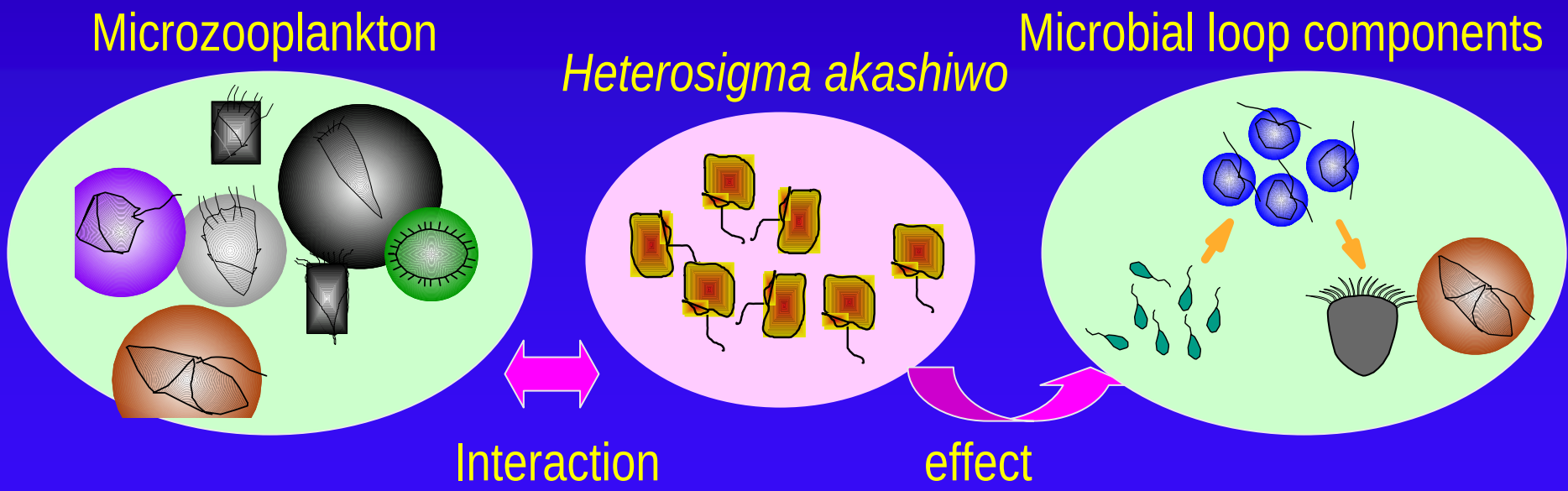
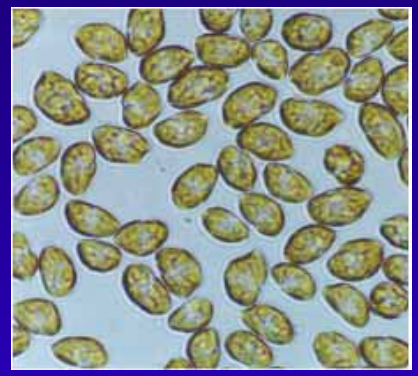
Effects of *Heterosigma akashiwo* blooms on planktonic food webs: responses of microbial loop components

Takashi Kamiyama

Tohoku National Fisheries Research Institute, FRA



Heterosigma akashiwo bloom



Heterosigma akashiwo
(Raphidophycea)

Cell characteristics

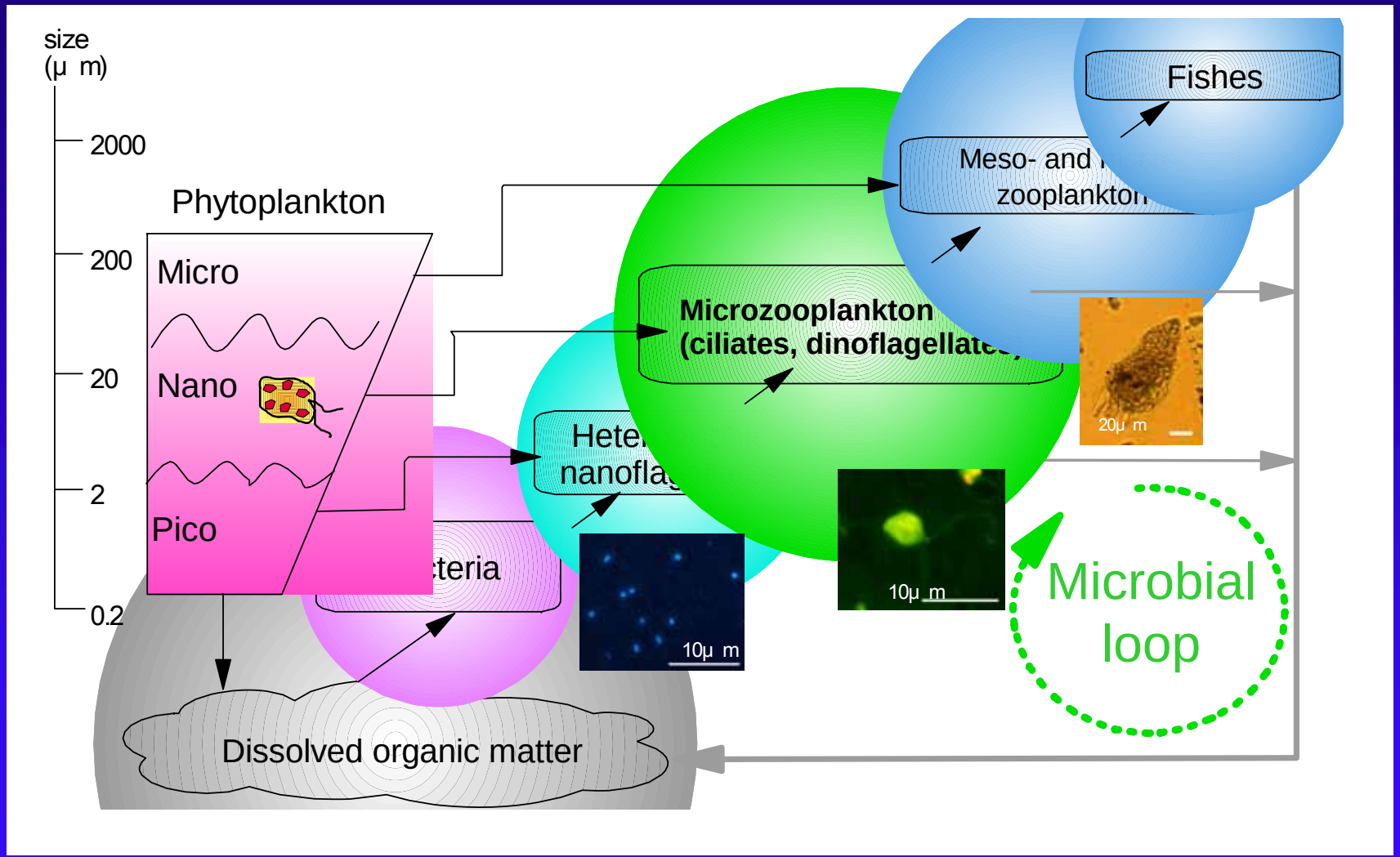
Cell dimension: 8-25 x 6-15 um

No cell wall, yellow-brown color and ovoid, slightly compressed shape

Bloom characteristics

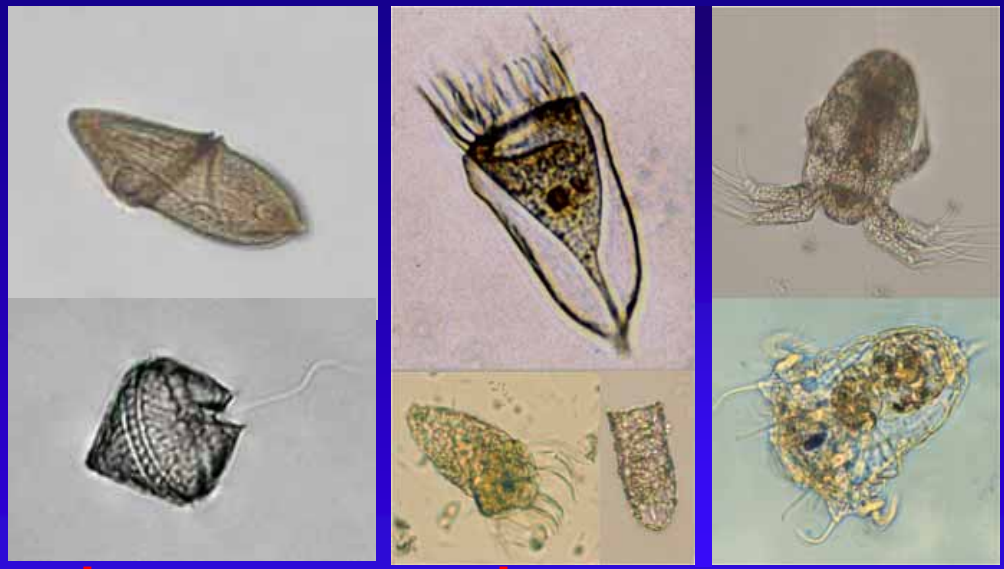
The bloom typically occurs in embayment where currents are week. The bloom tends to occur from May to July. This is associated with optimal temperature (15-30 ^{o}C) for its growth. (Honjo 1993)

Planktonic food chains in marine ecosystem



Microzooplankton

zooplankton which can go through the mesh size of 200 μm



Metazoan (copepod nauplii, rotifers, etc)

Ciliates (tintinnid and aloricate ciliates)

Dinoflagellates (Heterotrophic or mixotrophic)

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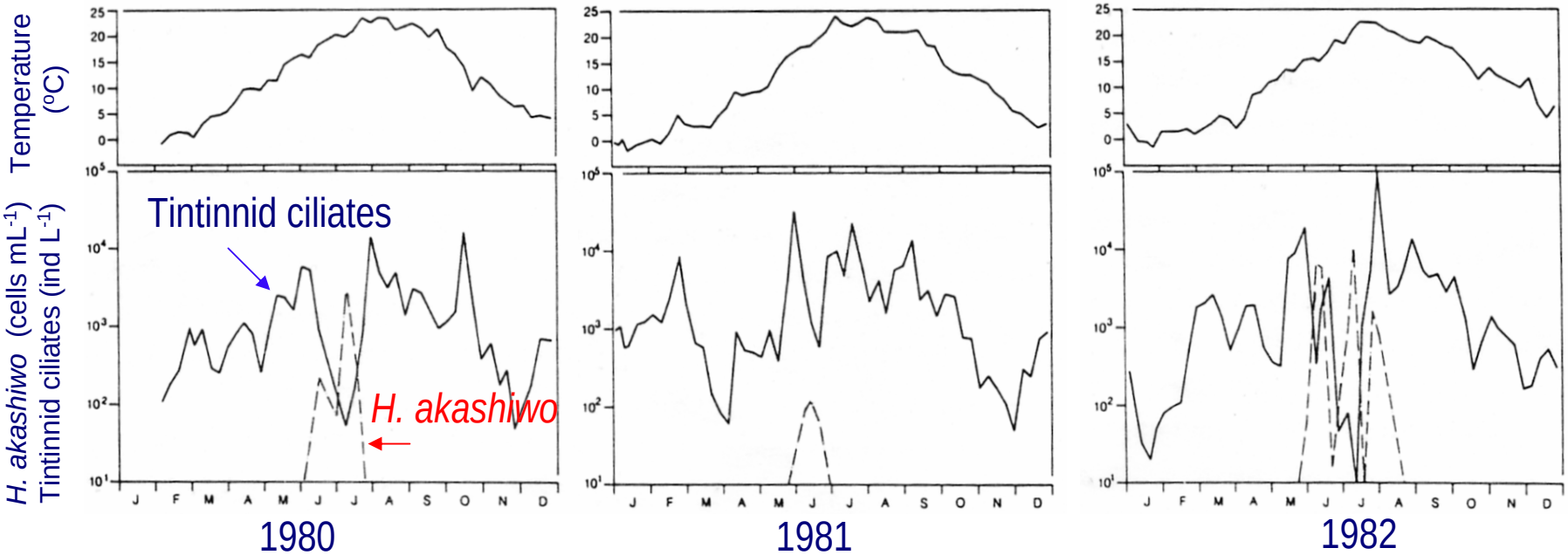
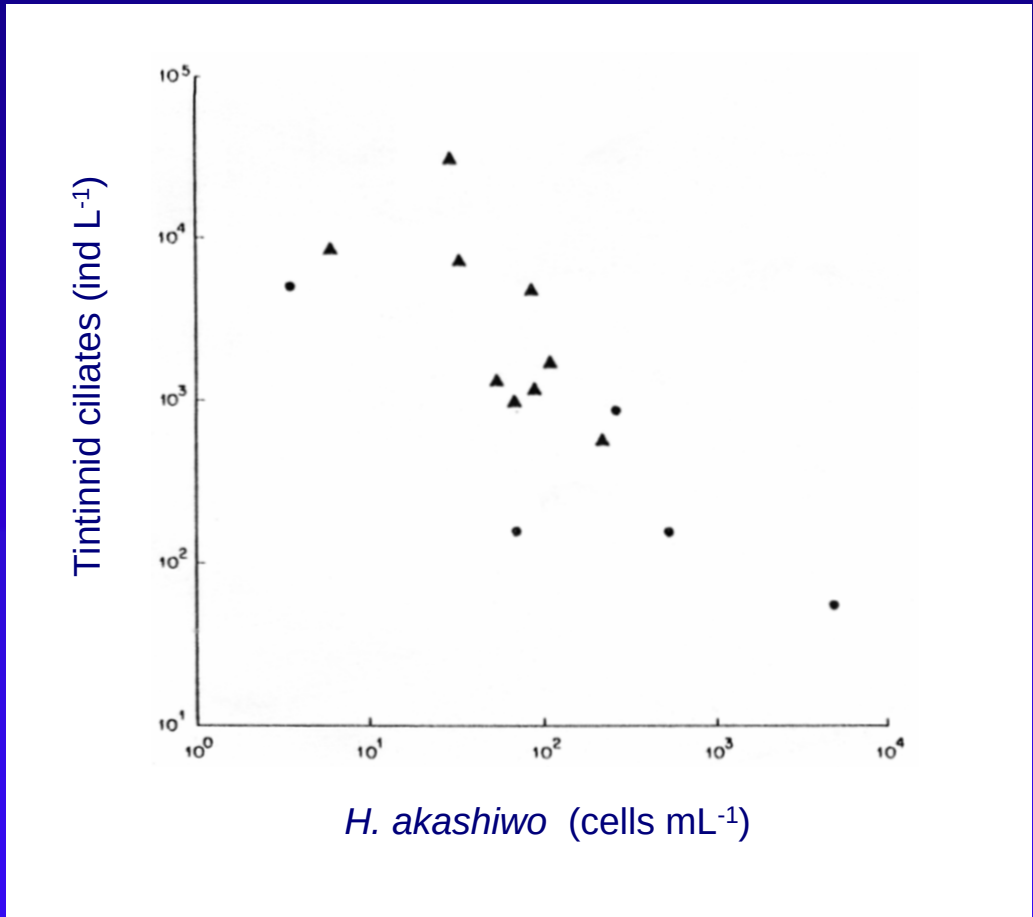
2. Feeding and growth responses of microzooplankton to *H. akashiwo*
3. Responses of bacteria, heterotrophic nanoflagellates, aloricate ciliates during the course of *H. akashiwo* blooms

1. Effects of *Heterosigma akashiwo* blooms on ciliate community

Effects of *H. akashiwo* blooms on population dynamics of tintinnid ciliates in Narragansett Bay (Verity 1987)

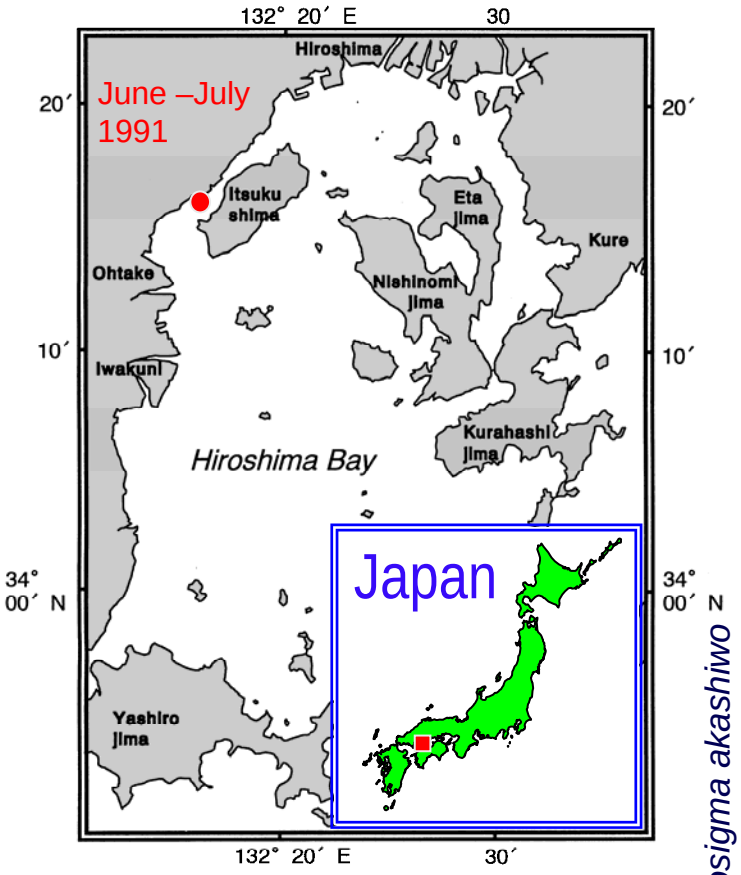


Relationships between *H. akashiwo* concentration and abundance of tintinnid ciliates in Narragansett Bay

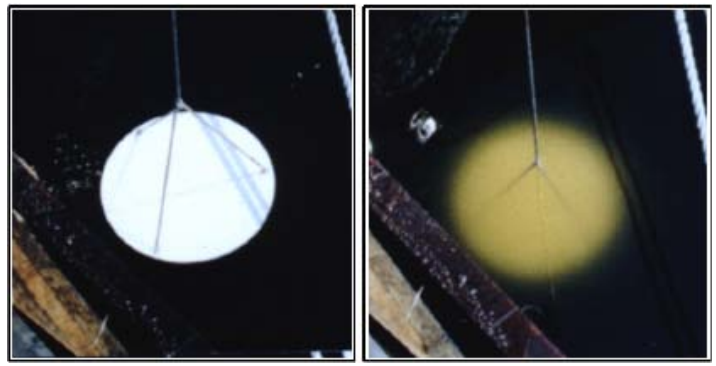


(Verity & Stoecker 1982)

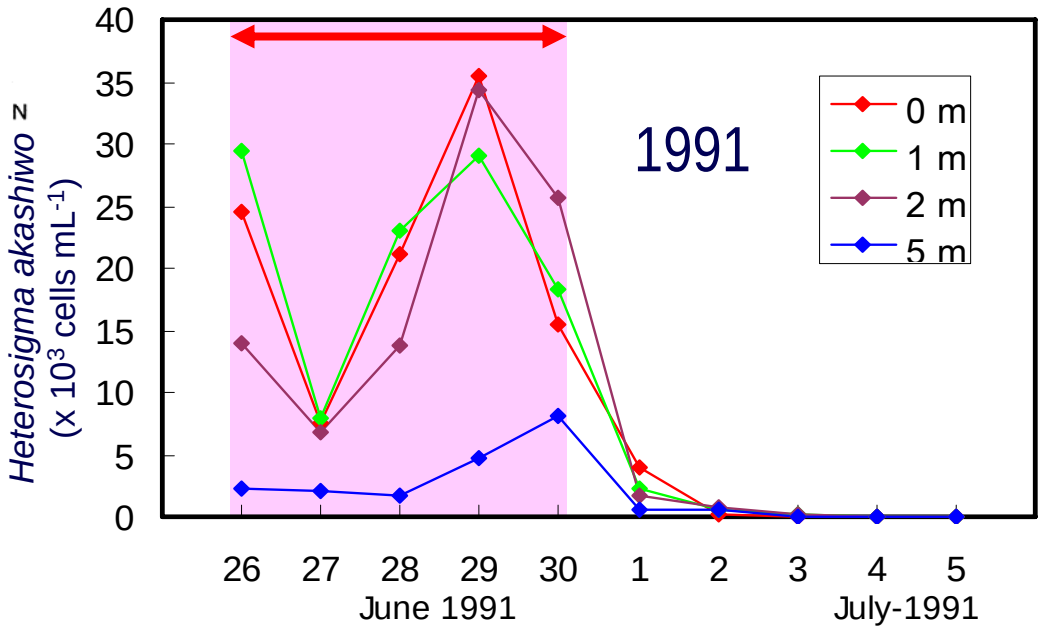
A bloom of *Heterosigma akashiwo* in 1991



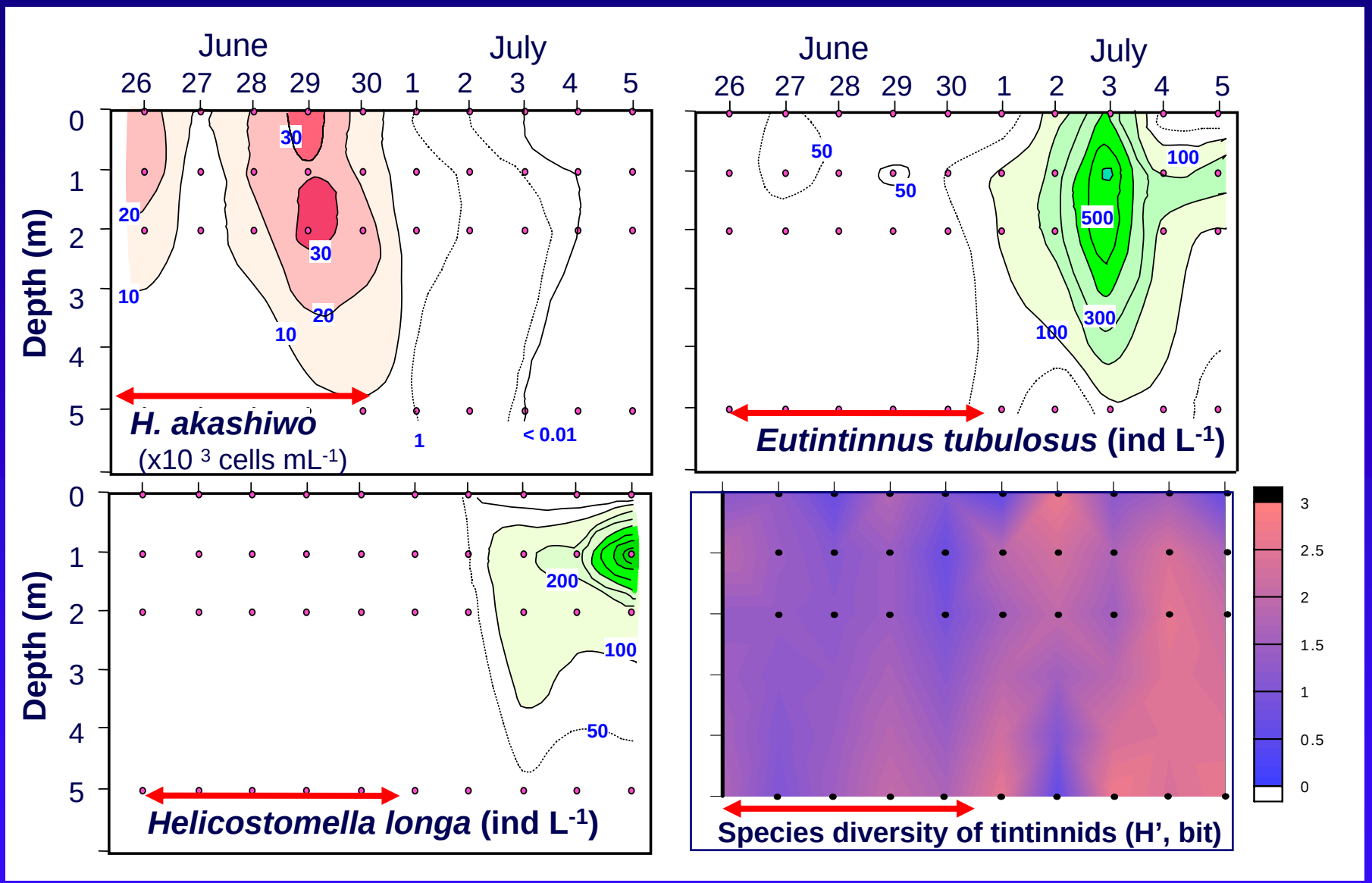
Depth at sampling site : ca. 6 m



Above the surface **5 – 6 cm layer**

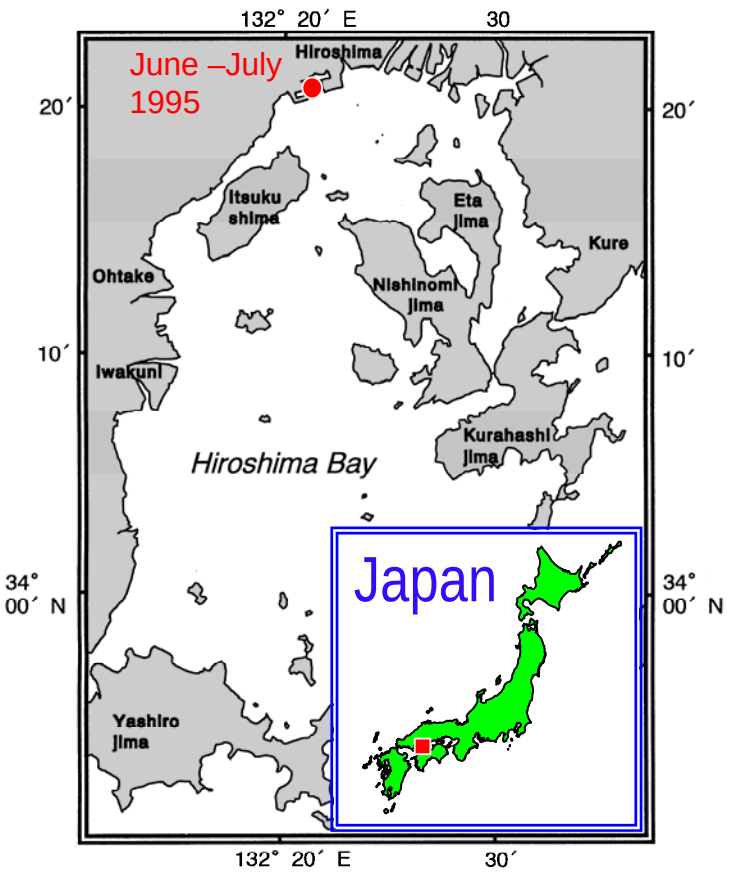


Changes in vertical distribution of *H. akashiwo*, abundances of 2 species and species diversity of tintinnid ciliates in 1991

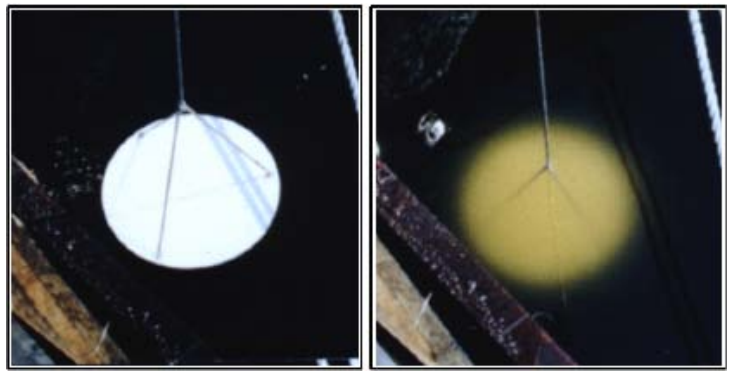


(redrawn from Kamiyama 1995)

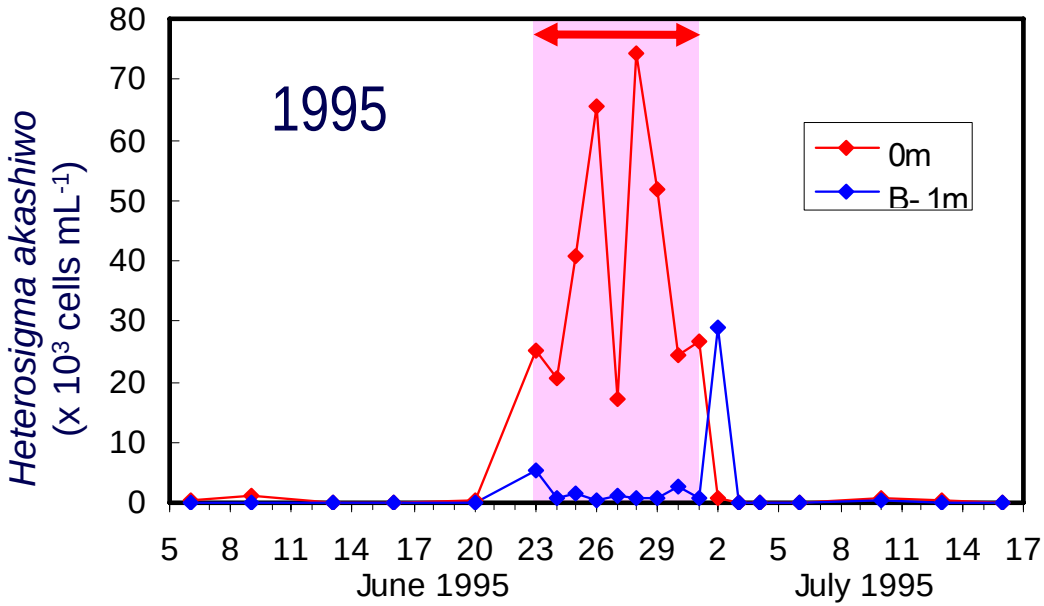
A bloom of *Heterosigma akashiwo* in 1995



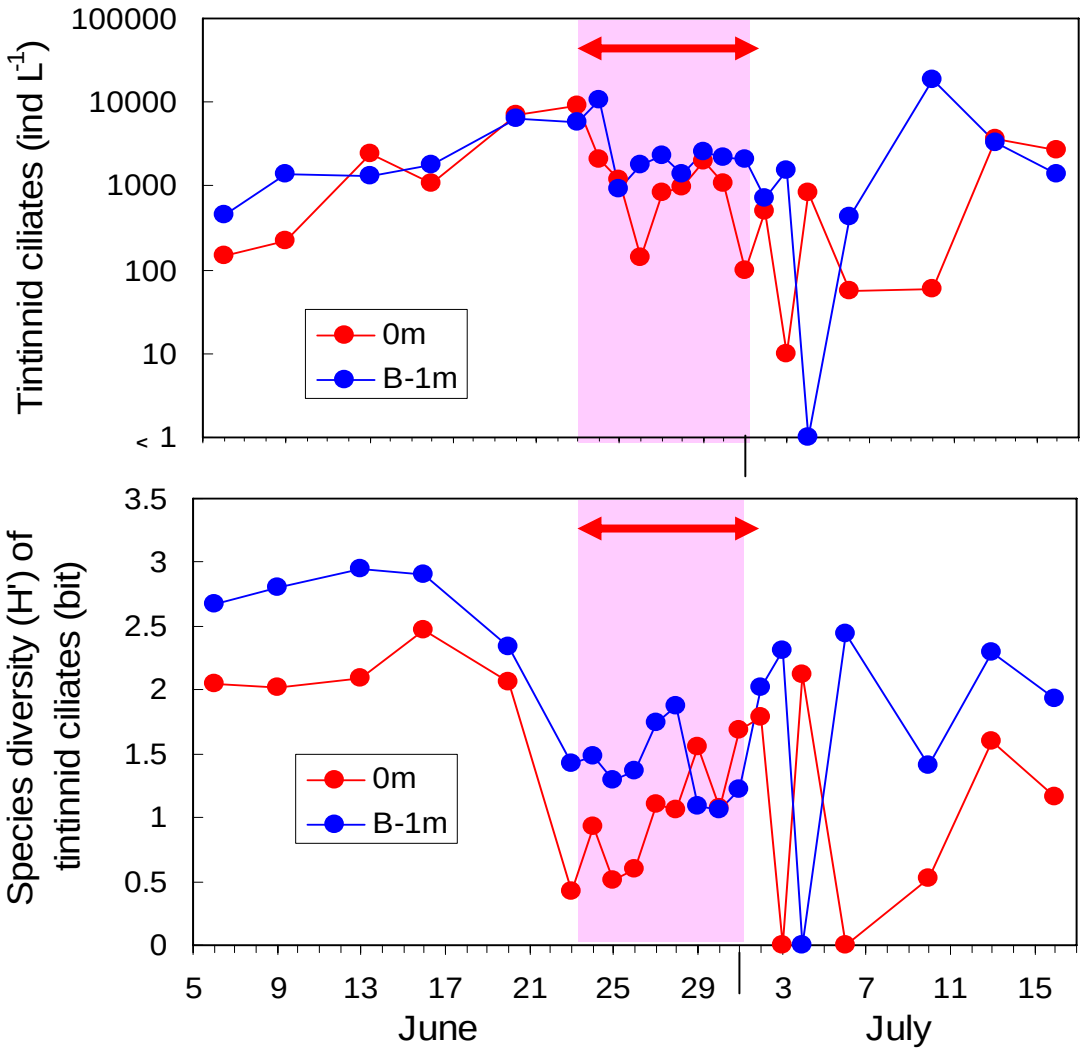
Depth at sampling site : ca. 5 m

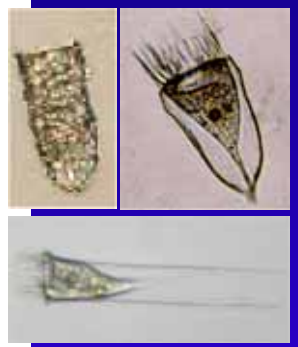


Above the surface 5 – 6 cm layer



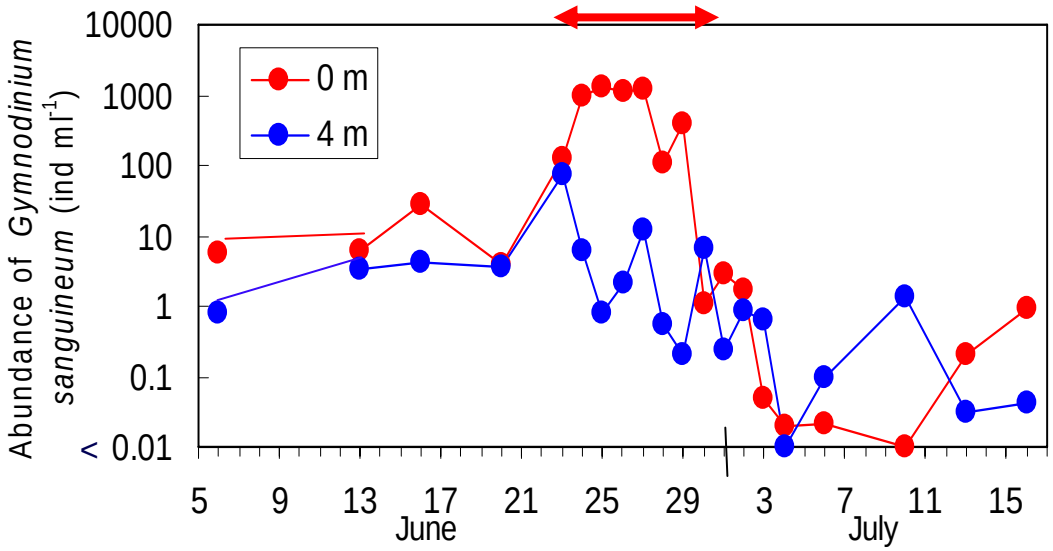
Changes in abundance and species diversity of tintinnid ciliates

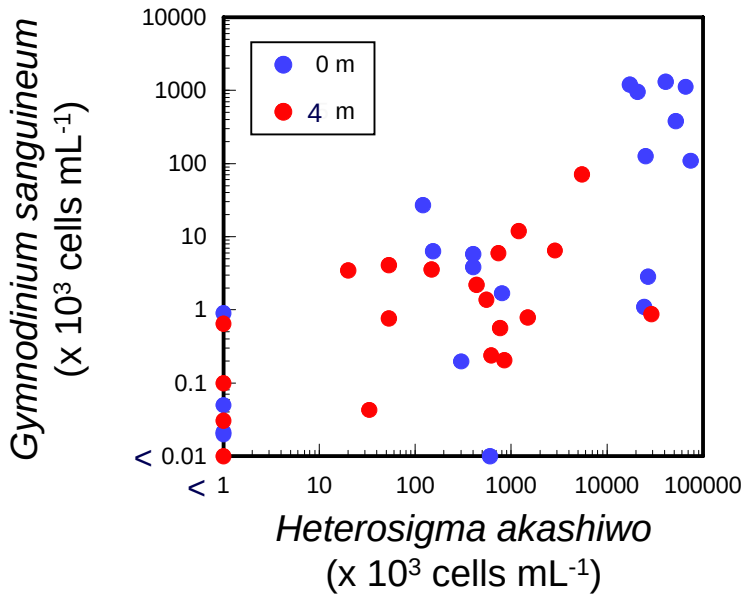




(redrawn from Kamiyama et al. 2000)

Changes in abundance of *Gymnodinium sanguineum* and relationships to the concentration of *H. akashiwo*



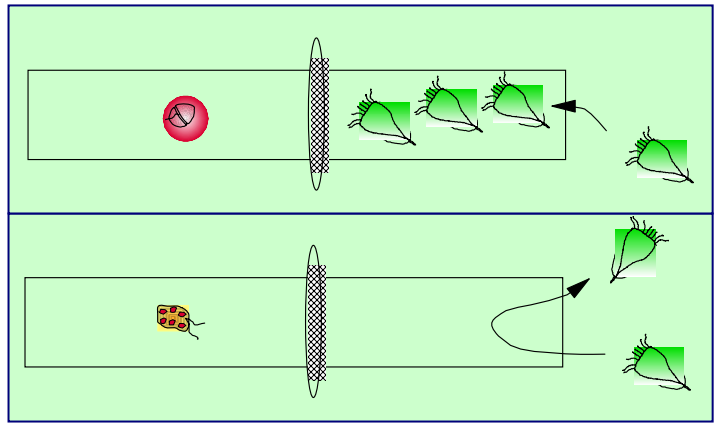


(redrawn from Kamiyama et al. 2000)

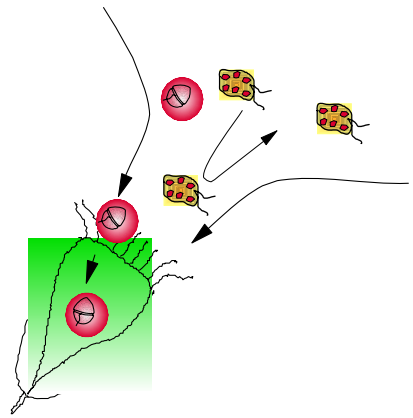
2. Feeding and growth response of microzooplankton to *H. akashiwo*

- Tintinnid ciliates reject *H. akashiwo* as a food source

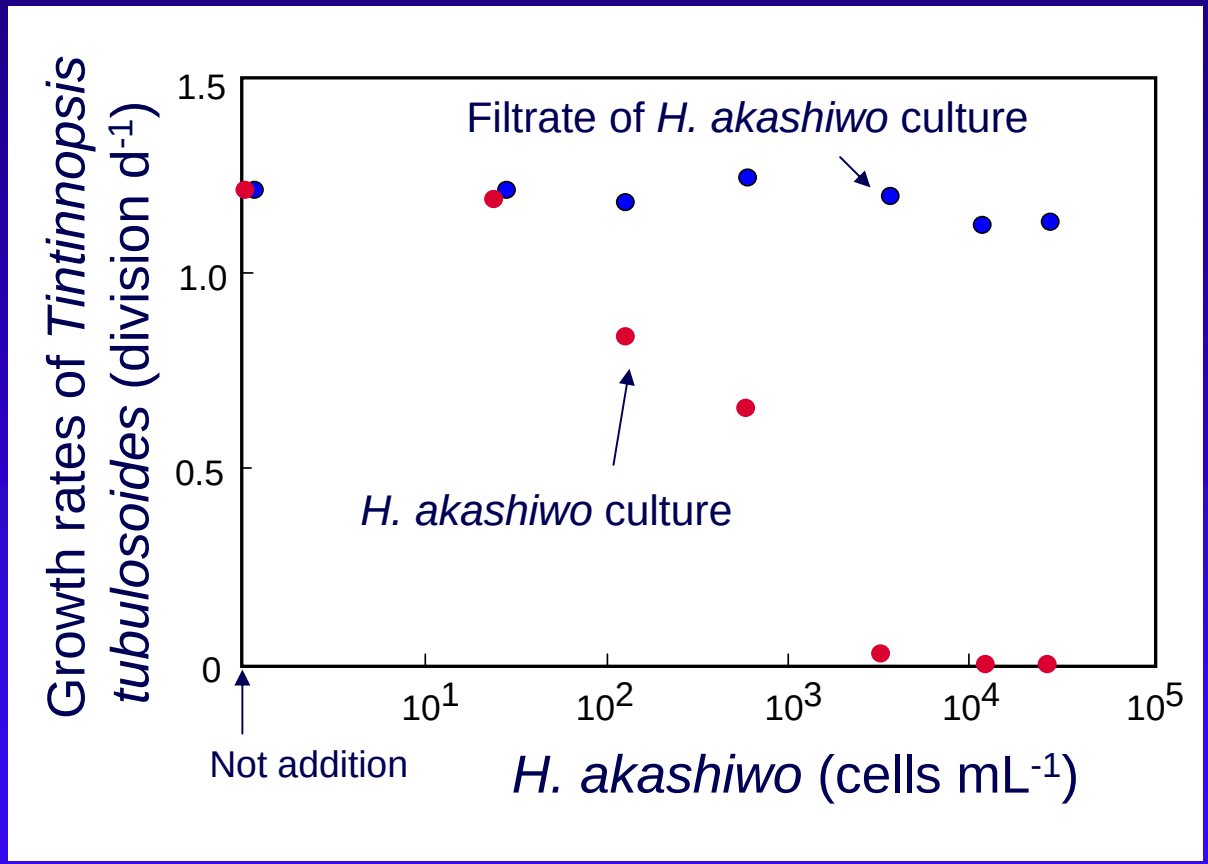
1. Avoidance due to chemosensory response of tintinnid ciliates (Verity 1988)



2. Rejection of a tintinnid ciliate to *H. akashiwo* observed using a high speed VTR system (Taniguchi and Takeda 1988)



✧Effects of *H. akashiwo* concentration and filtrate of the culture on growth of tintinnid ciliates



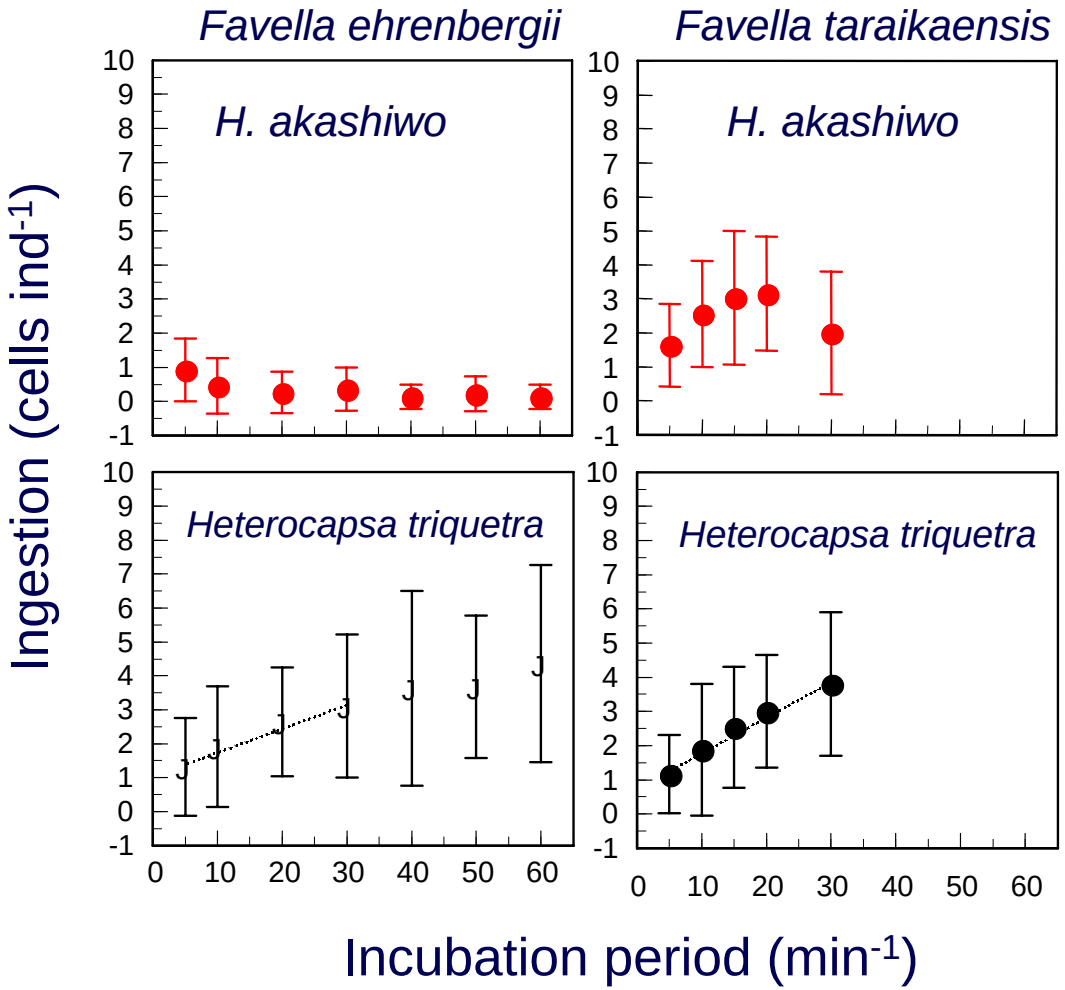
Test condition:
Non toxic alga, *Isochrysis galbana* (10^5 cells mL^{-1}) + *H. akashiwo* culture or its filtrate at each concentration

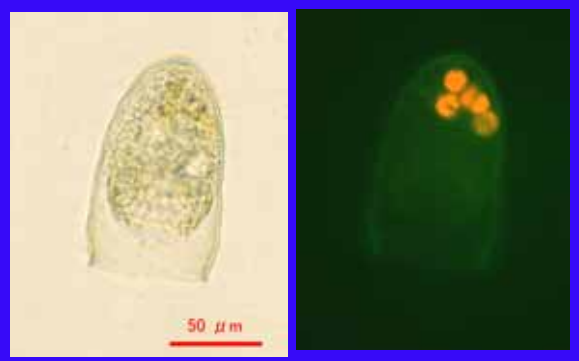
(redrawn from Verity & Stoecker 1982)

- Mortality of tintinnids occurred at > 5 x 10^3 cells mL^{-1} of *H. akashiwo*
- Filtrate of *H. akashiwo* culture did not influence the growth of tintinnid ciliates

✧Ingestion and not ingestion of *H. akashiwo* by tintinnid ciliates

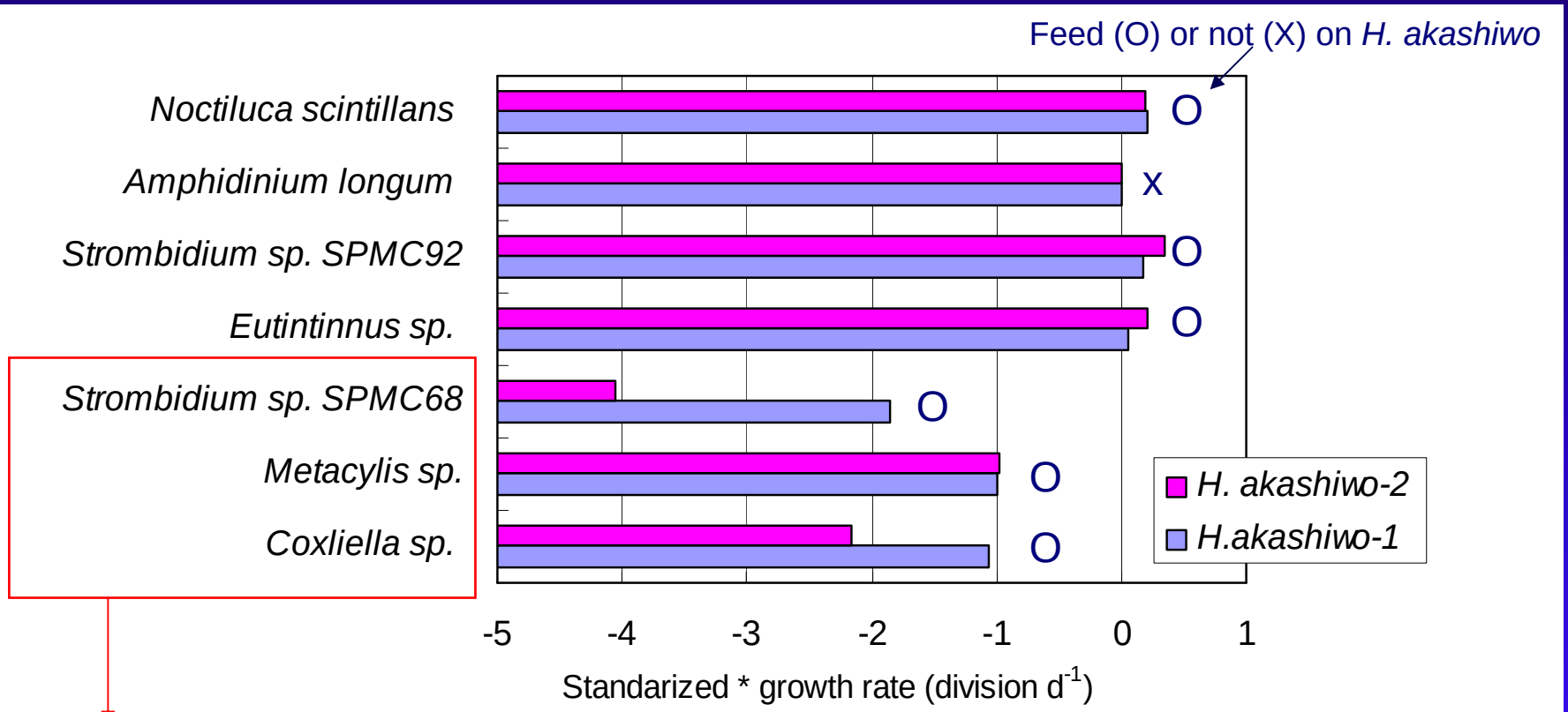
Changes in the number of *H. akashiwo* cells within the food vacuoles of tintinnid ciliates with incubation period





(redrawn from Kamiyama & Arima 2001)

Growth responses of ciliates and dinoflagellates to *H. akashiwo*

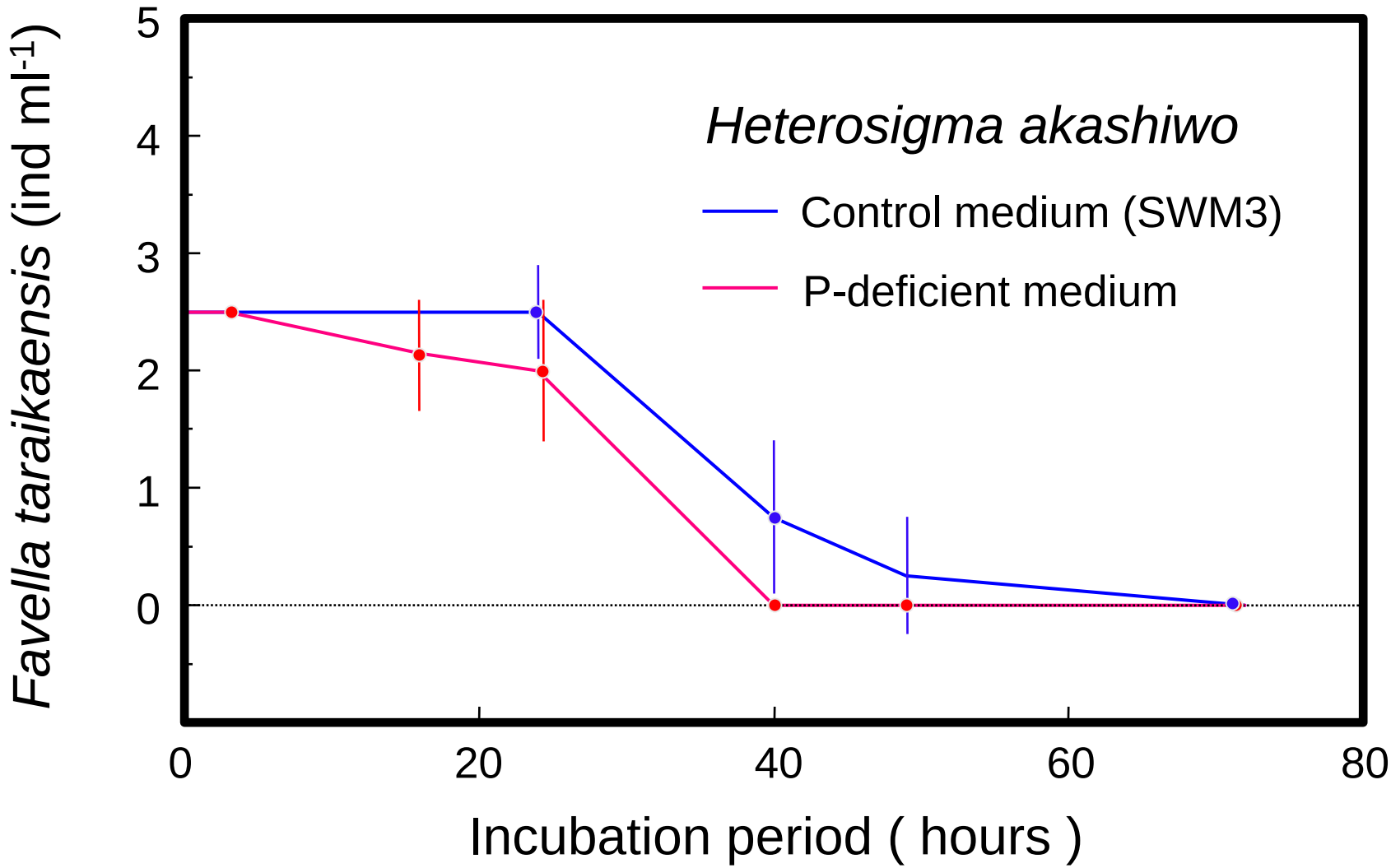


These species ingested *H. akashiwo* but mortality of them was observed.

(data from Clough & Strom 2005)

Toxic effects may be induced by ingested *H.akashiwo* cells

Effect of *H. akashiwo* cultured under phosphorus limitation on survival of a tintinnid ciliate



(Kamiyama unpublished data)

Growth rates of dinoflagellates and ciliates on a diet of *H. akashiwo,* when *H. akashiwo* was available food for these protists

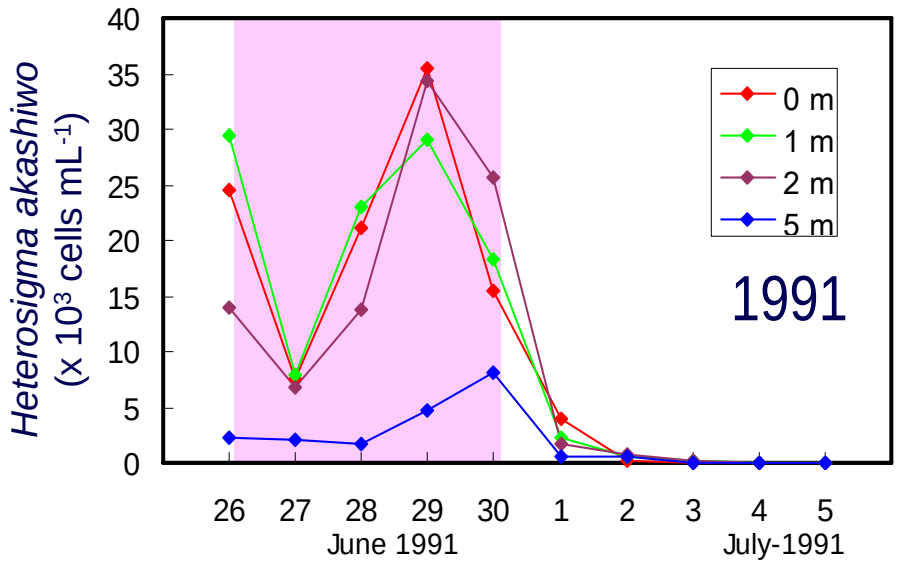
	Growth rate (μ, d^{-1})			References
	H. akashiwo	Other algae (control)		
Dinoflagellates				
Gyrodinium dominans	0.05	0.03	*Pramimonas parkeae*	Nakamura et al. 1995
Gyrodinium dominans	0.23	0.1	*Pramimonas parkeae*	Nakamura et al. 1995
Noctiluca sincilance	0.31	0.34	*Heterocapsa triquetra*	Nakamura et al. 1998
Oxyrrhis marina	1.43	-	-	Jeong et al. 2003
Pfiesteria piscicida	0.92	1.05	*Amphidinium carterae*	Jeong et al. 2006
Ciliates				
Tiarina fusus	0.10	0.13	*Scrippsiella trochoidea*	Jeong et al. 2002
Strombidium SPMC 92	0.18-0.30	0.43	*Rhodomonas* sp.	Clough & Strom 2005
Eutintinnus sp.	0.02	0.13	*Rhodomonas* sp.	Clough & Strom 2005

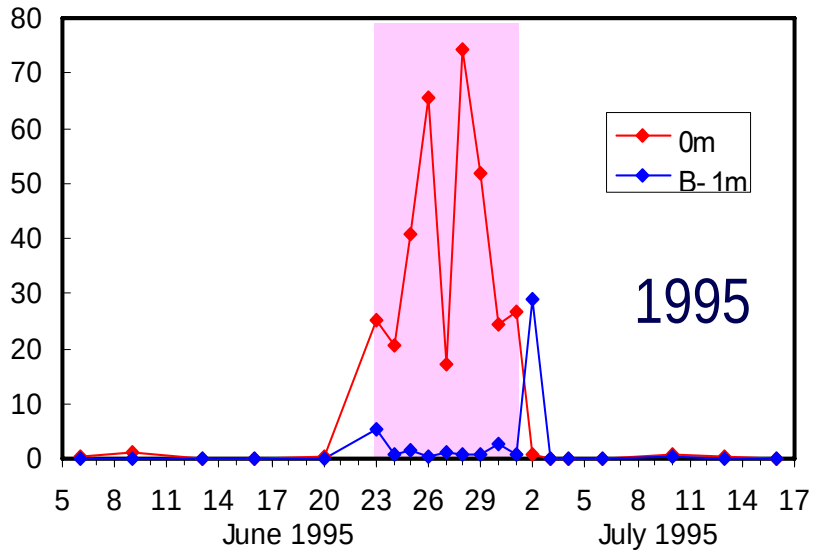
Some kinds of dinoflagellates can grow on a diet of *H. akashiwo.*

Comparing with ciliates, dinoflagellates may be tolerant of toxic effect of *H. akashiwo.*

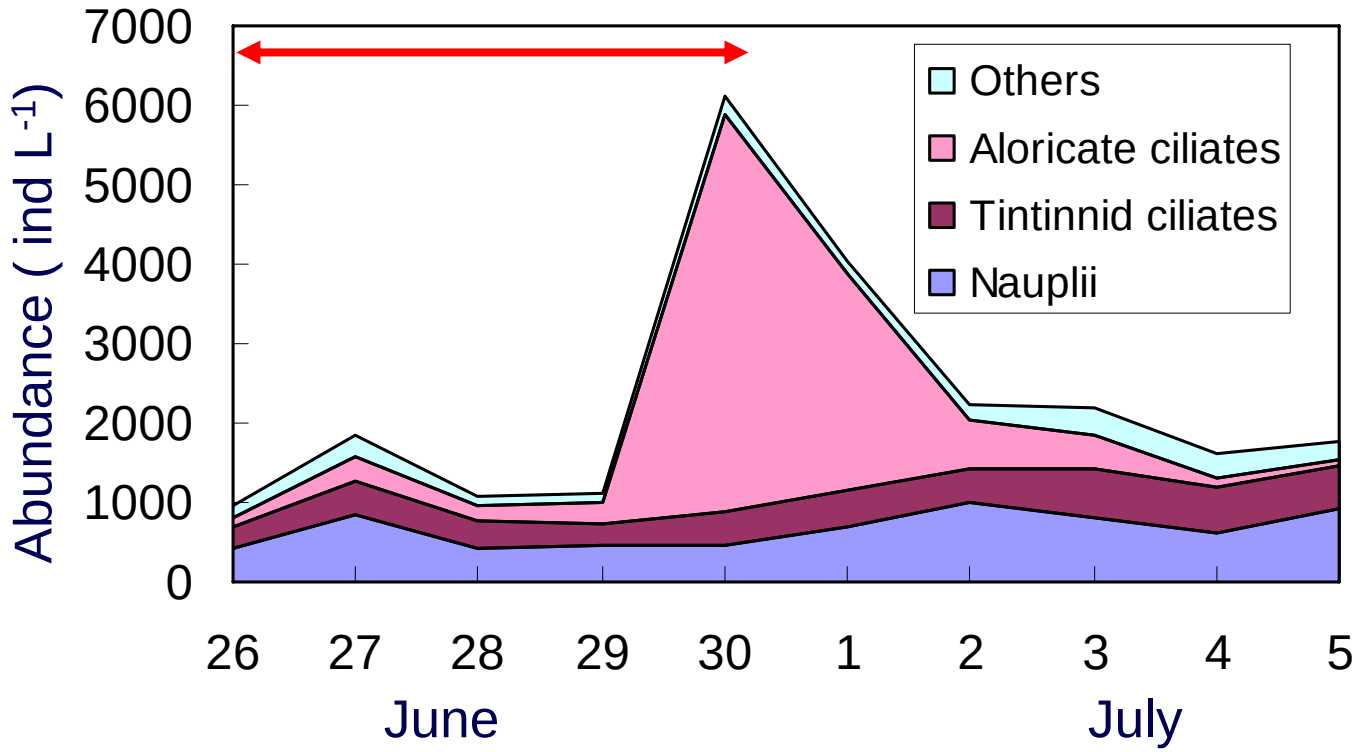
3. Responses of bacteria, heterotrophic nanoflagellates, aloricate ciliates during the course of *H. akashiwo* blooms

What happens at the end of *H.akashiwo* blooms?

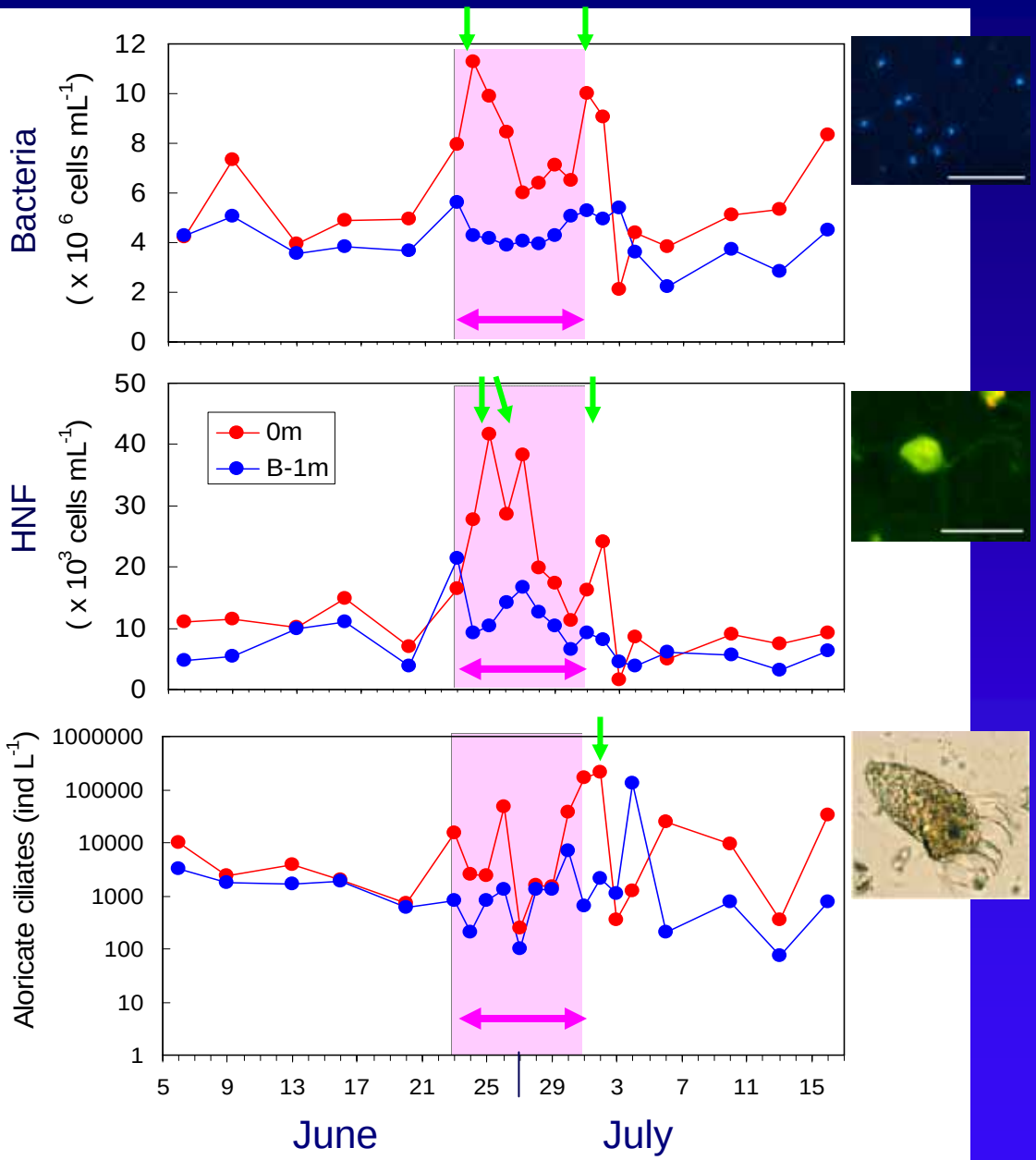




Changes in micorzooplankton abundance during the decay of a *H. akashiwo* bloom in 1991



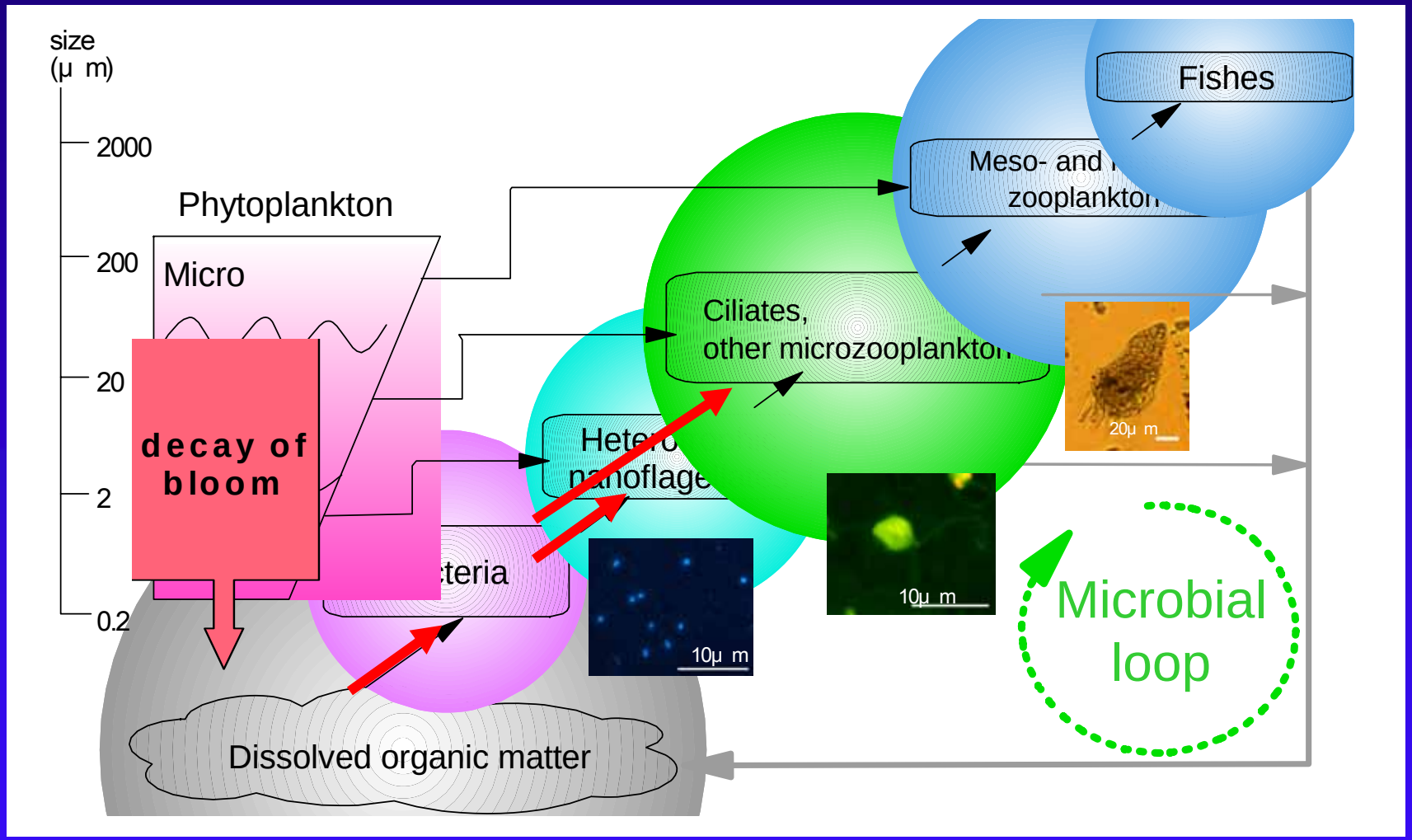
(Kamiyama 1995)



Changes in abundances of bacteria, heterotrophic nanoflagellates (HNF) and aloricate ciliates

(redrawn from Kamiyama et al. 2000)

What happens at the end of *H.akashiwo* blooms?



Decay of the bloom strongly enhanced the system of the microbial loop during just a few days

Conclusion

1. Generally, *H. akashiwo* blooms cause decay of tintinnid ciliate community.
2. Some tintinnid ciliates can avoid or reject *H. akashiwo.*
3. But, occasionally ciliates ingest *H. akashiwo*, and subsequently are damaged, probably due to toxin of the algal cells or short-lived extracellular products .
4. The toxic effects of *H. akashiwo* on ciliates may be variable in response to *H. akashiwo* strain, concentration, environmental factors such as nutrient conditions.
5. Some species of dinoflagellates can grow on a diet of *H. akashiwo*.
6. Decay of *H. akashiwo* blooms strongly enhances energy flow within microbial loop.