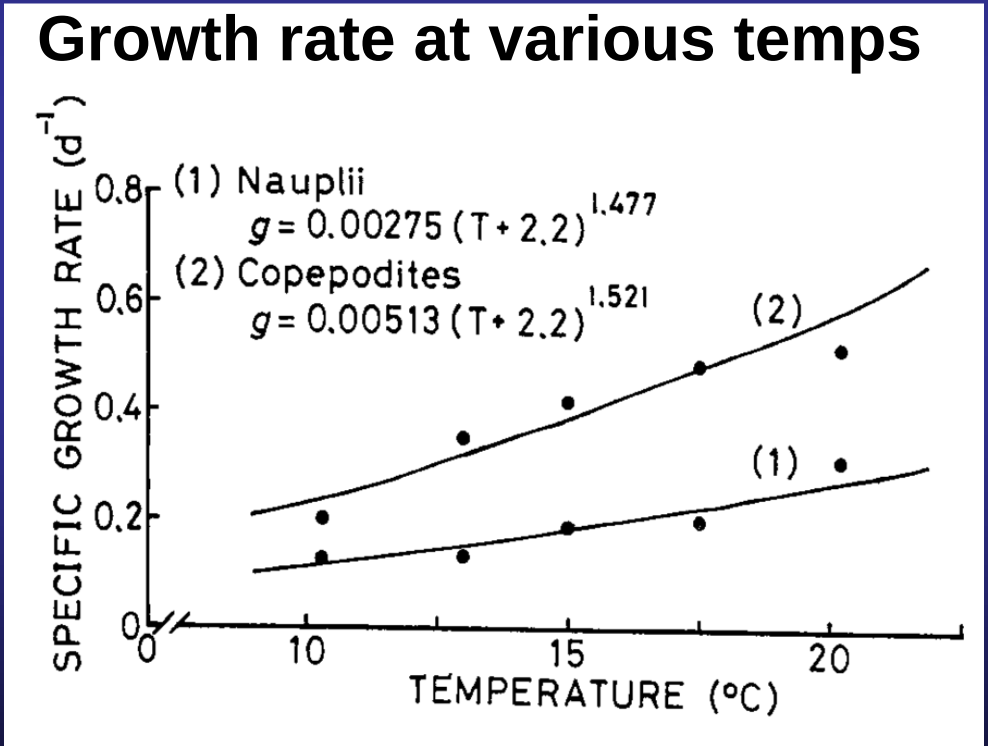


(Uye, 1991)

Individual-based production rates

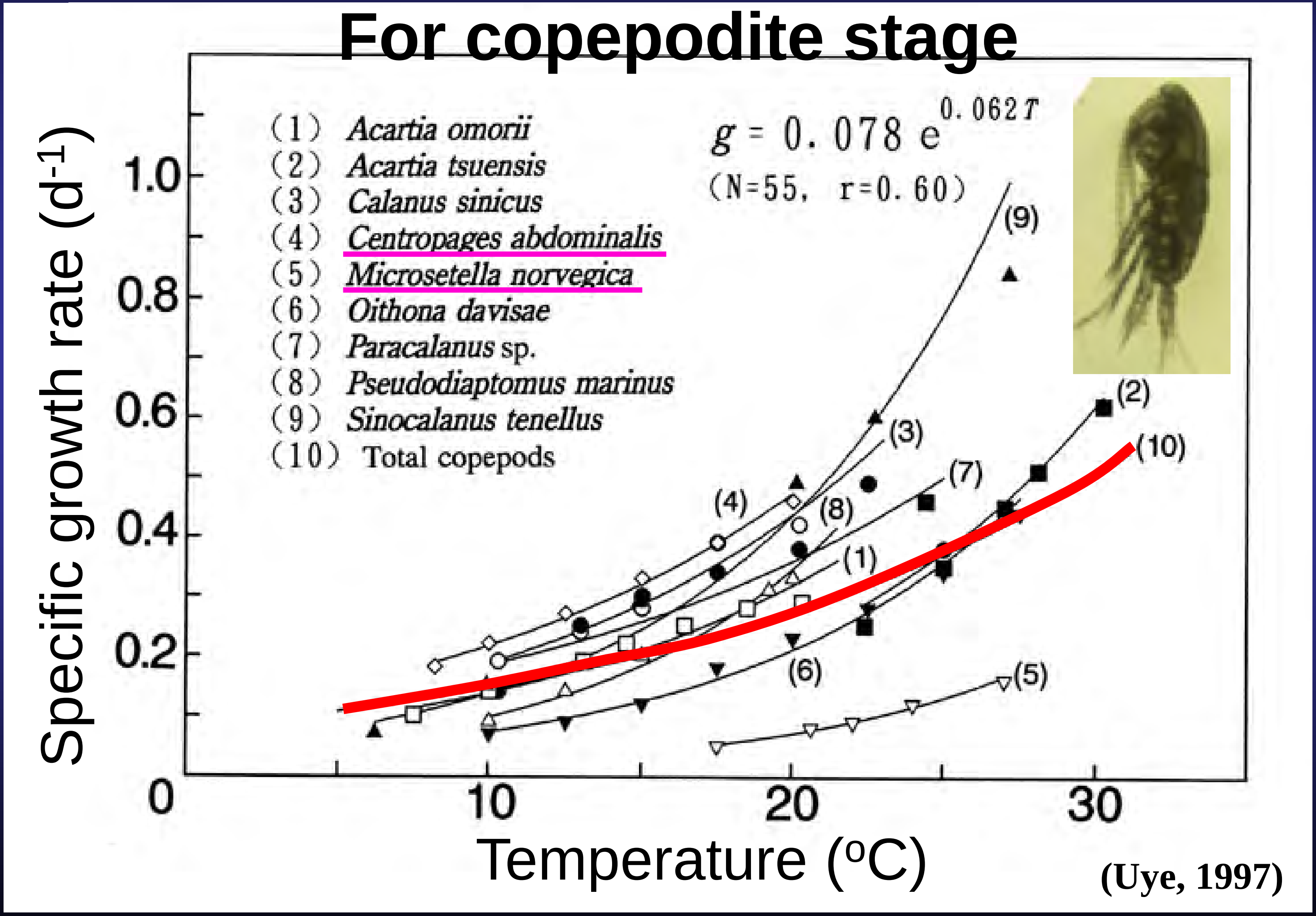
Somatic growth rates of *Paracalanus* sp.





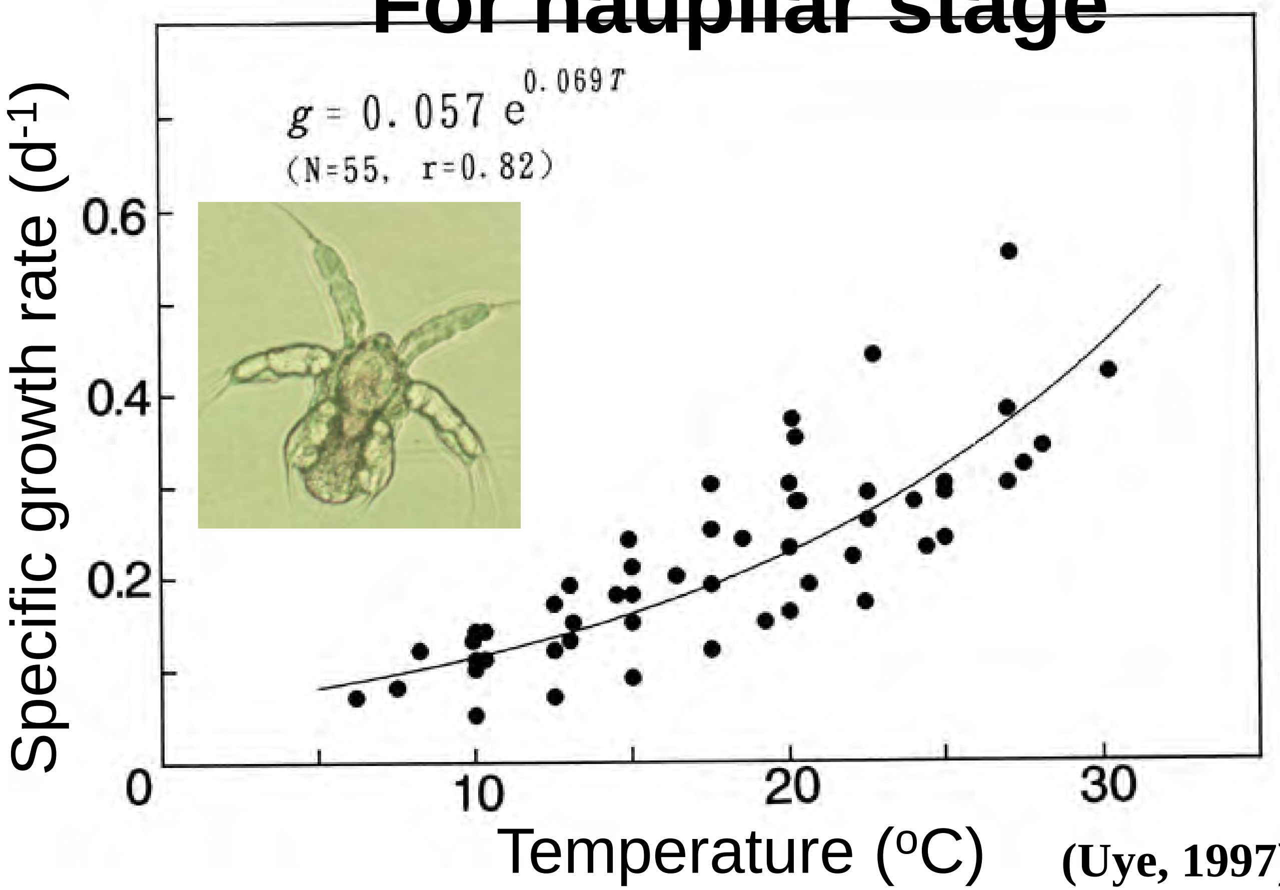
(Uye, 1991)

Relationships between copepod specific growth rate and temperature



Relationships between copepod specific growth rate and temperature

For naupliar stage



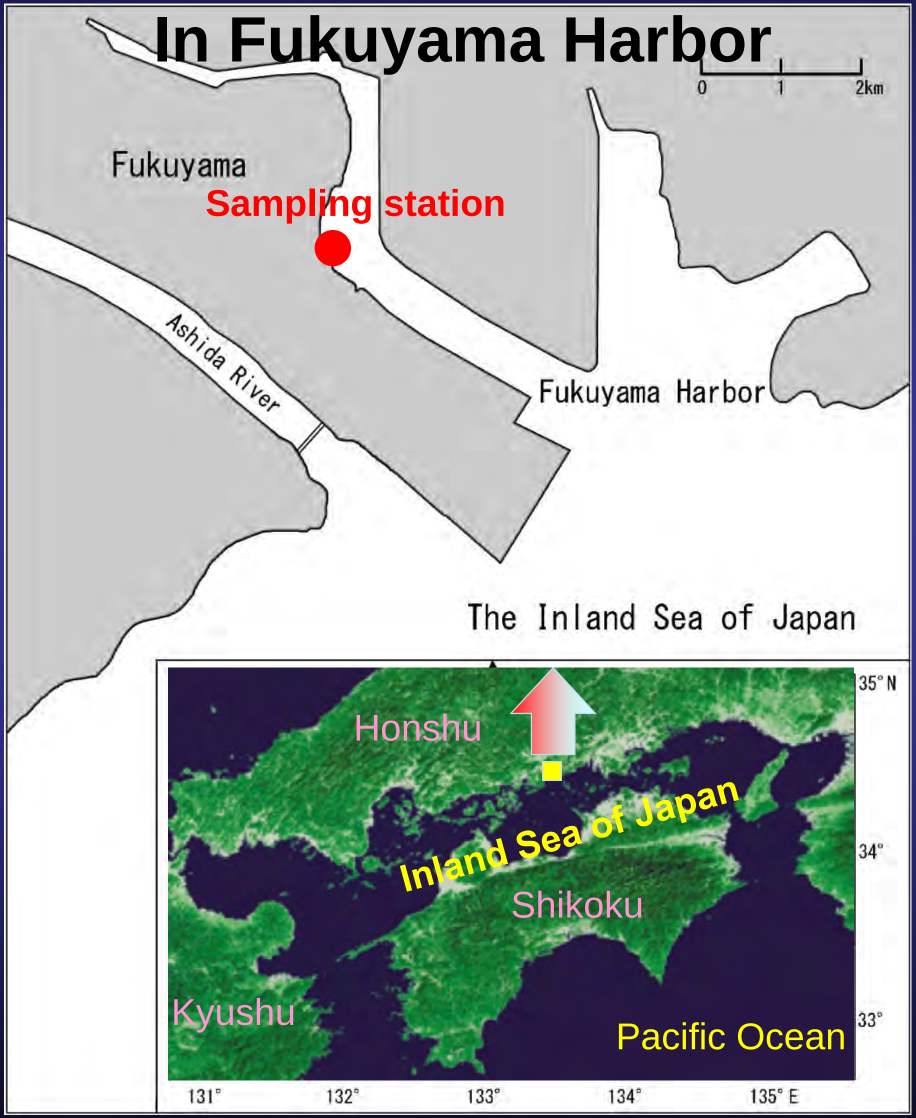
(Uye, 1997)

For adult F

Average growth rate of copepods from the Inland Sea of Japan:
from 0.1 d^{-1} in winter to 0.5 d^{-1} in summer

Population-based production rates

Sampling site and methods

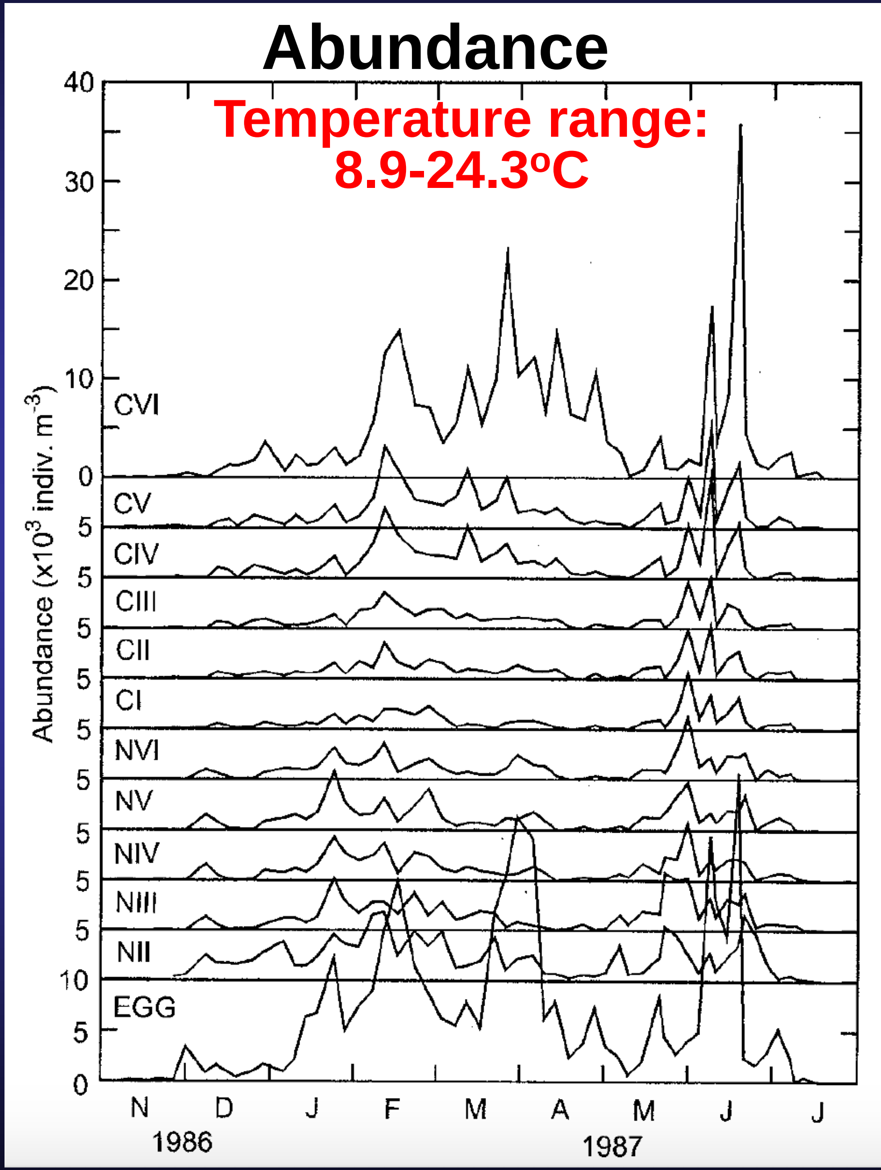


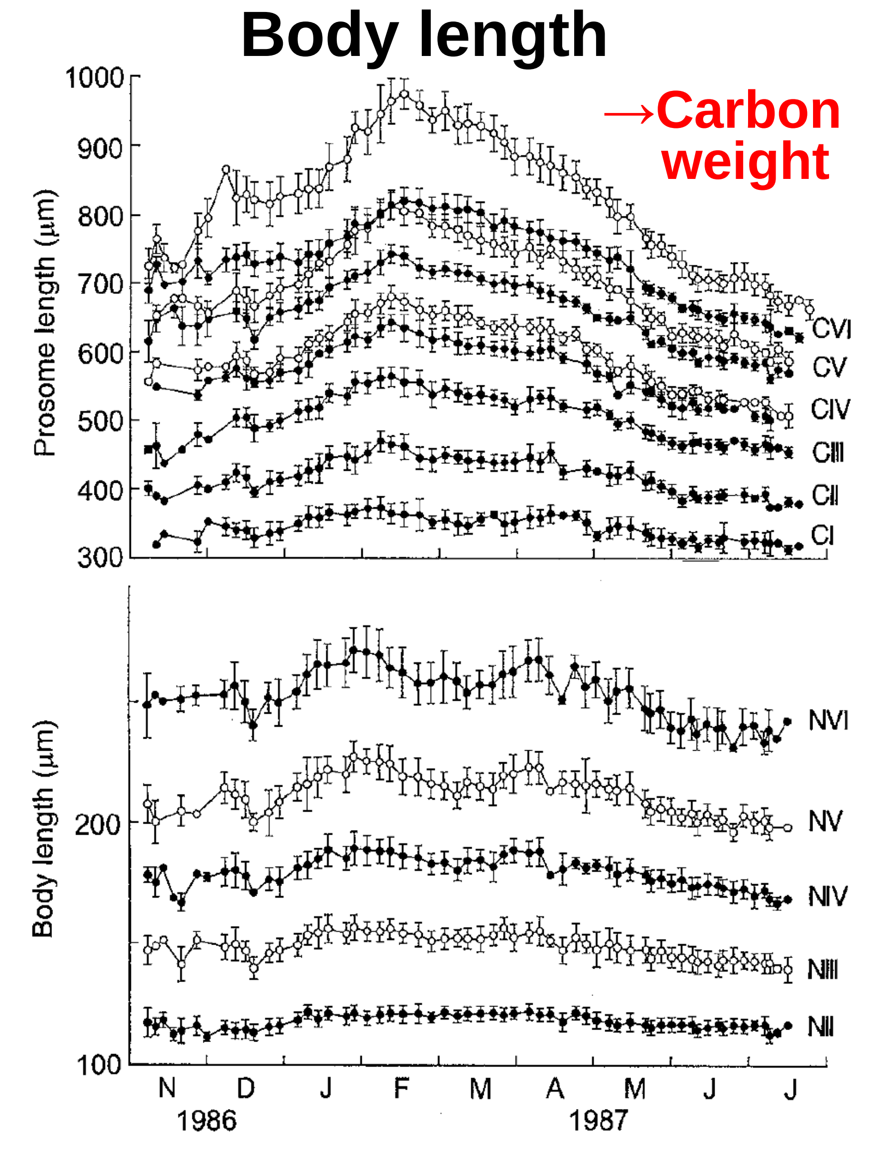
By oblique tows of a modified NORPAC net (mouth diameter: 45 cm, mesh opening: 62 μm) from the bottom (depth: 7-8 m) to the surface

High frequency: 3-7 day internals from 7 November 1986 to 8 November 1987

At nocturnal high tide (local time: 17:00-07:00)

Production rate of *Acartia omorii* population

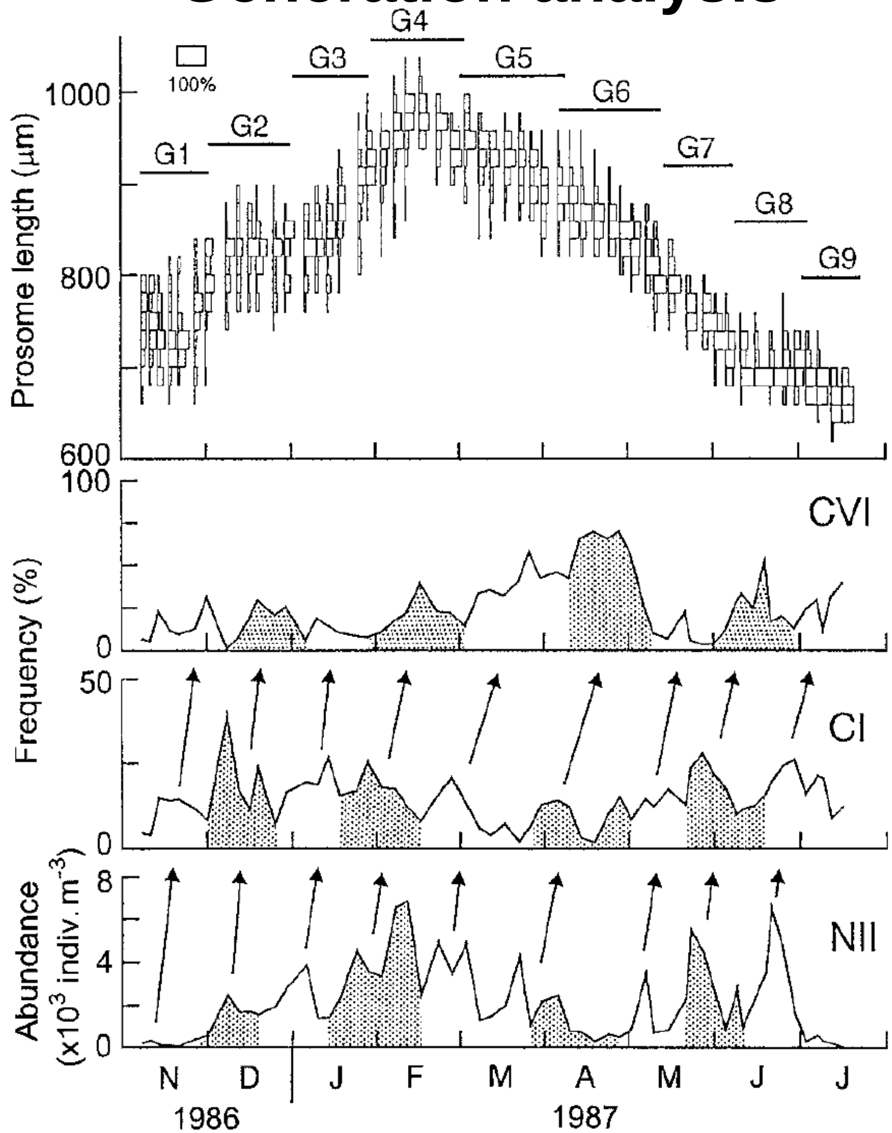




(Liang and Uye, 1996)

Production rate of *Acartia omorii* population

Generation analysis

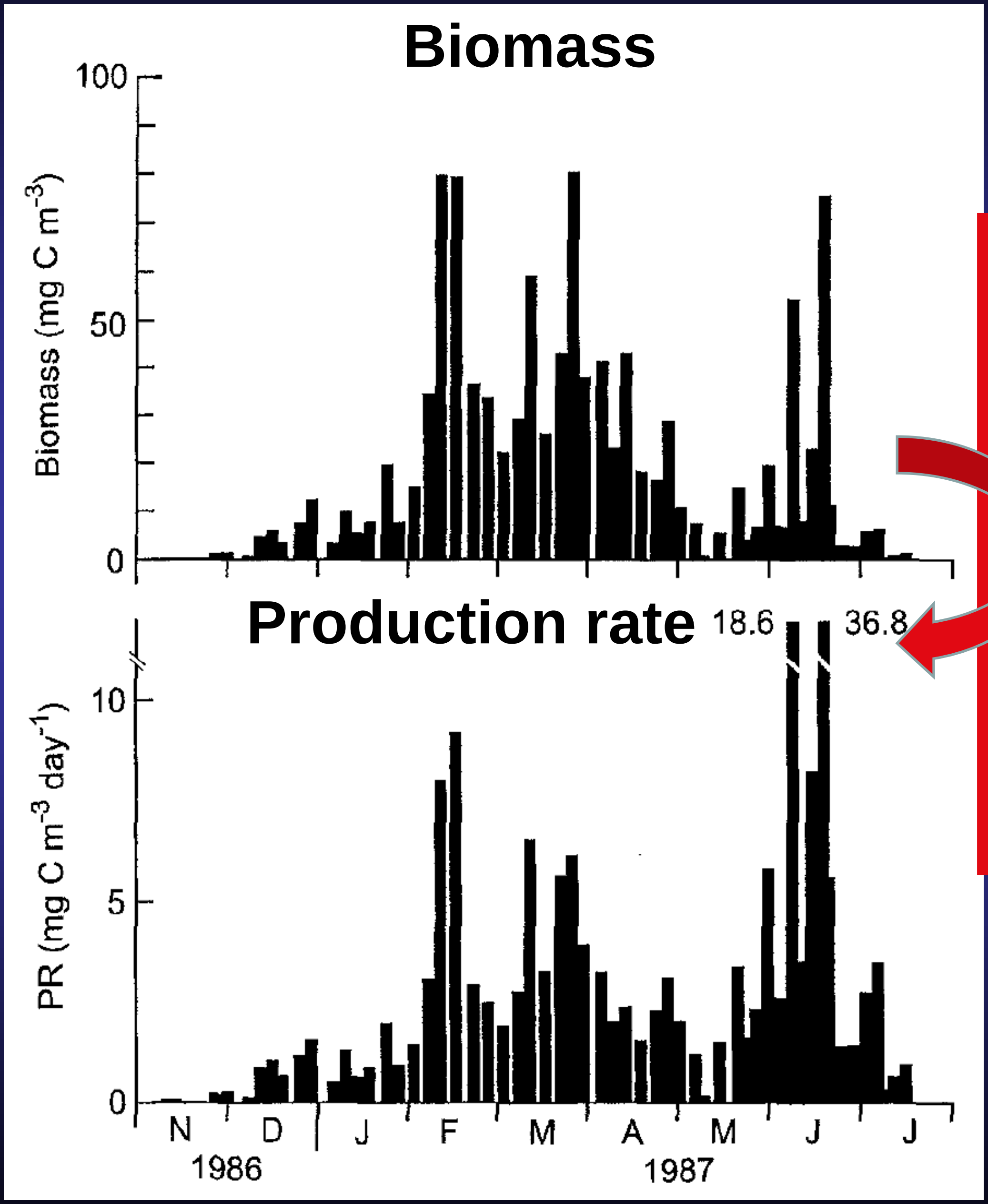


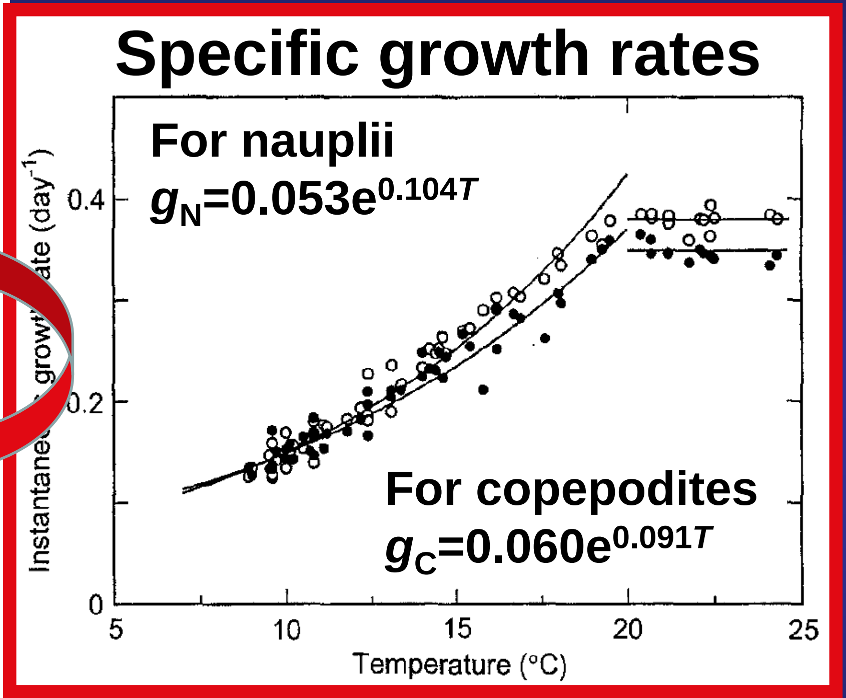
Gener-ation	Av. Temp. (ºC)	Observed GT (d)	Predicted DT (d)
G2	14.3	**21**	**25.0**
G3	12.2	**25**	**31.4**
G4	9.9	**34**	**41.5**
G5	10.1	**38**	**40.0**
G6	12.8	**31**	**29.3**
G7	16.5	**20**	**20.2**
G8	20.5	**18**	**14.7**
G9	21.9	**18**	**14.7**

Development times in Fukuyama Harbor ≒ Development times in the culture experiments

(Liang and Uye, 1996)

Production rate of *Acartia omorii* population

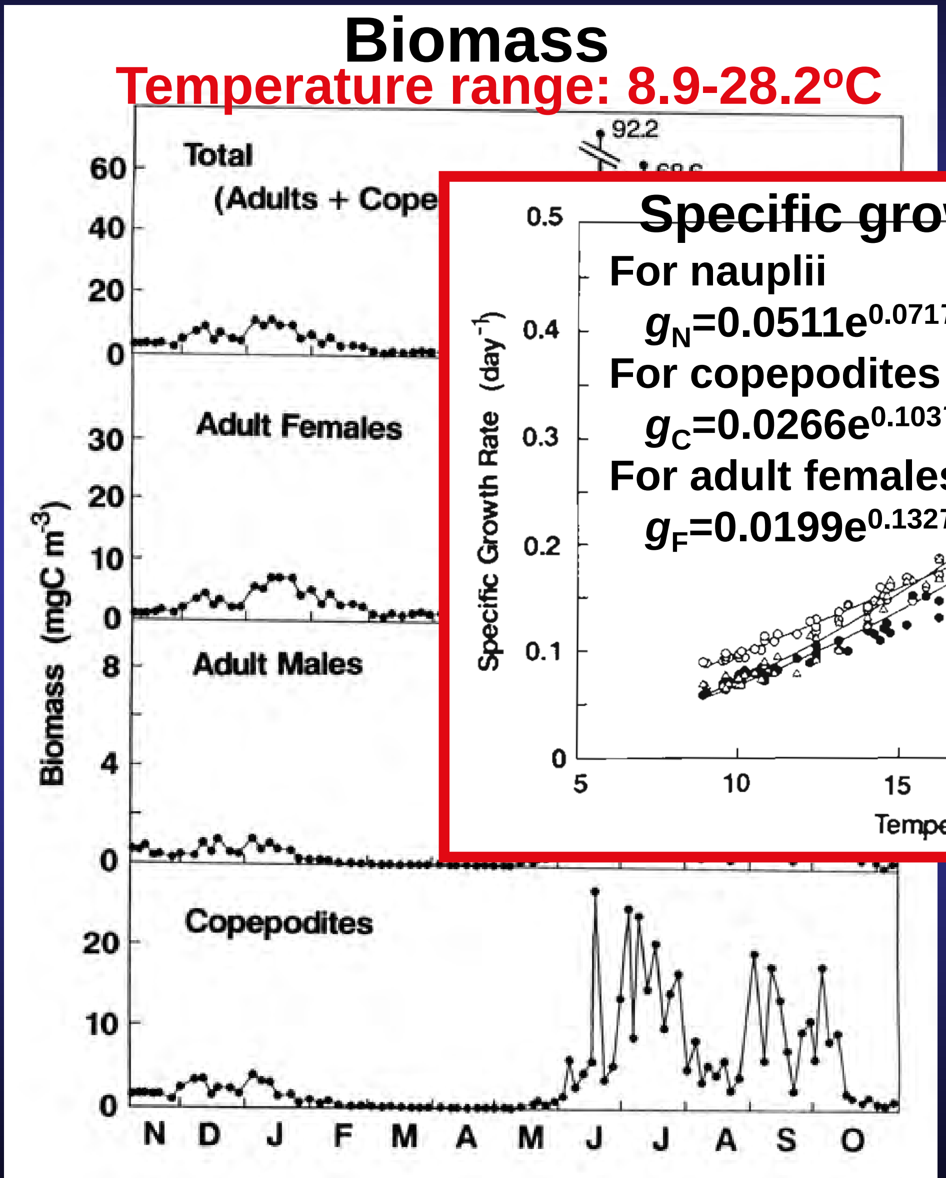


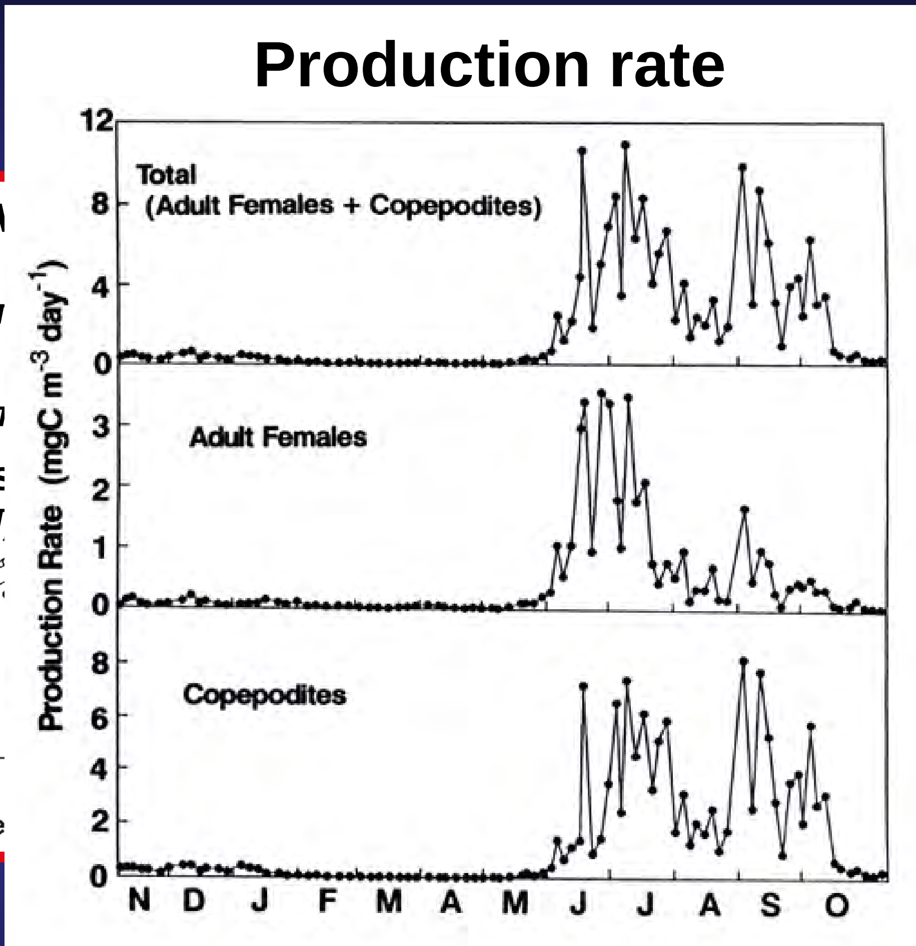


Annual integrated production rate = 749 mg C m^{-3} yr^{-1}

(Liang and Uye, 1996)

Production rate of *Oithona davisae* population



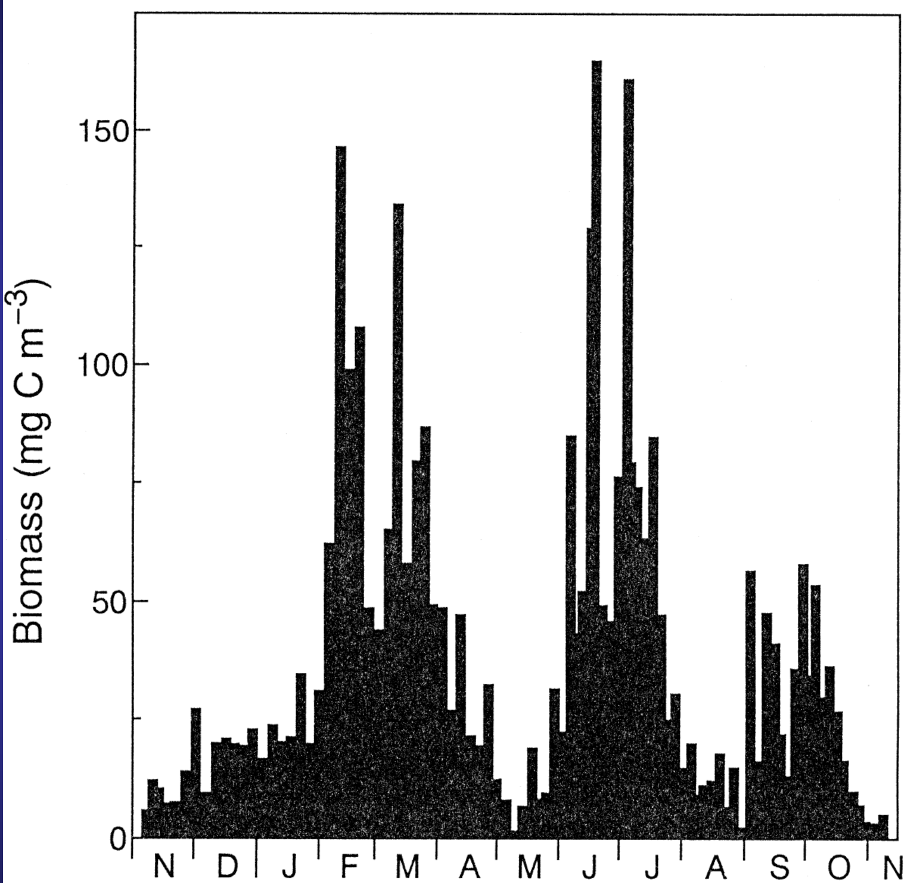


Annual production rate = 650 mg C m^{-3} yr^{-1}

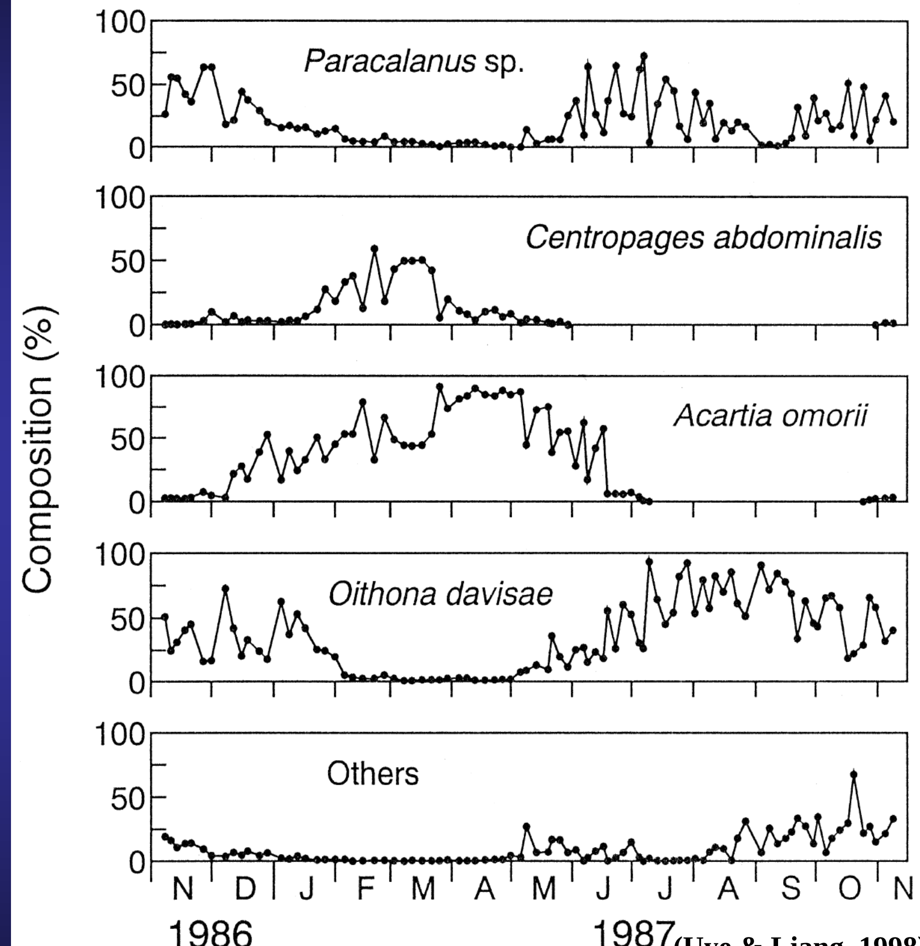
(Uye & Sano, 1998)

Copepod community-based production rates

Total copepod biomass



Taxonomic composition



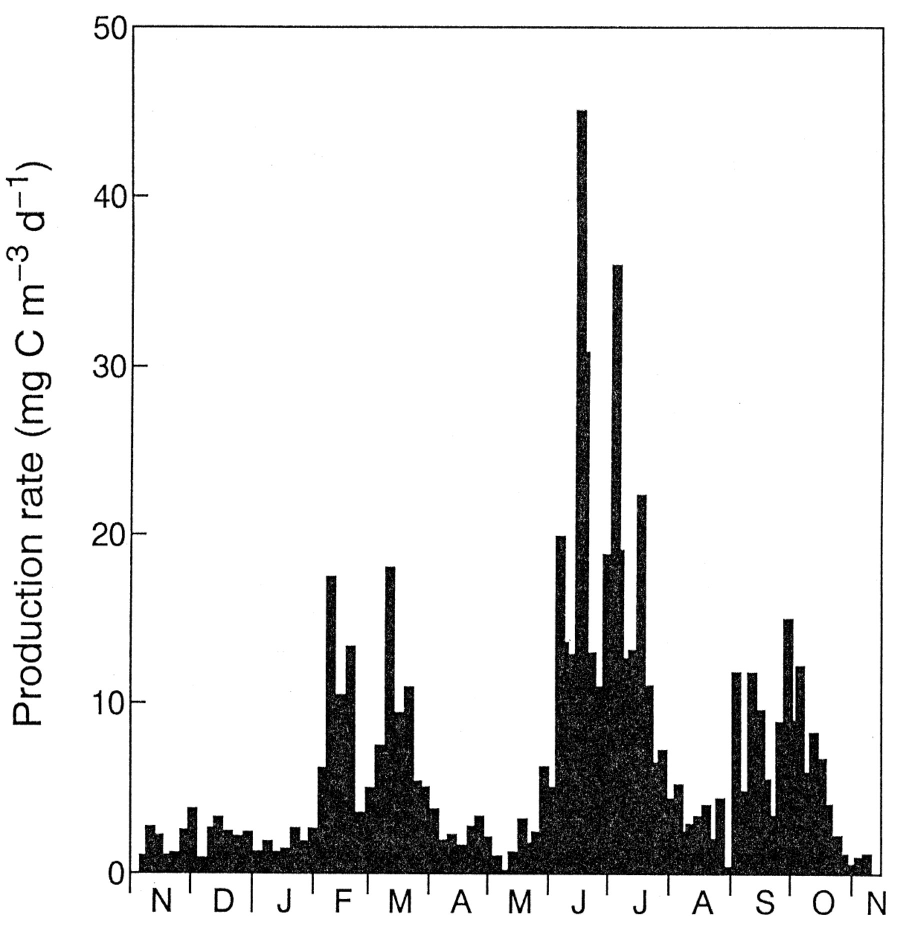
(Uye & Liang, 1998)

Annual mean biomass = 39.1 mg C m^{-3}
28.0 g C m^{-3} in Narragansett Bay,
33.2 g C m^{-3} in Long Island Estuary,
21.5 g C m^{-3} in New Port River Estuary

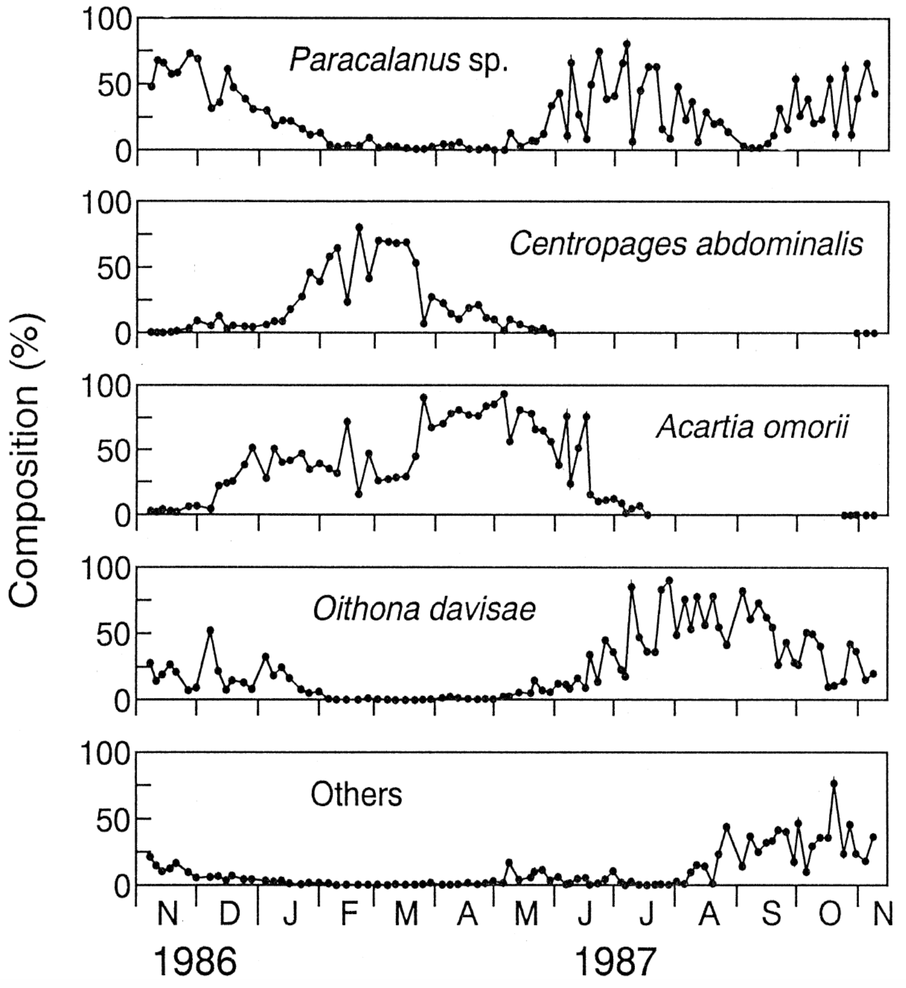
Others: *Acartia erythraea, A. pacifica, Centropages tenuiremis, Parvocalanus crassirostris, Pseudodiaptomus marinus*, *Tortanus forcipatus*, and *T. gracilis*

Production rate of copepod community

Total copepod production rate



Taxonomic composition

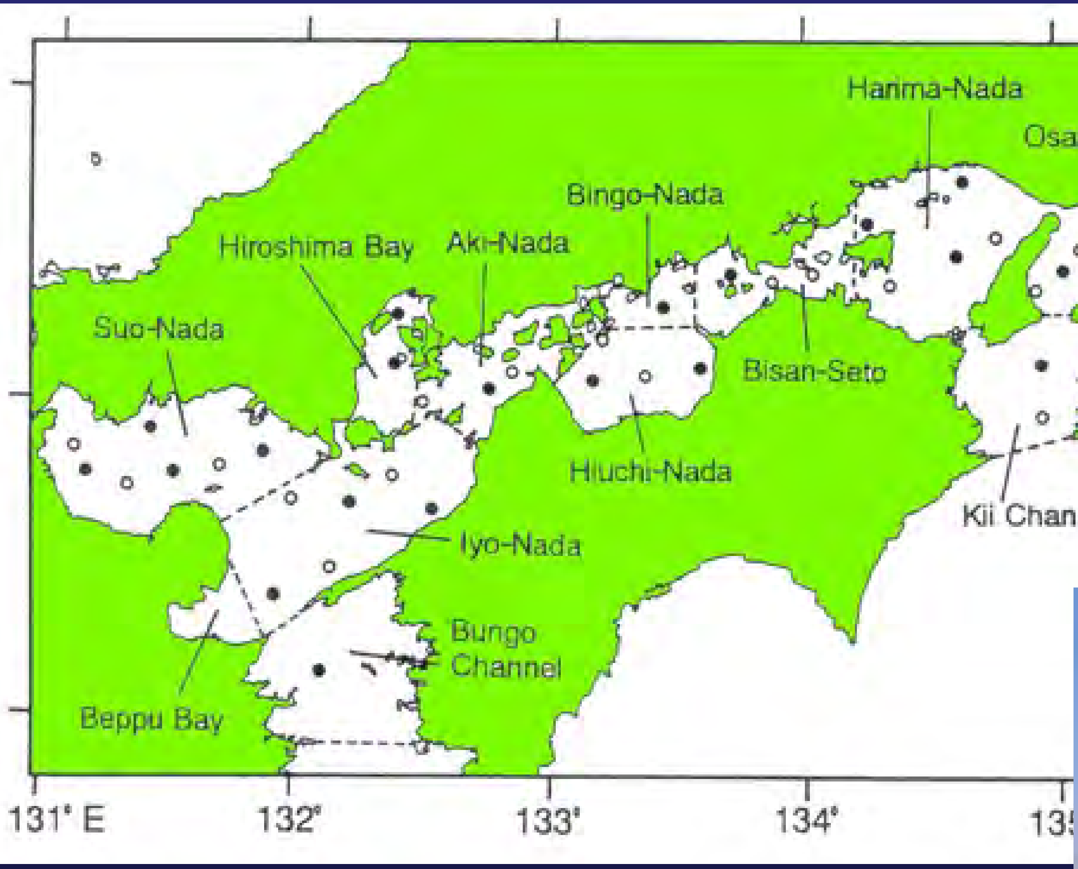


Annual integrated production rate =
2.5 g C m^{-3} yr^{-1} or 18.4 g C m^{-2} yr^{-1}

(Uye & Liang, 1998)

Zooplankton community-based production rates

Research cruise in October 1993, January, April, and June 1994, in the Inland Sea of Japan

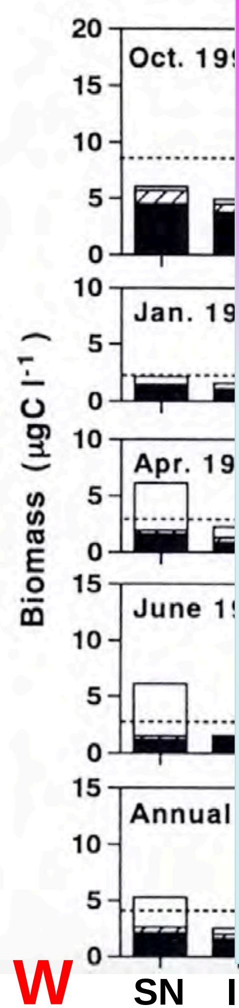


1. General oceanographic surveys at 39 st
2. Phytoplankton primary production at 21 st
3. Zooplankton production at 21 st

Divided into 10 regions (bay, Nada, Seto, and channel)

Hiroshima University R/V "Toyoshio Maru"

Microzooplankton biomass and production rate



Specific grow

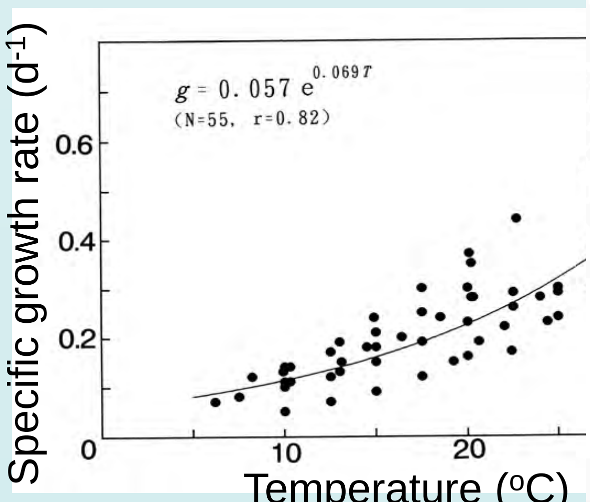
Ciliates: ln*g*=0.1438*T*-0.

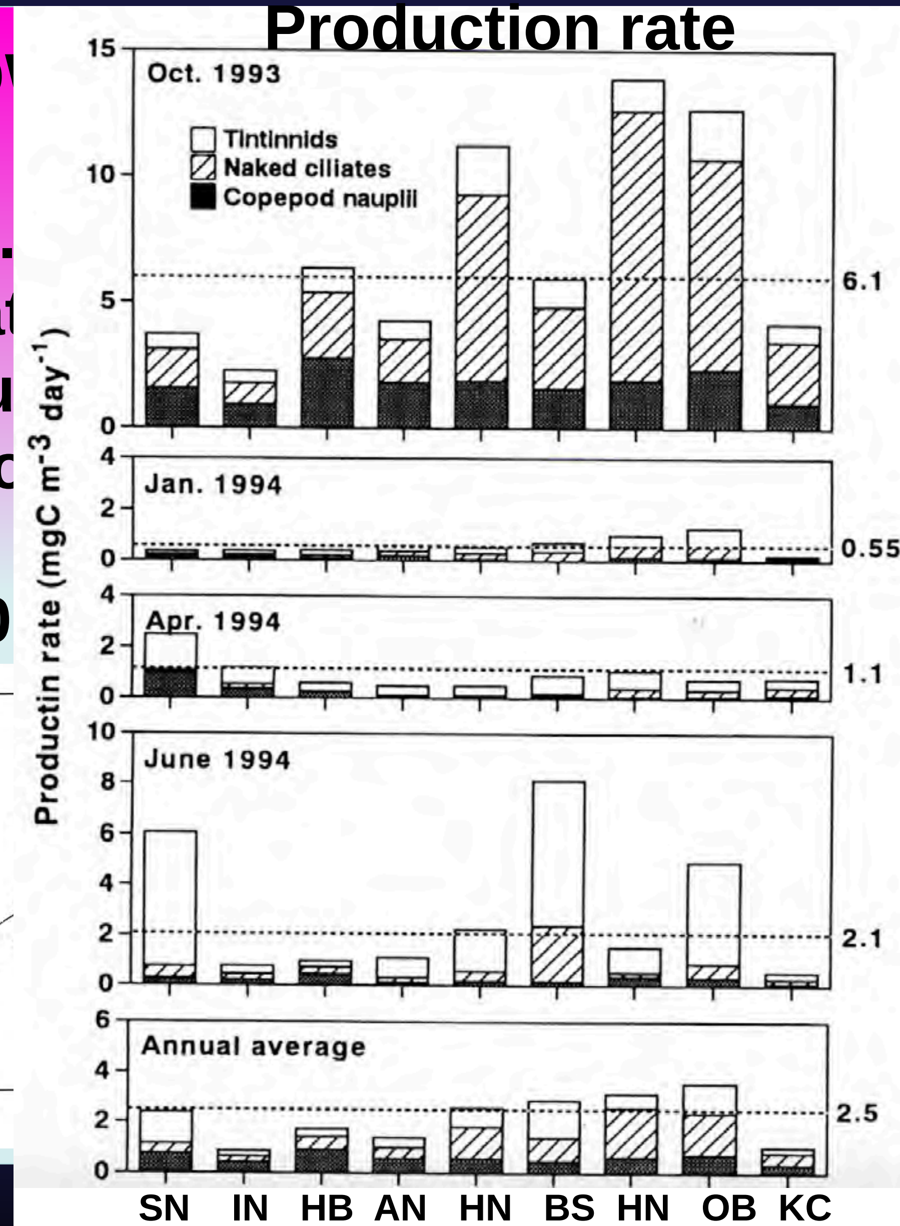
***T*: temperat**

***V*: cell volu**

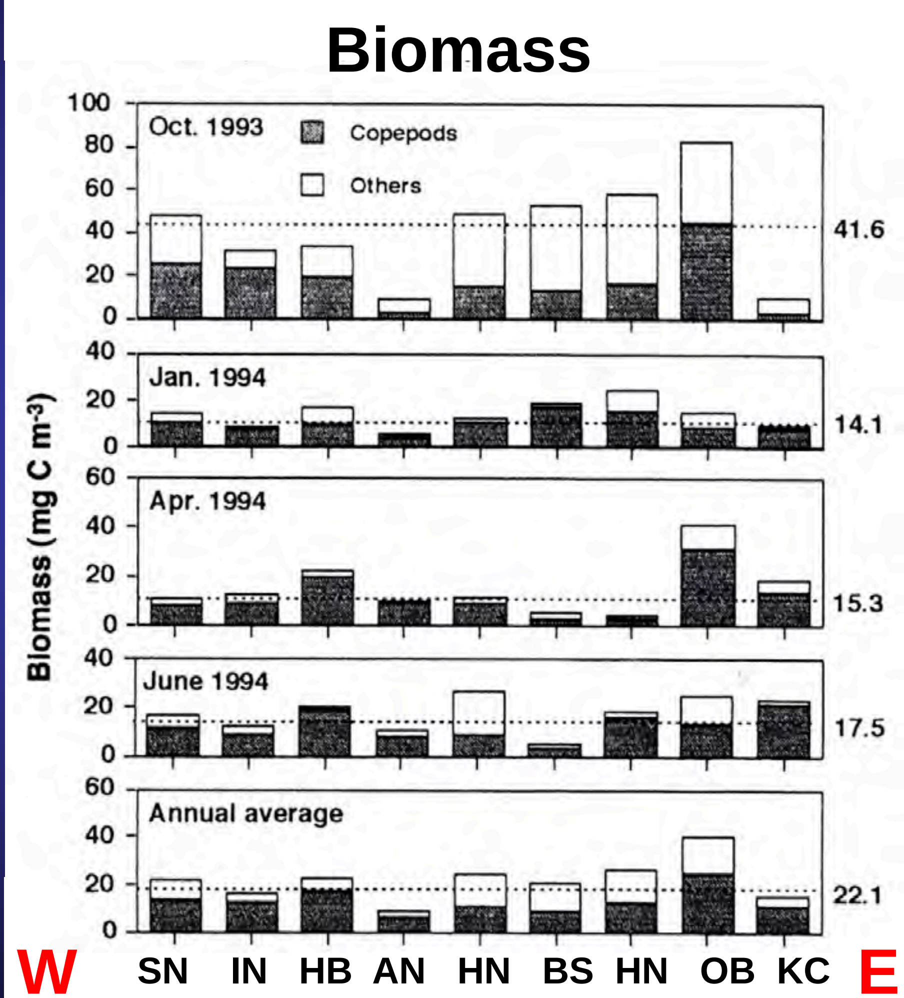
(Mo

Copepod nauplii: *g*=0.0



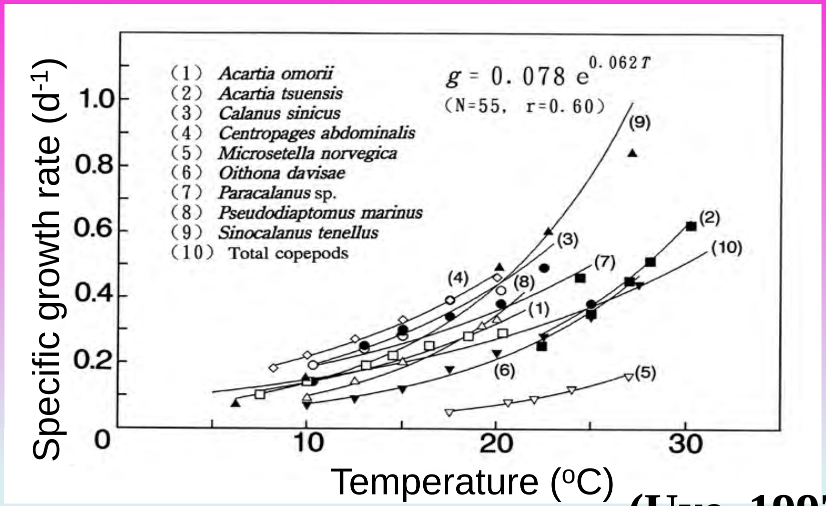


Net-zooplankton biomass and production rate



Specific growth rate (*g*)

Copepods



(Uye, 1997)

Larvaceans

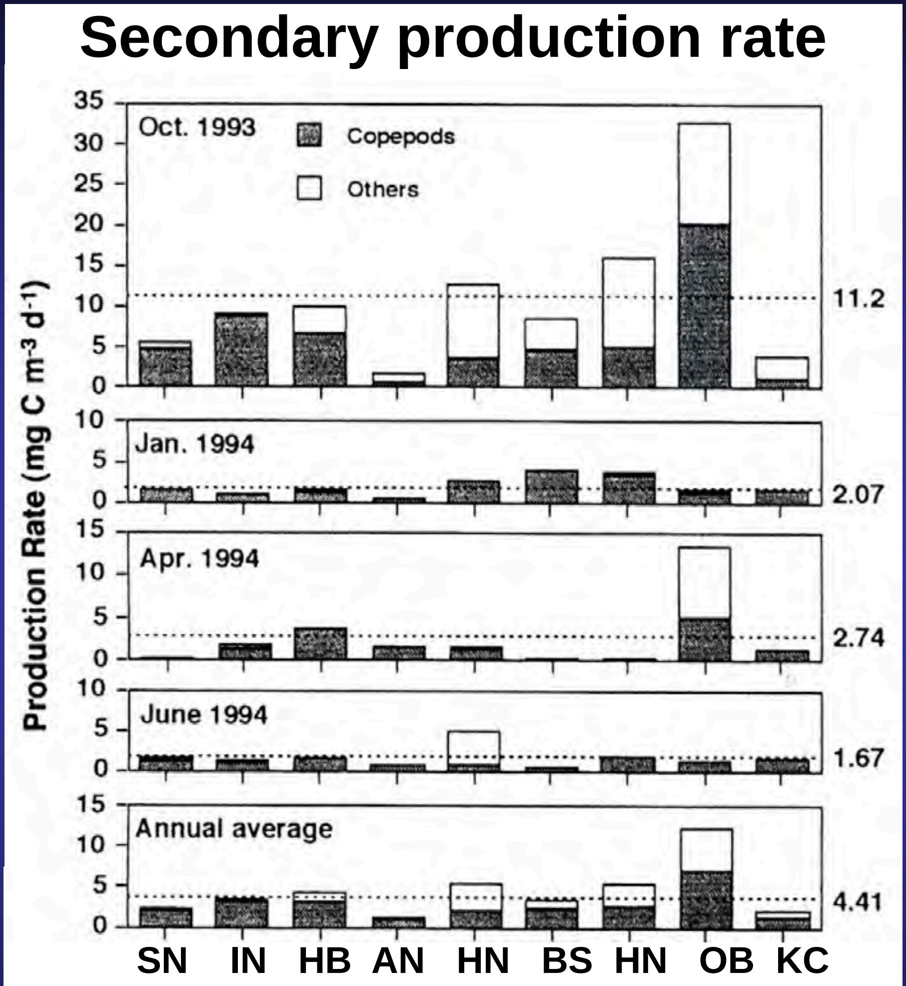
$g=0.077e^{0.13T}$ (Uye & Ichino, 1995)

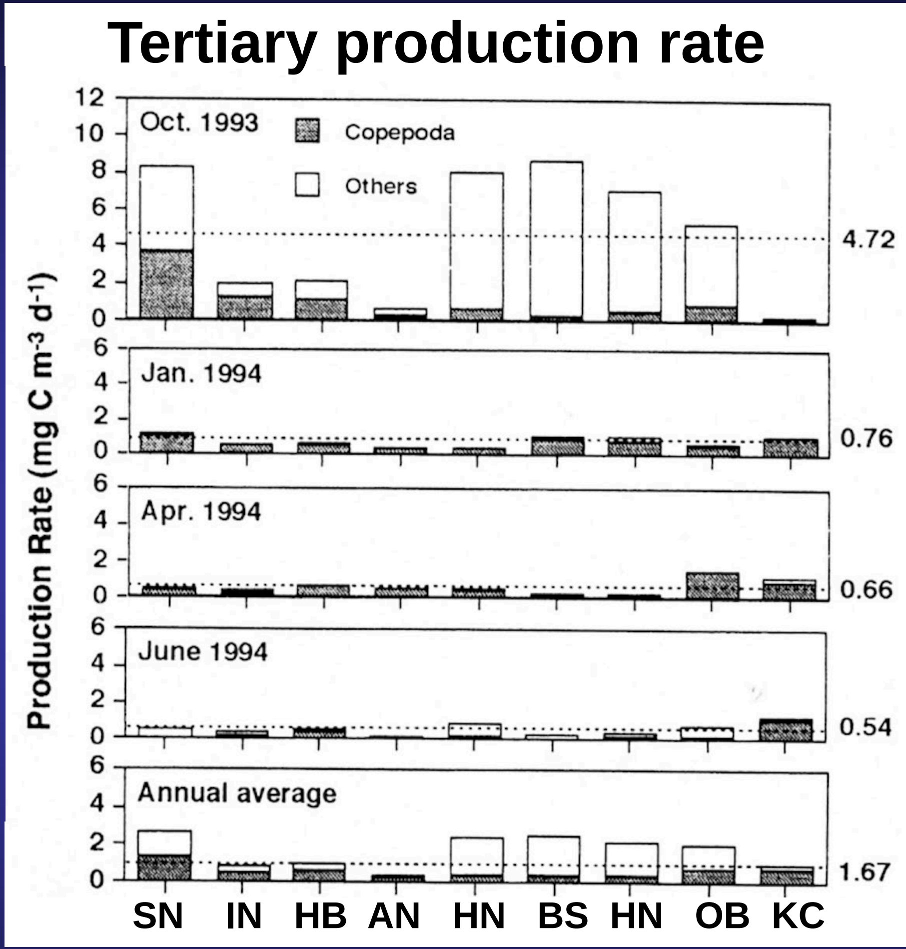
Other taxa (Cnidarians, polychaetes, cladocerans, malacostrarans, chaetognaths, thaliaceans, and benthos larvae)

Ikeda-Motoda's physiological method

(Ikeda & Motoda, 1978)

Net-zooplankton secondary and tertiary production rate



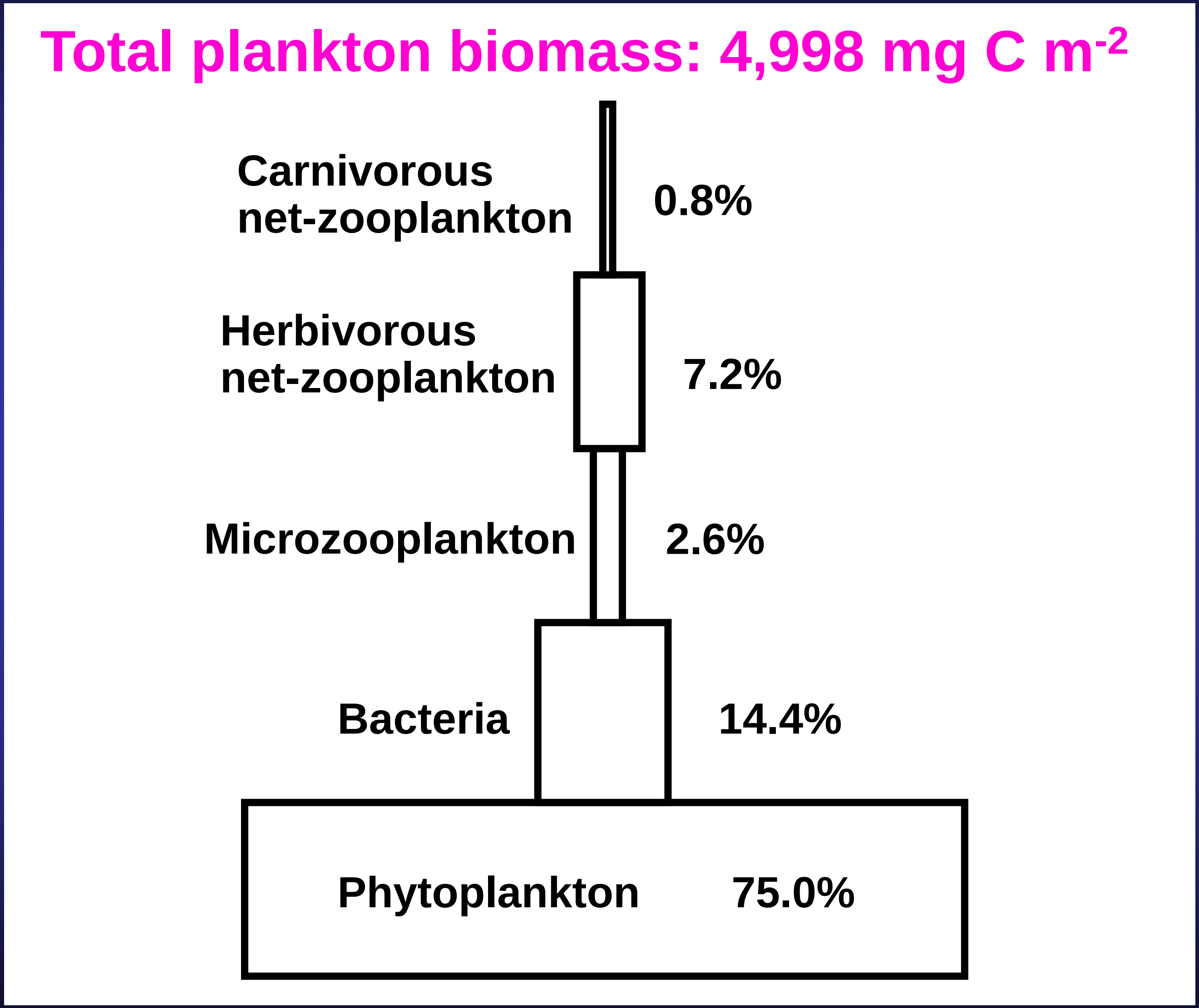


Herbivores: Appendicularians, benthos larvae, cladocerans, herbivorous copepods, thaliaceans

Omnivores: Copepods (*Acartia, Centropages, Oithona, Temora*), Malacostracans

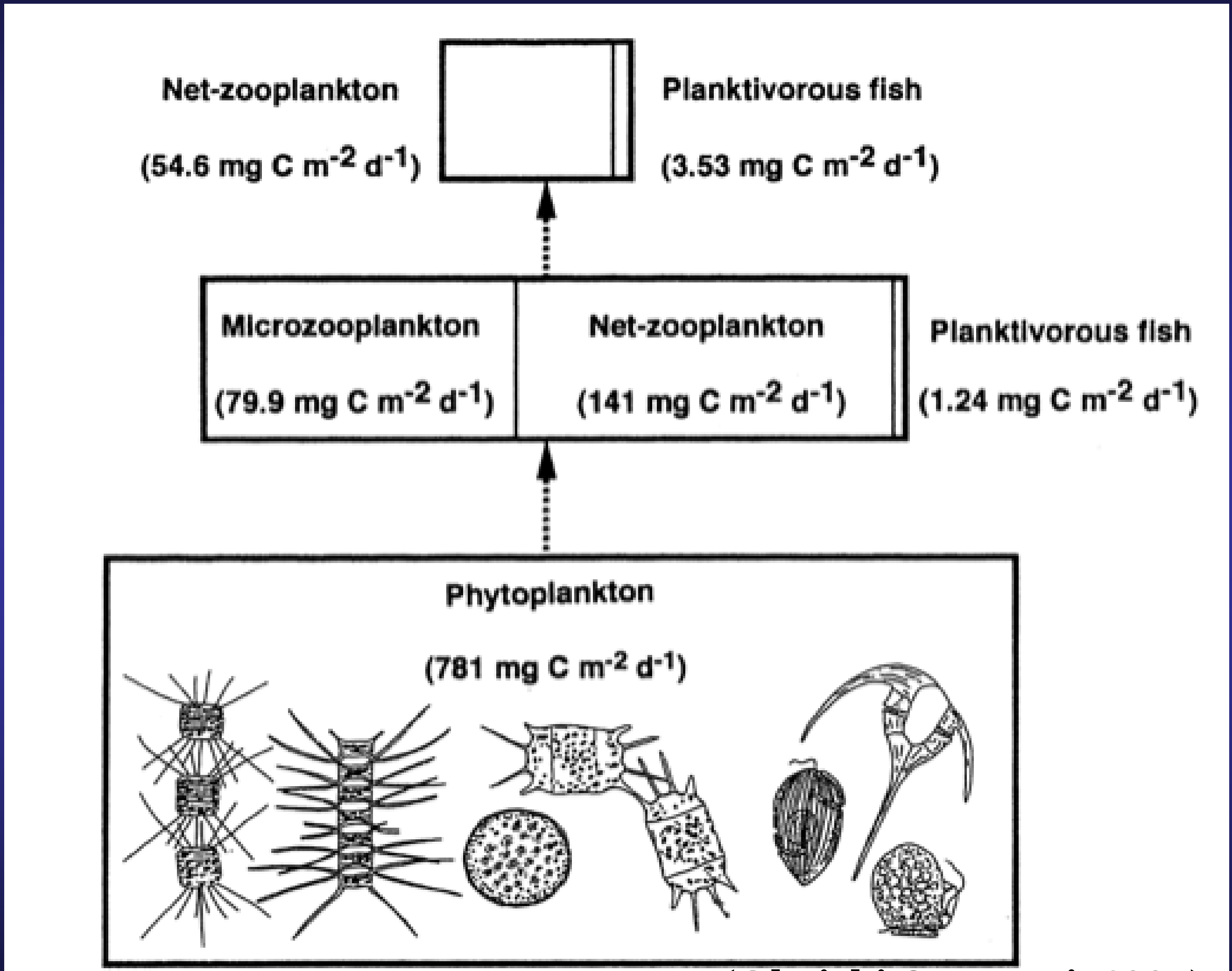
Carnivores: Chaetognaths, cnidarians, carnivorous copepods, fish larvae

Food chain structure of the Inland Sea of Japan

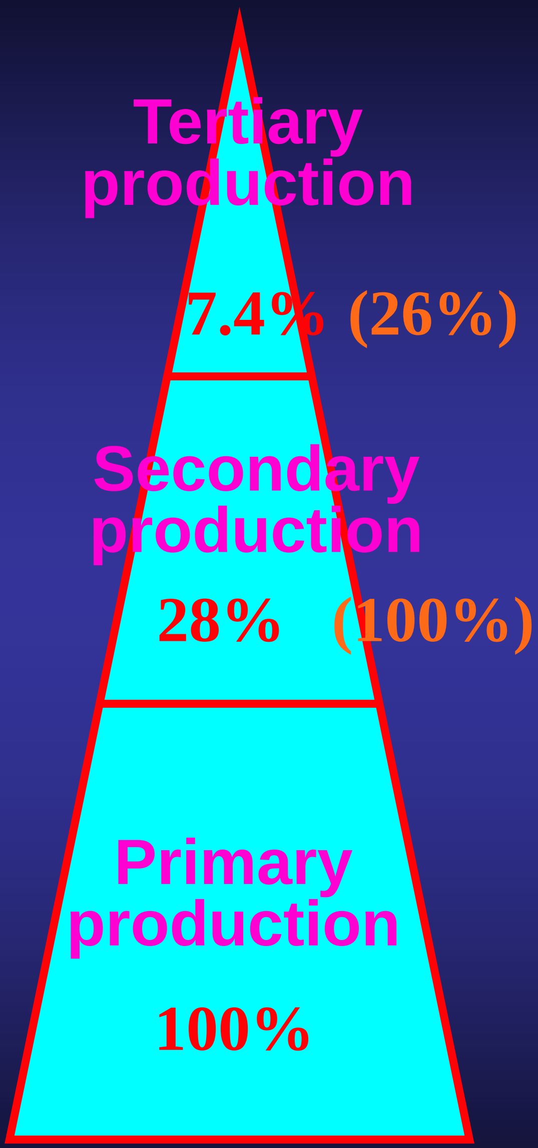


(Redrawn from Okaichi & Yanagi, 1997)

Food chain structure of the Inland Sea of Japan

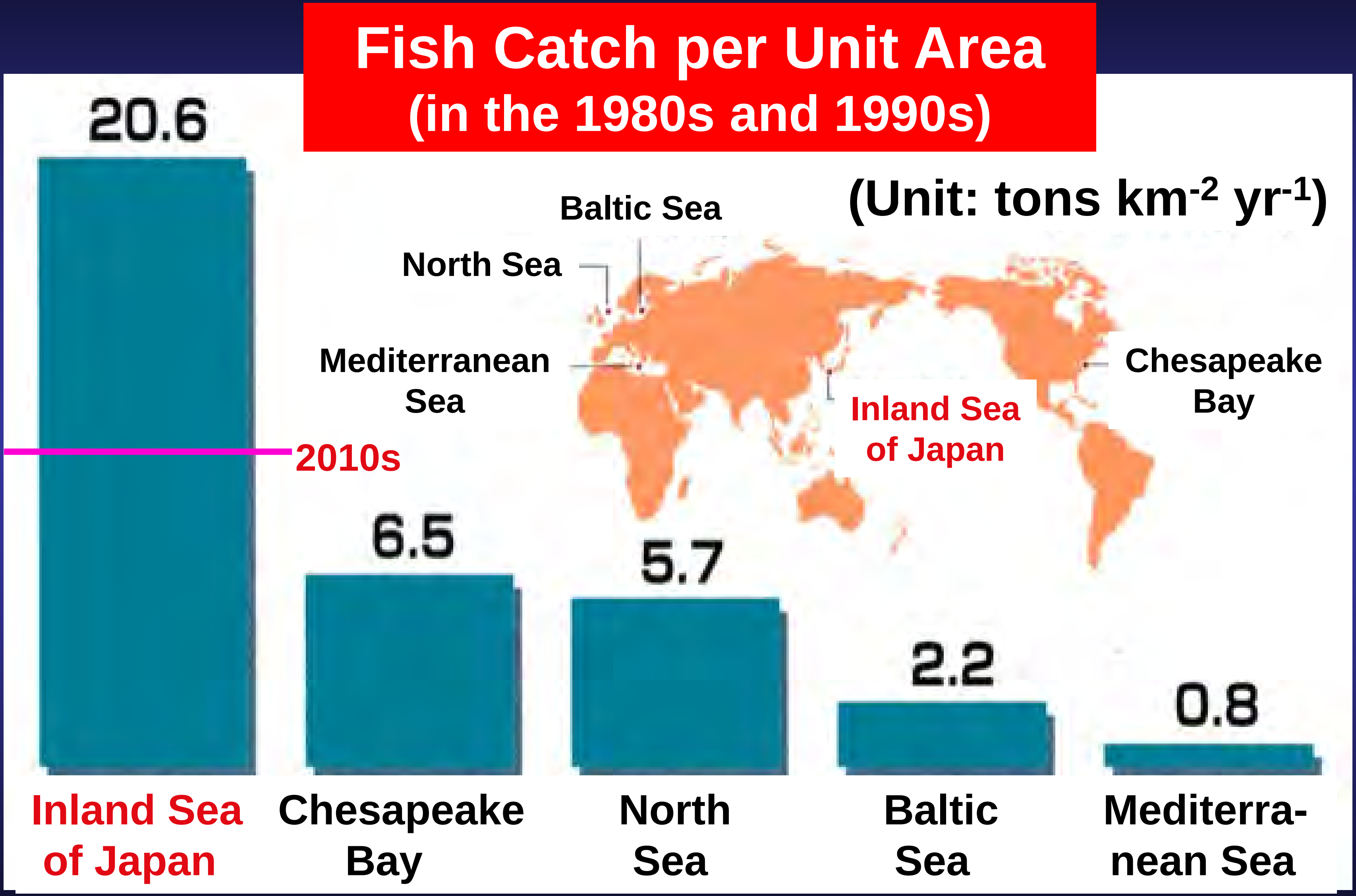


(Okaichi & Yanagi, 1997)



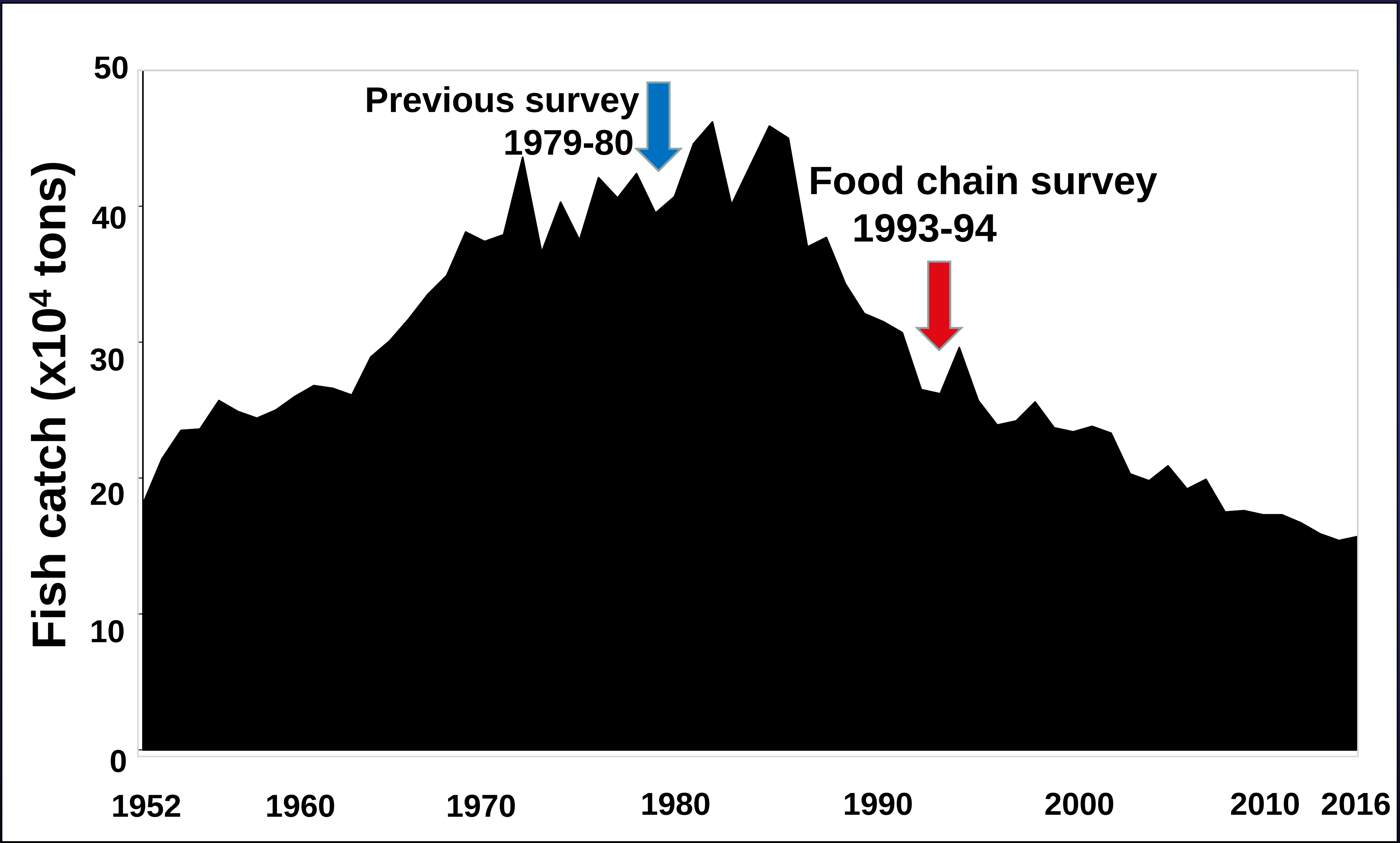
High transfer efficiency between trophic levels

Productive fishing ground

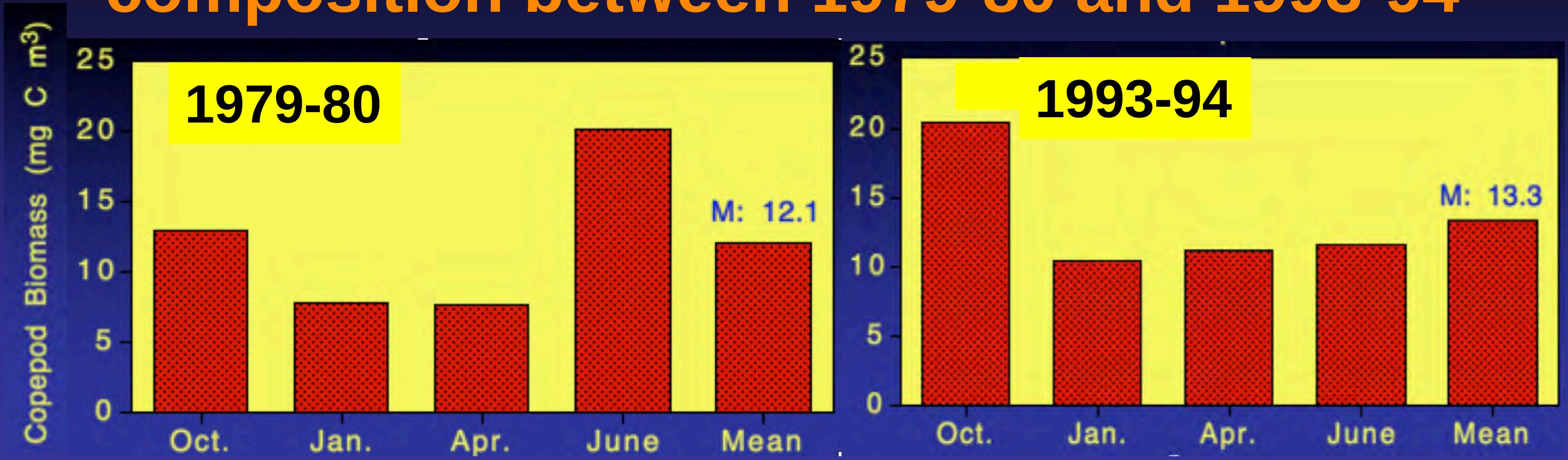


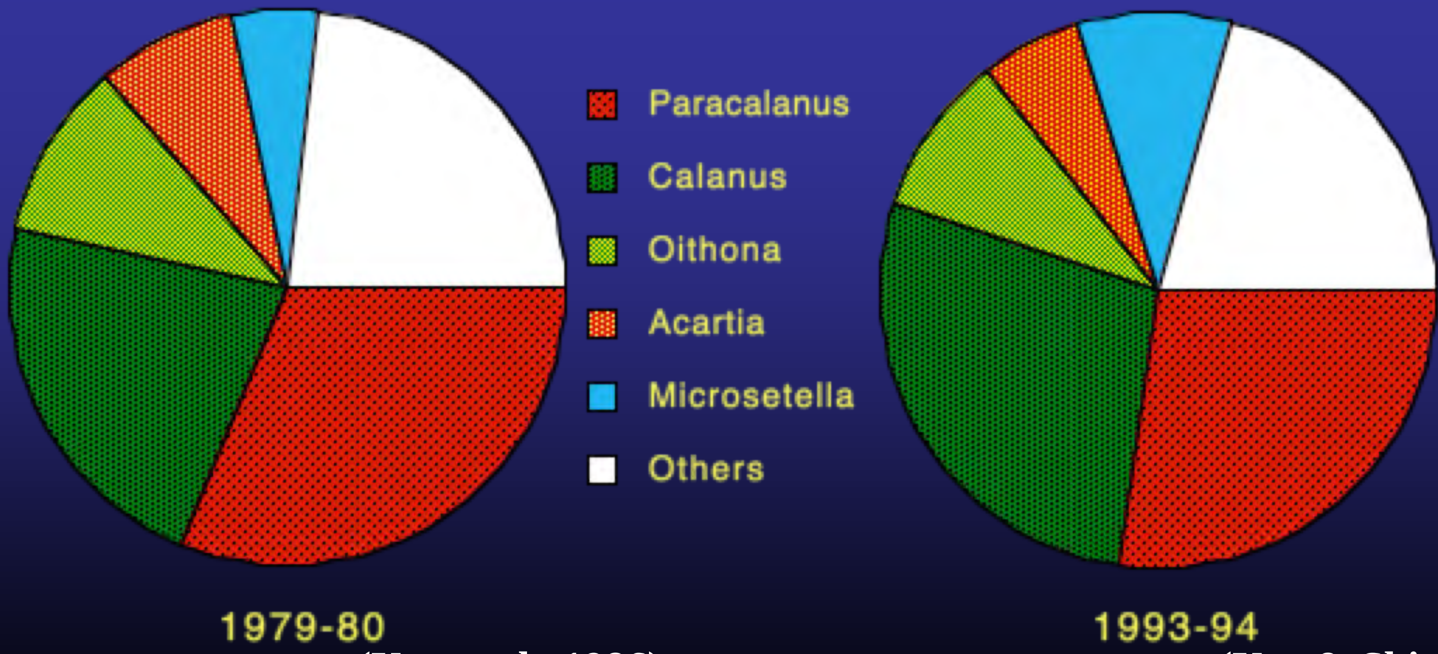
(Modified from Takeoka, 1997)

Deterioration of productive ecosystem
Decrease in fish catch after the 1980s



Comparison of copepod biomass and taxonomic composition between 1979-80 and 1993-94





(Uye et al., 1986)

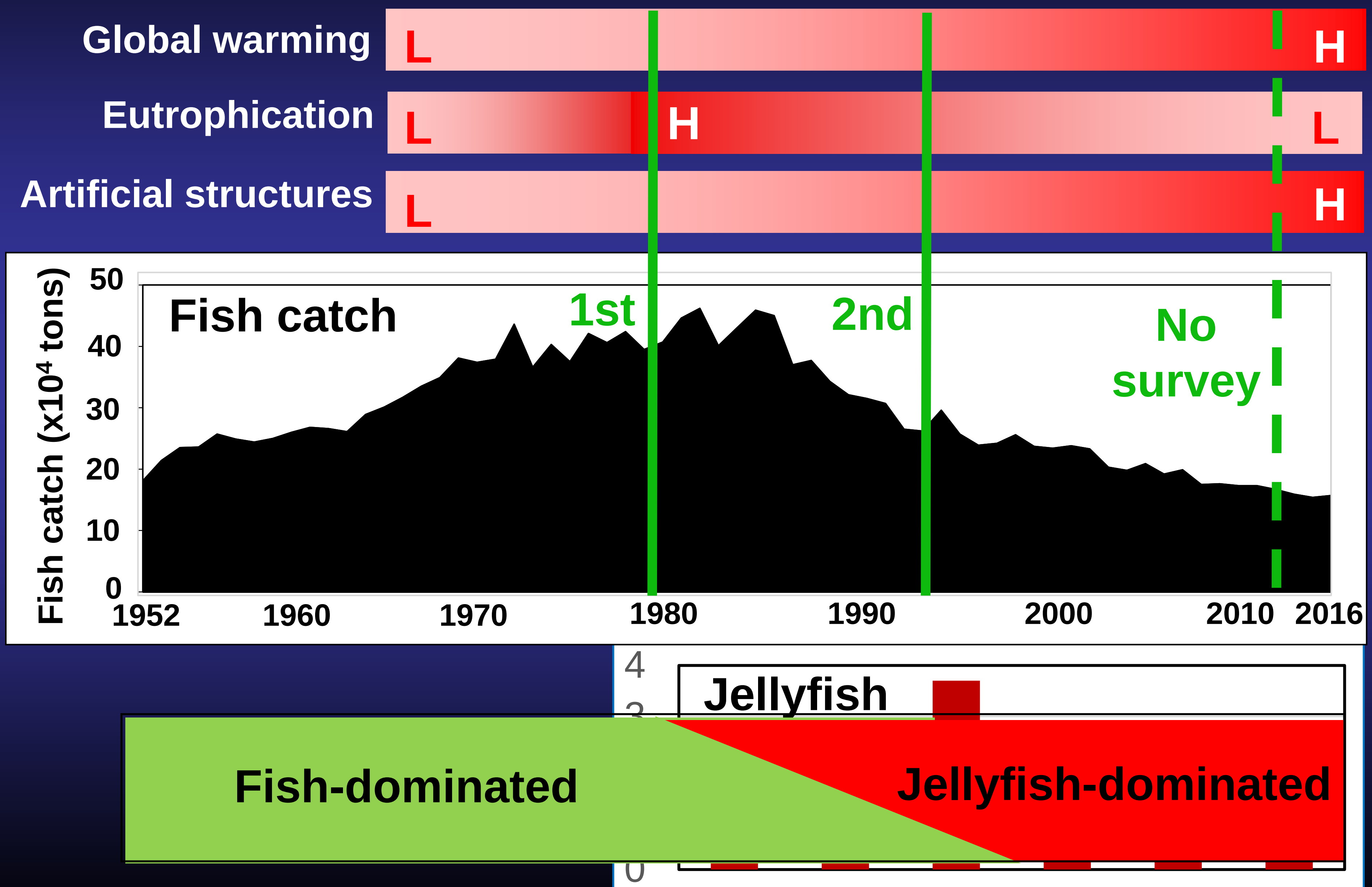
(Uye & Shimazu, 1997)

Jellyfish trends in the Inland Sea of Japan

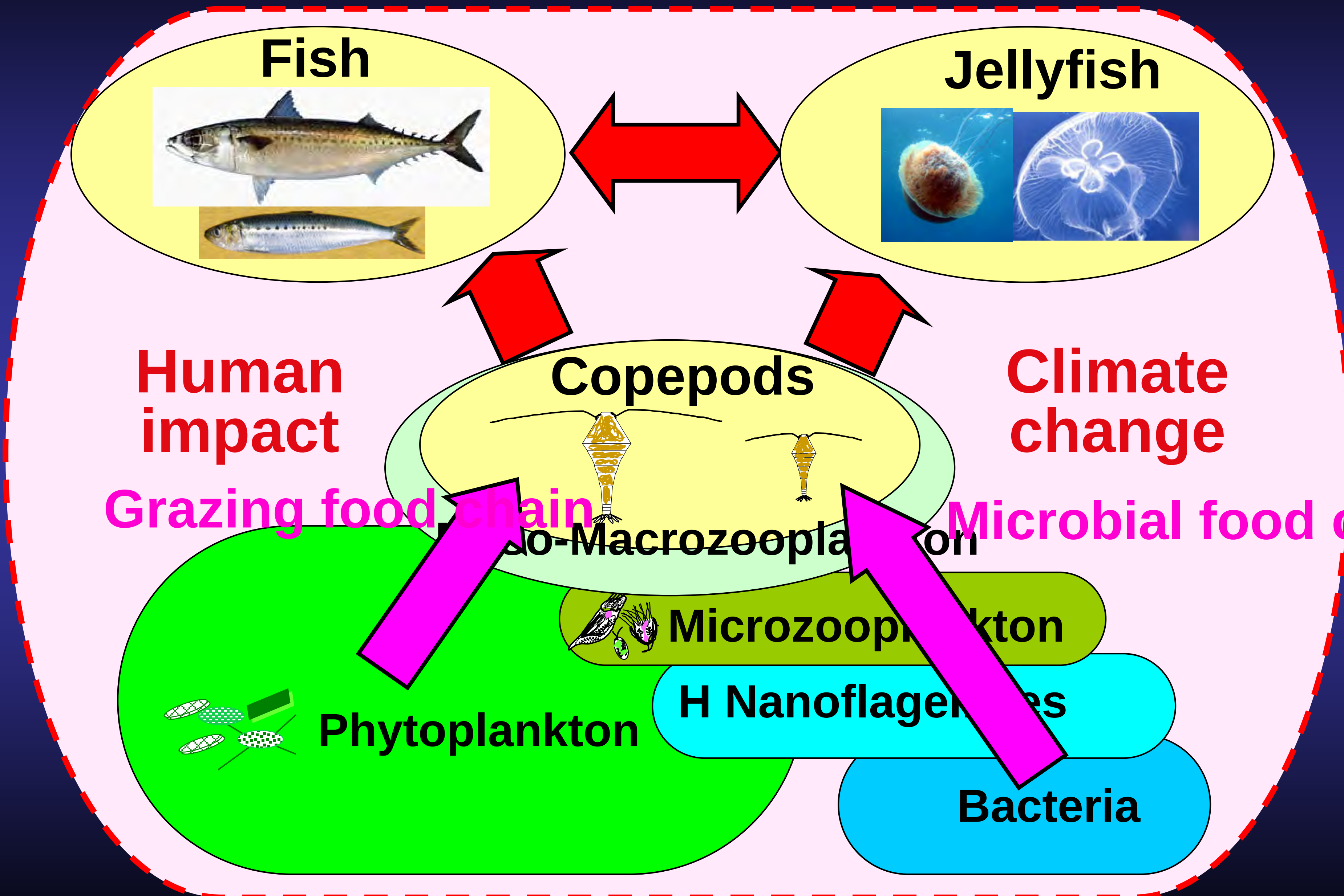
Since the 1990s, many fishermen claimed that jellyfish aggregations damage their fisheries, and in 2000 a unprecedentedly large population outbreak of *Aurelia coerulea* occurred in the western Inland Sea of Japan

Aurelia coerulea
medusae

Environmental changes in the Inland Sea of Japan leading to jellyfish-dominated ecosystem



Trophic structure in marine coastal waters



Conclusion

1. The Inland Sea of Japan, a former productive fishing ground, shows a typical example of ecosystem deteriorated by human impacts.
2. To understand the effects of human impacts, it is necessary to clarify the energy flux through whole trophic processes up to fish.
3. Zooplankton production is a key process.
4. Individual-based specific growth rates are always the foundation for the population-based and community-based production estimates.
5. Needs accumulation of their growth rate data.