Changes in coastal environment and mass occurrence of jellyfish in Tokyo Bay

Haruto ISHII

(Tokyo University of Marine Science and Technology)

Ecosystem in hyper eutrophicated bay

・High concentrations of nutrients (Inflow from river and drain, supply from bottom layer by mixing)

・High conc. N & P; Low conc. Si

・Microflagellates prevail over diatoms

・Production of the inedible algae enters the energy flow via detritus food chain

DOC → Bacteria → Heterotrophic nanoflagellates

→ Ciliates（Microzooplankton）

Detritus Food Chain

・Zooplankton consists mainly of small copepods (Microflagellate feeder)

・Gelatinous plankton (Microzooplankton or small zooplankton feeder) dominates

・Low ecological energy efficiency from phytoplankton (Microflagelaltes) to fish

・Microflagellates → Small zooplankton → Gelatinous plankton

Ciliates（Microzooplankton）

Jelly Food Chain

・Decrease of biodiversity

・No predation on large gelatinous plankton; Top down controll on jellyfish population cannot be observed

Problems accompanied with mass occurrence of jellyfish

・Decrease in fishing activities by clogging and bursting trawl nets

(Accumulation of dead jellyfish on bottom)

－*Aurelia aurita, Chrysaora melanaster, Nemopilema nomurai*

・Coastal power plants by blocking intakes for cooling water

－*Aurelia aurita*, Ctenophora

・Toxins

－Cubomedusae

Mass occurrence of large jellyfish (*Nemopilema nomurai*) in Japan Sea

Photo in Awashima-Island

Mass occurrence of *N. nomurai* is observed in

1920, 1958, 1995, 2002, 2003 & 2005

Surface aggregation of *Aurelia aurita* in Tokyo Bay

Transition of Ecosystem

Muscle Food Chain

Diatoms → Mesozooplankton → Fish

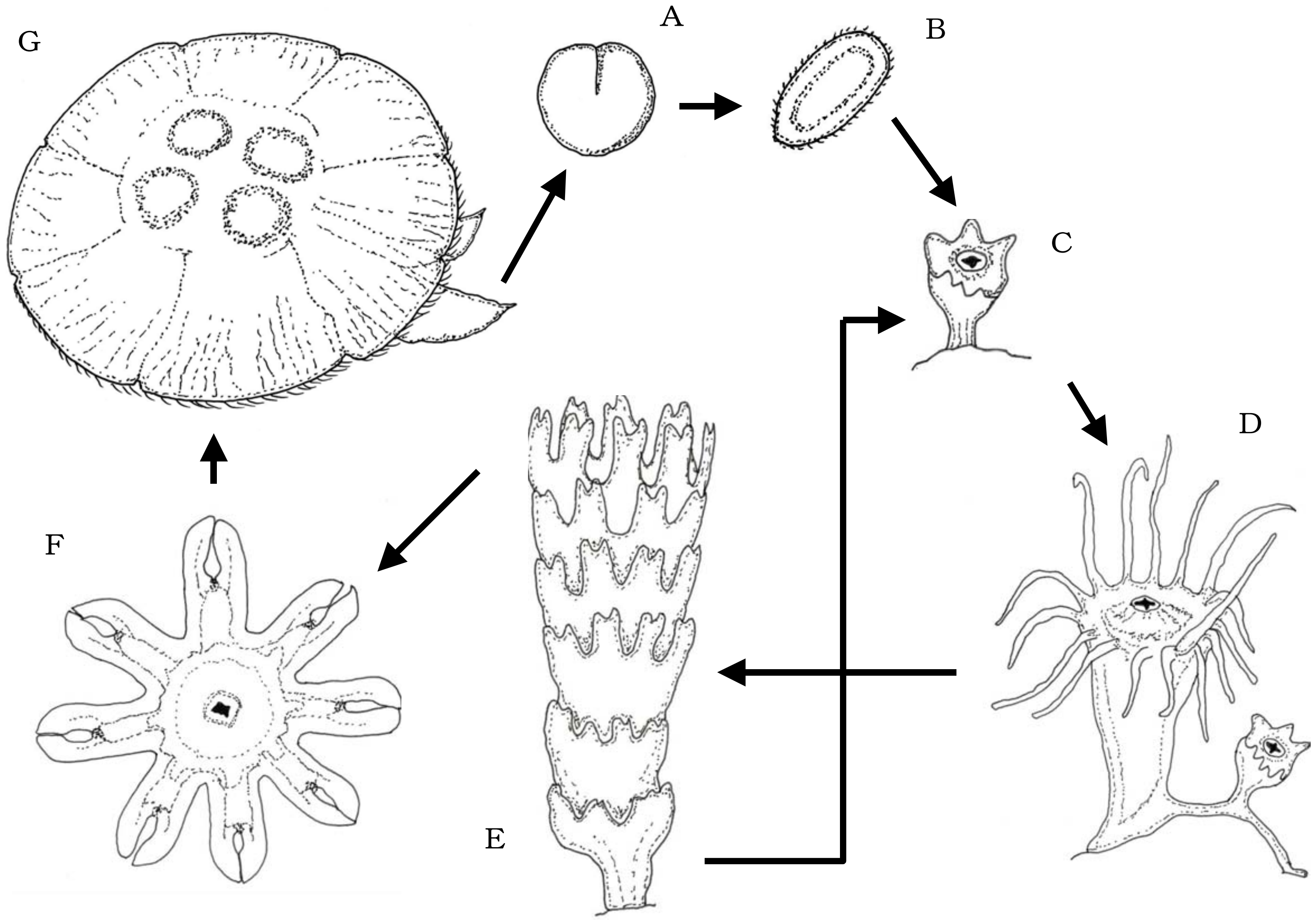
(Observed mainly in upwelling systems)

Jelly Food Chain

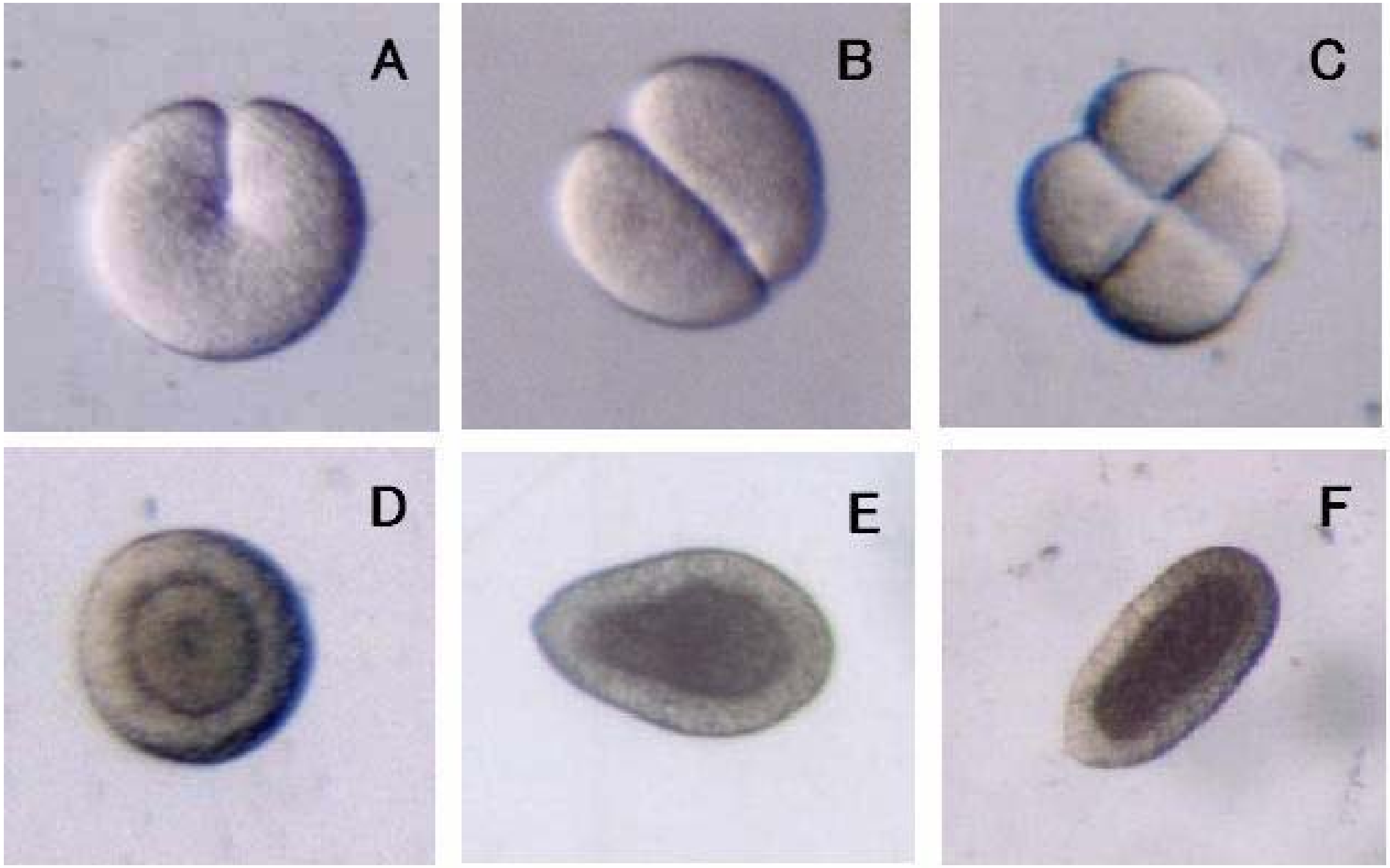
Microflagellate → Small zooplankton → Jellyfish

(Observed mainly in eutrophicated coastal systems)

Relationship between changes in coastal environment and mass occurrence of jellyfish in eutrophicated bay will be explained based on knowledge about phytoplankton responses to nutrients and food size spectra of zooplankton

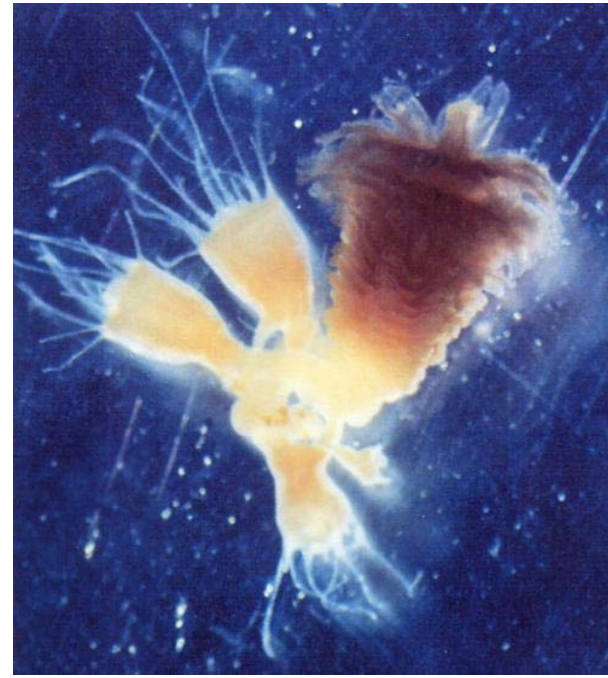


The life cycle, including the annual sexual medusa stage and the perennial asexual polyp or scyphistoma stage: (A) first cleavage of zygote, (B) planula, (C) polyp, (D) asexual budding of daughter polyp, (E) strobila, (F) ephyra, and (G) medusa

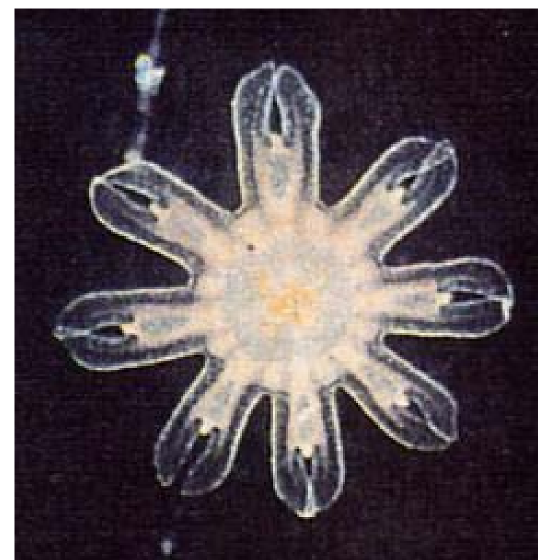


(A) first cleavage of zygote - (F) planula

Polyp with asexual budding of daughter polyp



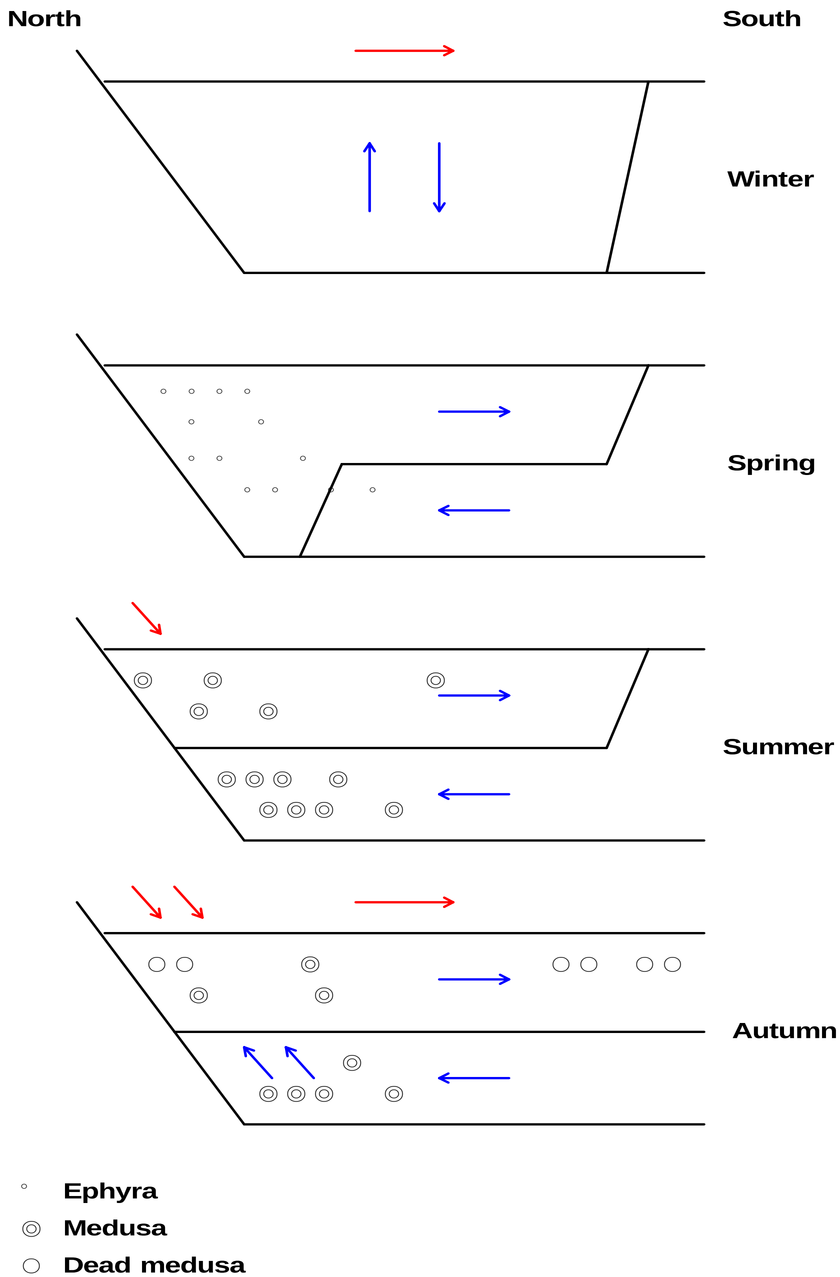
Strobila



Ephyra

Medusa

Seasonal population changes of *A. aurita* in Tokyo Bay



Tokyo Bay

Changes of the salinity and nutrient concentration in Tokyo Bay;

1950s～2000s

Salinity decreaing (30.6→29.5 PSU)

Phosphate having a peak in 1970s (2→1 μg–at l^{-1})

Ammonium increasing (5→20 μg–at l^{-1})

Nitrite increasing (1→4 μg–at l^{-1})

Nitrate increasing (5→25 μg–at l^{-1})

Silicate decreasing (60→20 μg–at l^{-1})

Increasing N and Decreasing Si

・Increasing river water and drainage → Eutrophication (N increasing)

・Dam construction, river improvement, coastal reclamation (disappearance of tideland) → Si decreasing

・Blooming of phytoplankton (Diatom Akashio event) → Si decreasing

Low levels Si / N change phytoplankton composition; Diatom → Microflagellate

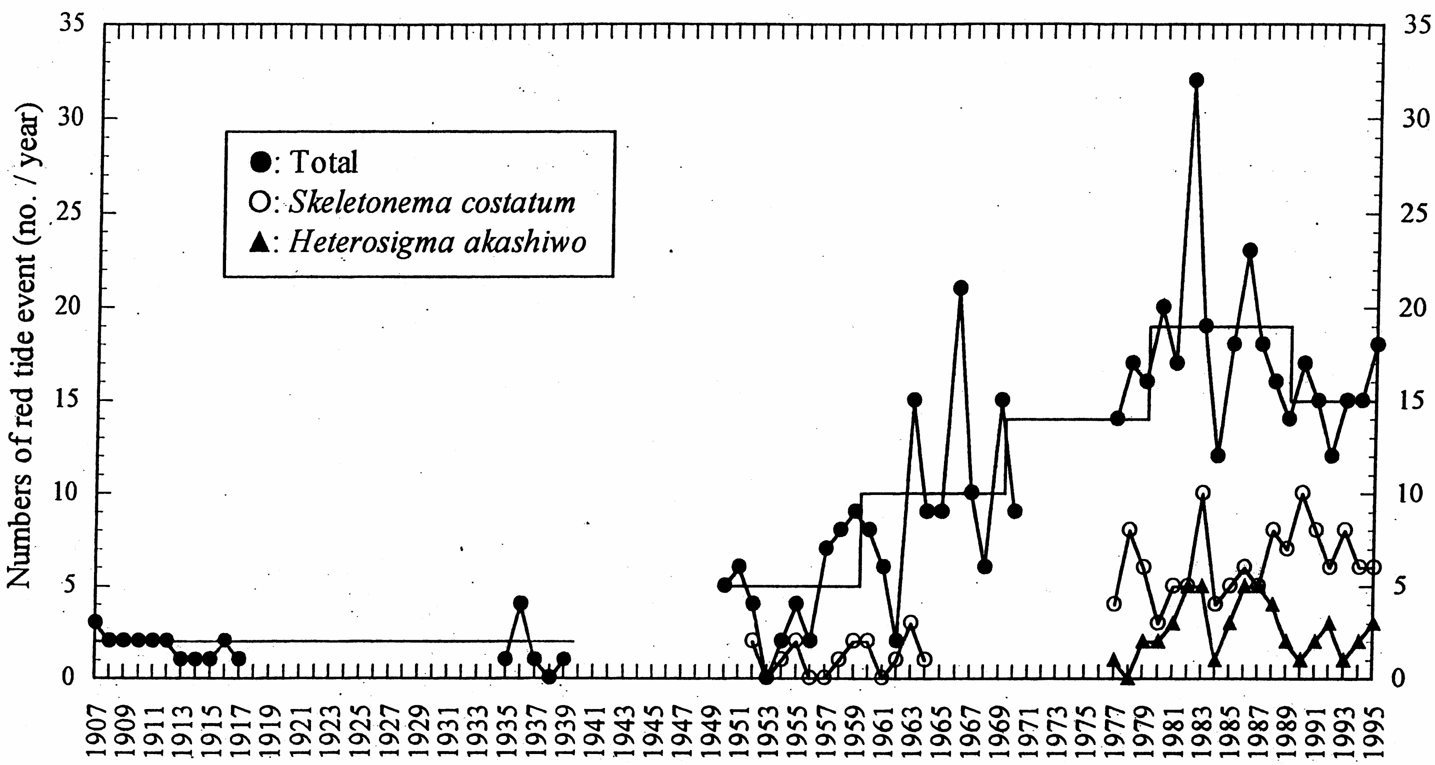
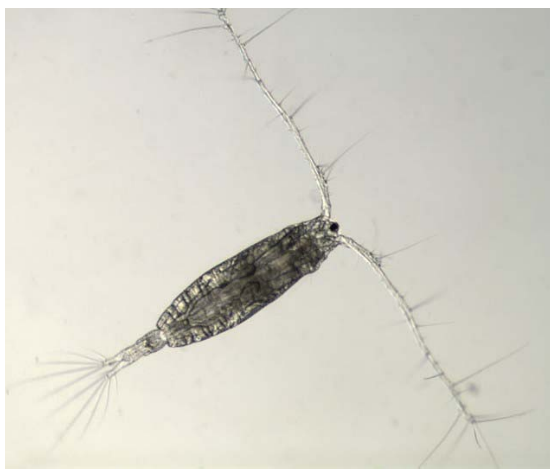


Fig. Changes in annual occurrence of total red tide events and the events by two main causative species (No./year) in Tokyo Bay from 1907 to 1995. Steplike line indicates the average number of red tide events in each period. Data from Asakura (1915), Nagata (1917), and Matsue (1935), Sugawara and Sato (1966a), Murata (1970), Tokyo-to Kankyo-hozen-kyoku Suishitsu-hozen-bu (1990-1997).

Nomura (1998)

Zooplankton community; Meso– → Small–

Abundance ($\times 10^3$ inds m^{-3})	1948	1971–72	1971–75	1979	1981–82	1983	2003
Oithona	515	470	600	1177	2045		1664
Acartia	28–38				23	13.2	1.9
	Yamaji (1955)	Marumo & Murano (1974)	Nishida (1985)	Nagasawa & Murano (1984)	Anakubo & Murano (1991)	Tsuda & Nemoto (1988)	Ishii unpubl.



Copepod (*Acartia omorii*)

Body length; 1 mm

Diatom feeder

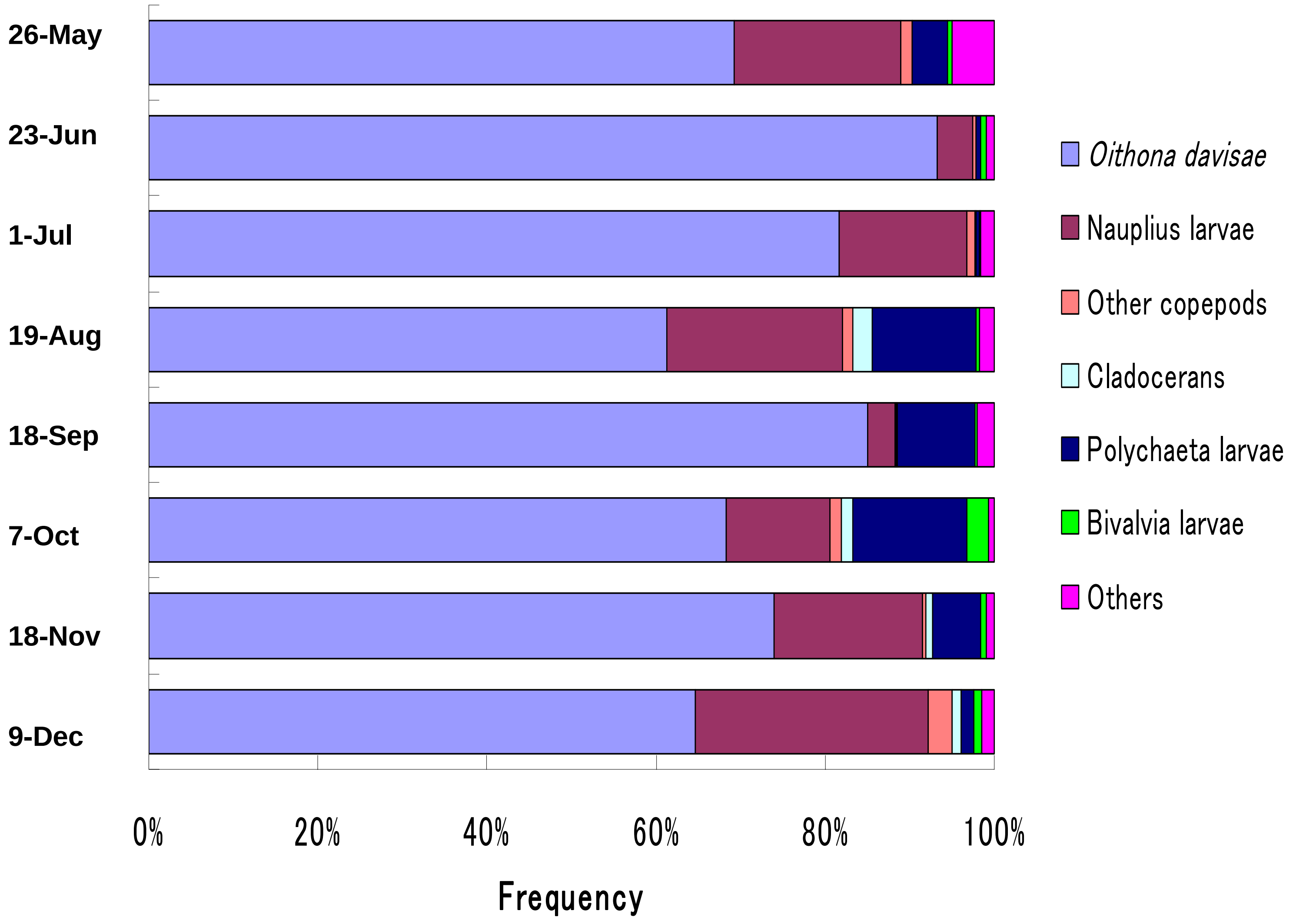
Small copepod

(Oithona davisae)

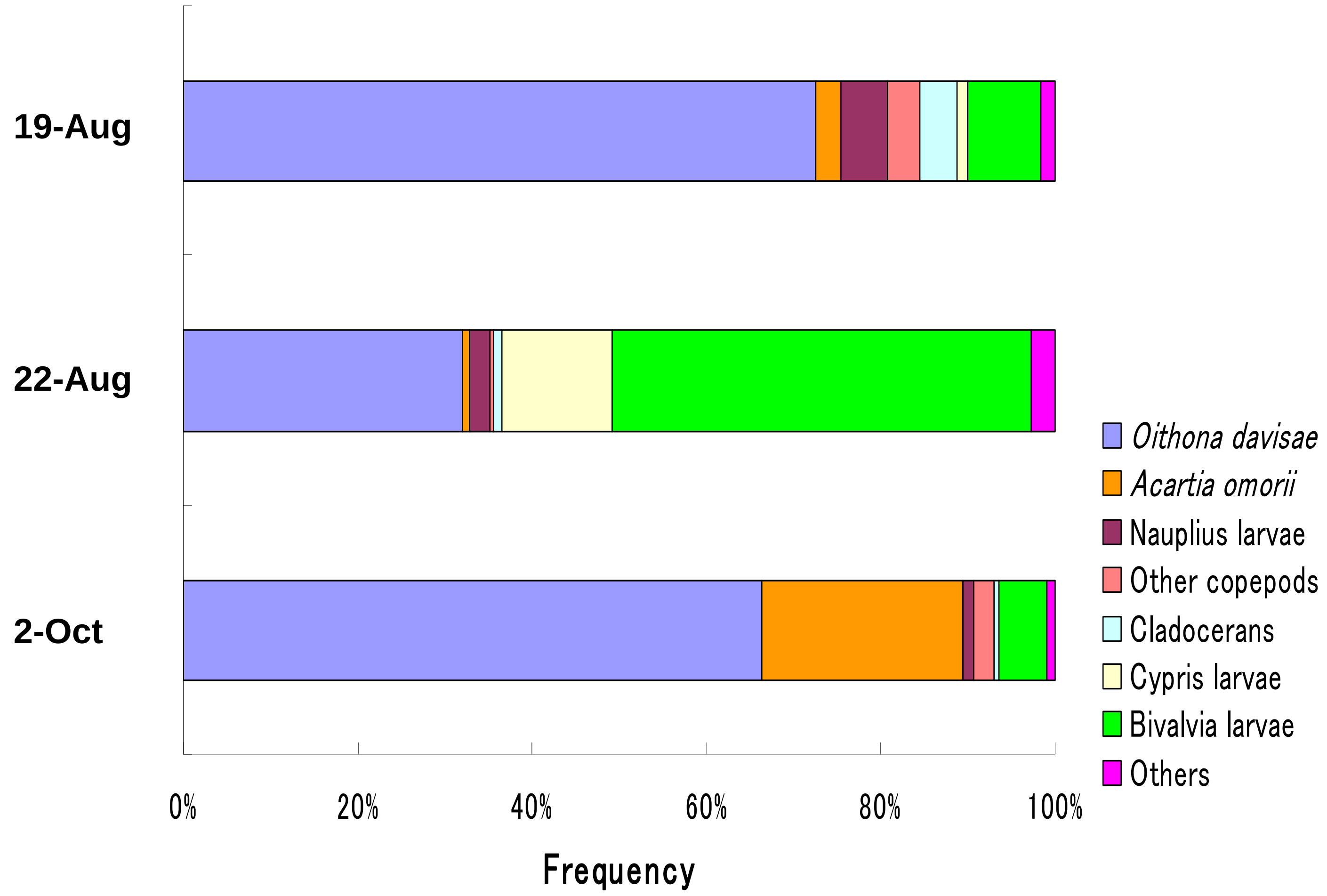
Body length; 0.3 mm

Microflagellate feeder

Zooplankton composition in the seawater



Prey composition in the stomach of medusae



Jellyfish

・Increase of the small prey abundance is suitable for jellyfish which are opportunistic tactile predator

Fish

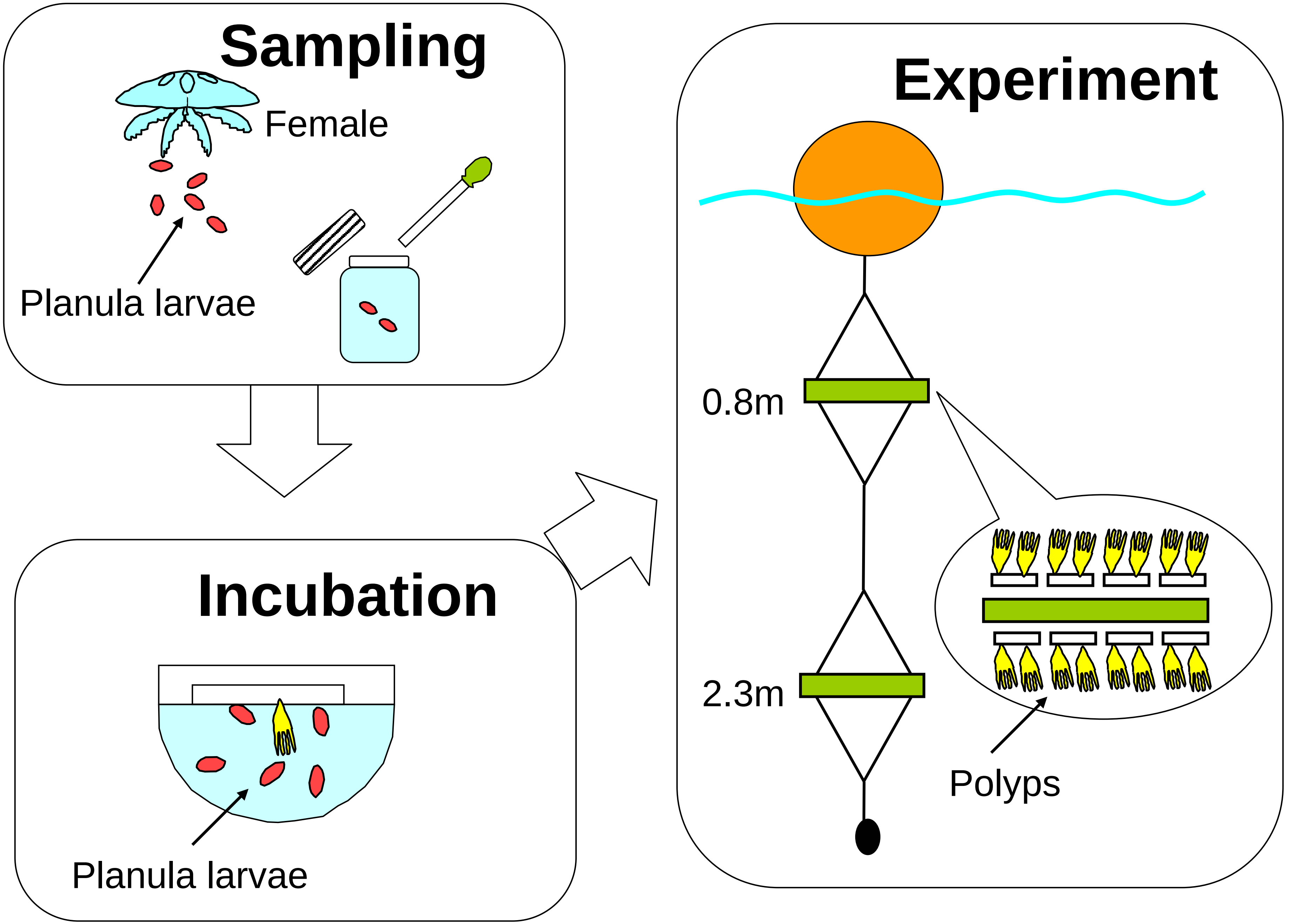
・Decrease of the large prey abundance and prey visibility is critical for planktivorous fish which are visual predator

Increase in the abundance of small copepod, *O. davisae*, have contributed to increases in jellyfish biomass relative to fish biomass

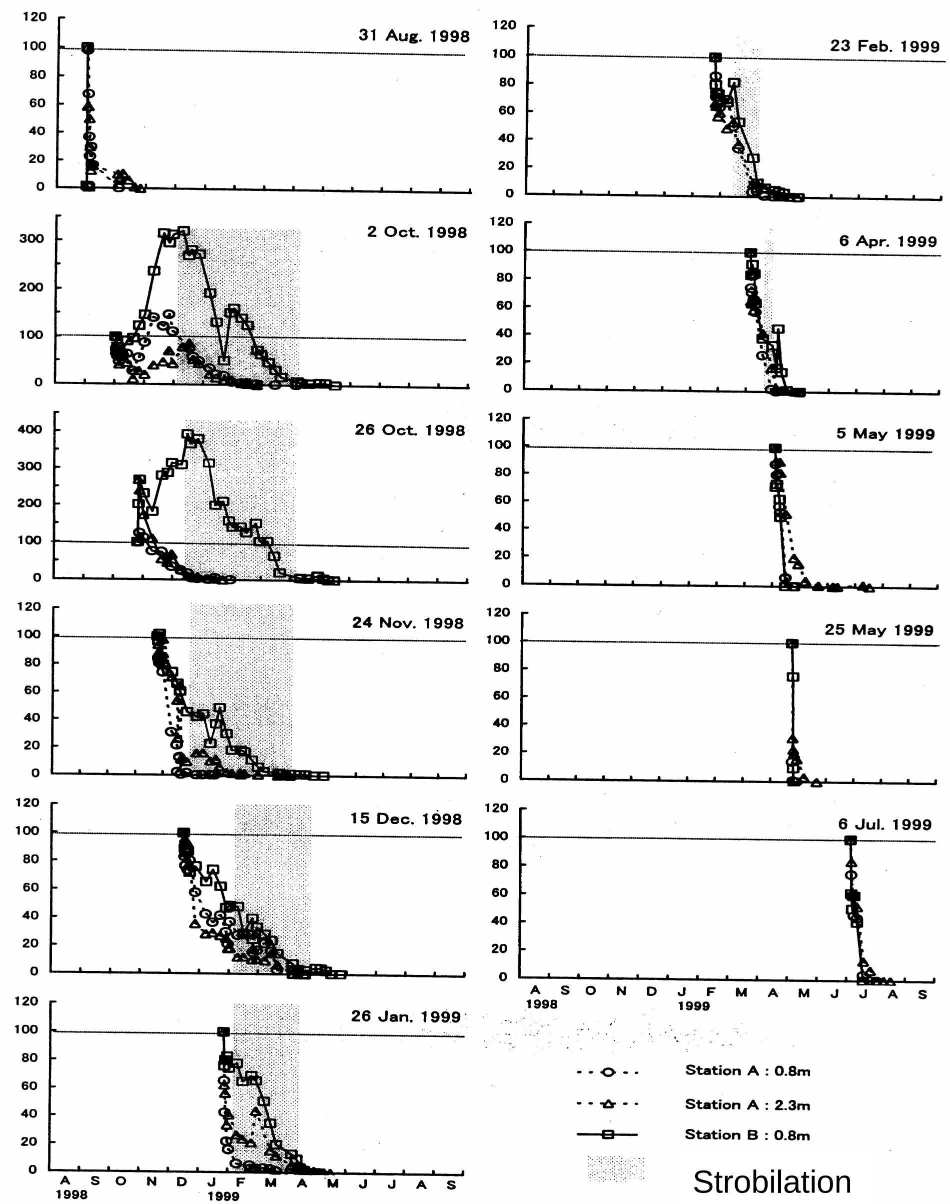
Polyp stage is characterized by asexual reproduction (budding, strobilation)

In coastal environment, settling substrate for polyp is increasing;

- Reclamation
- Quay
- Bottom of a ship



Sampling
Female
Planula larvae
Incubation
Planula larvae
Experiment
0.8m
2.3m
Polyps



Survivorship of polyps on the settling plates (%)

Most of the settled substrate in the innermost part of Tokyo Bay is occupied by the other benthic organisms such as *Mitilus galloprovincialis*.

This observation means that *A. aurita* polyps are exposed to keen competition for space with other organisms, especially during spring and summer.

If the recruitment of planula larvae is restricted to summer, the consequent ephyra production could be low in the following spring.

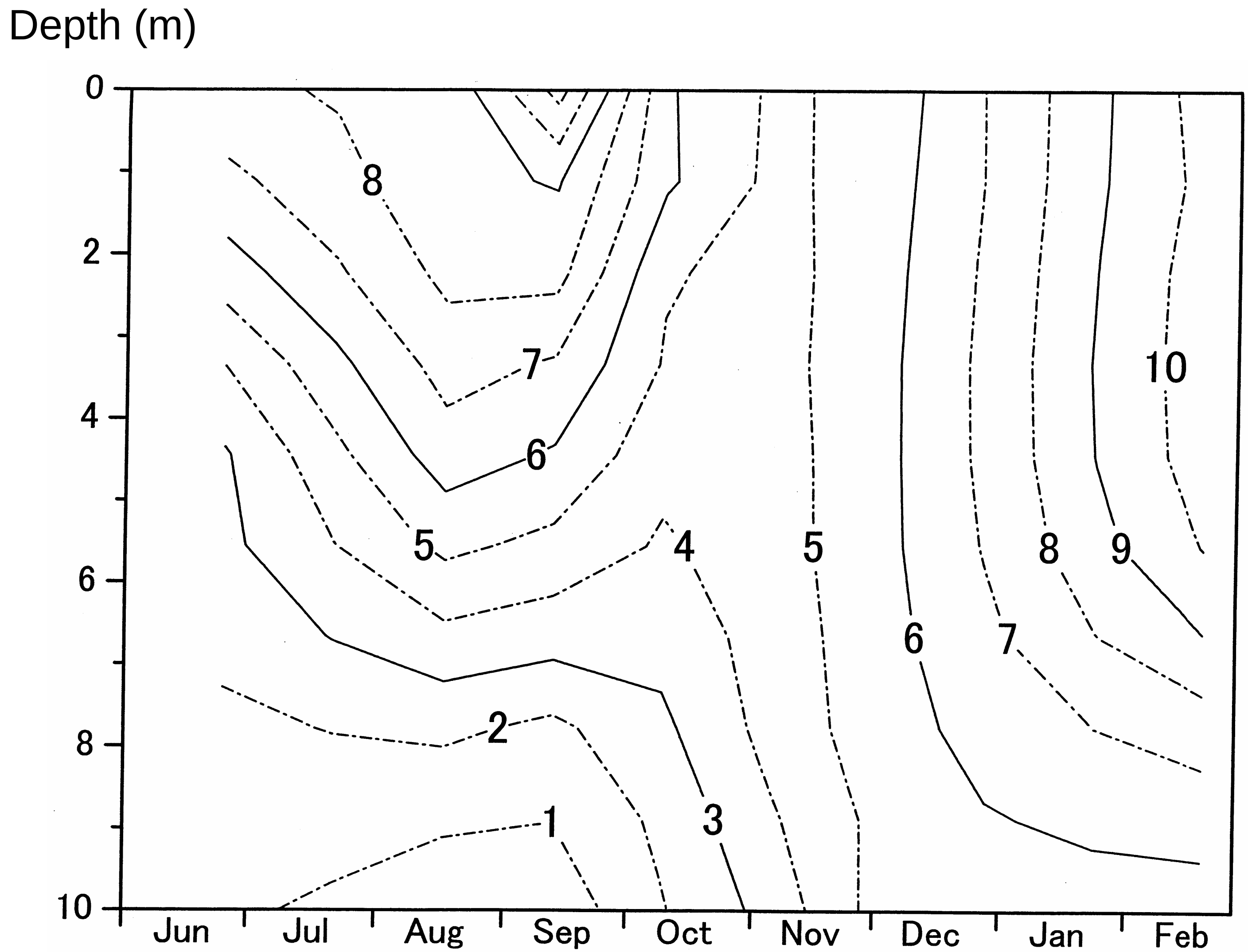
The presence of ripe medusae with planulae, even in autumn and winter, would contribute to increasing settlement and survival of polyps.

Dense aggregation of *M. galloprovincialis*. No polyps are observed.

We found the polyp aggregations in the dysoxic bottom water during summer (Peak season of planula release).

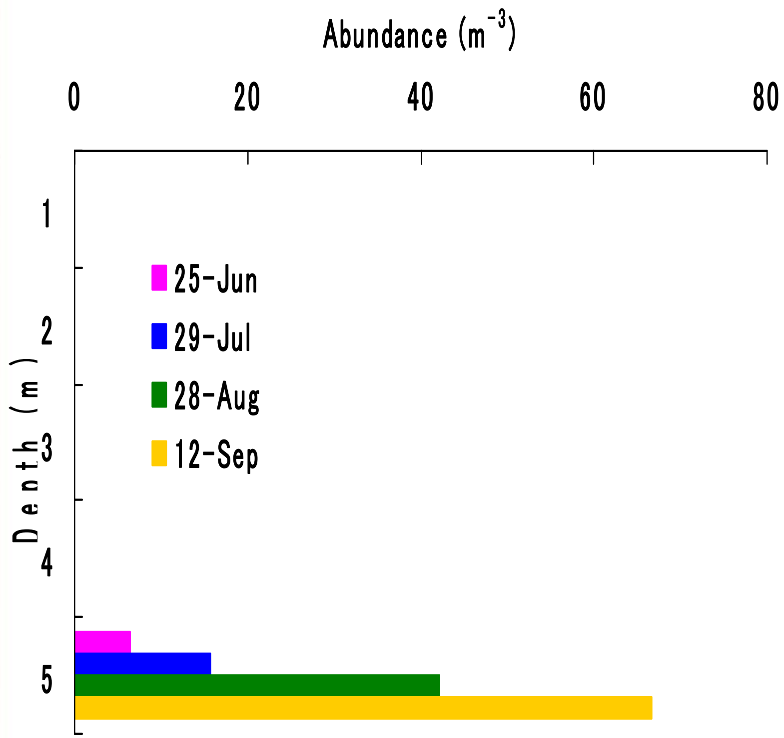
This layer is characterized by low recruitment and growth of other benthic organisms such as *M. galloprovincialis,* resulting an abundant settlement and high survival during the polyp stage.

Dense aggregation of *A. aurita* polyps.

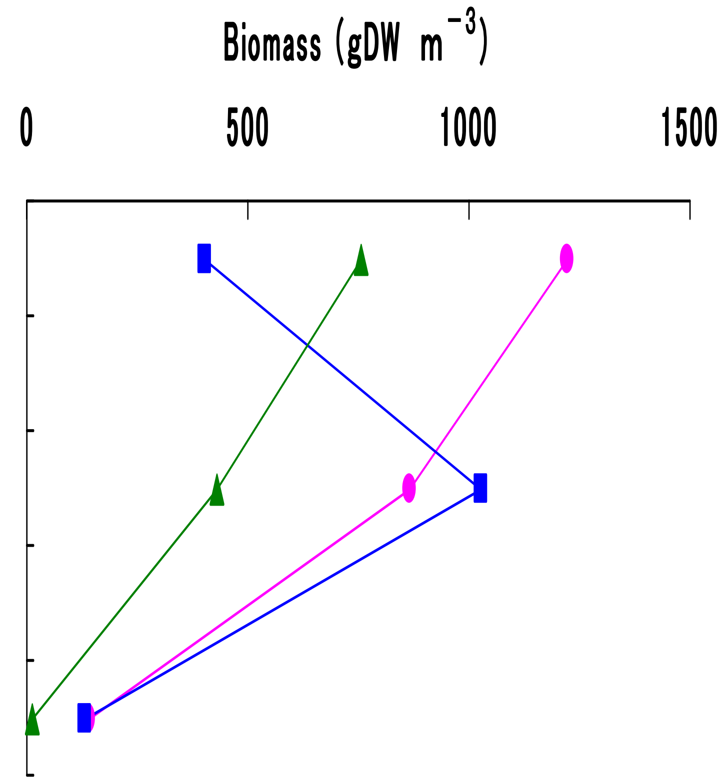


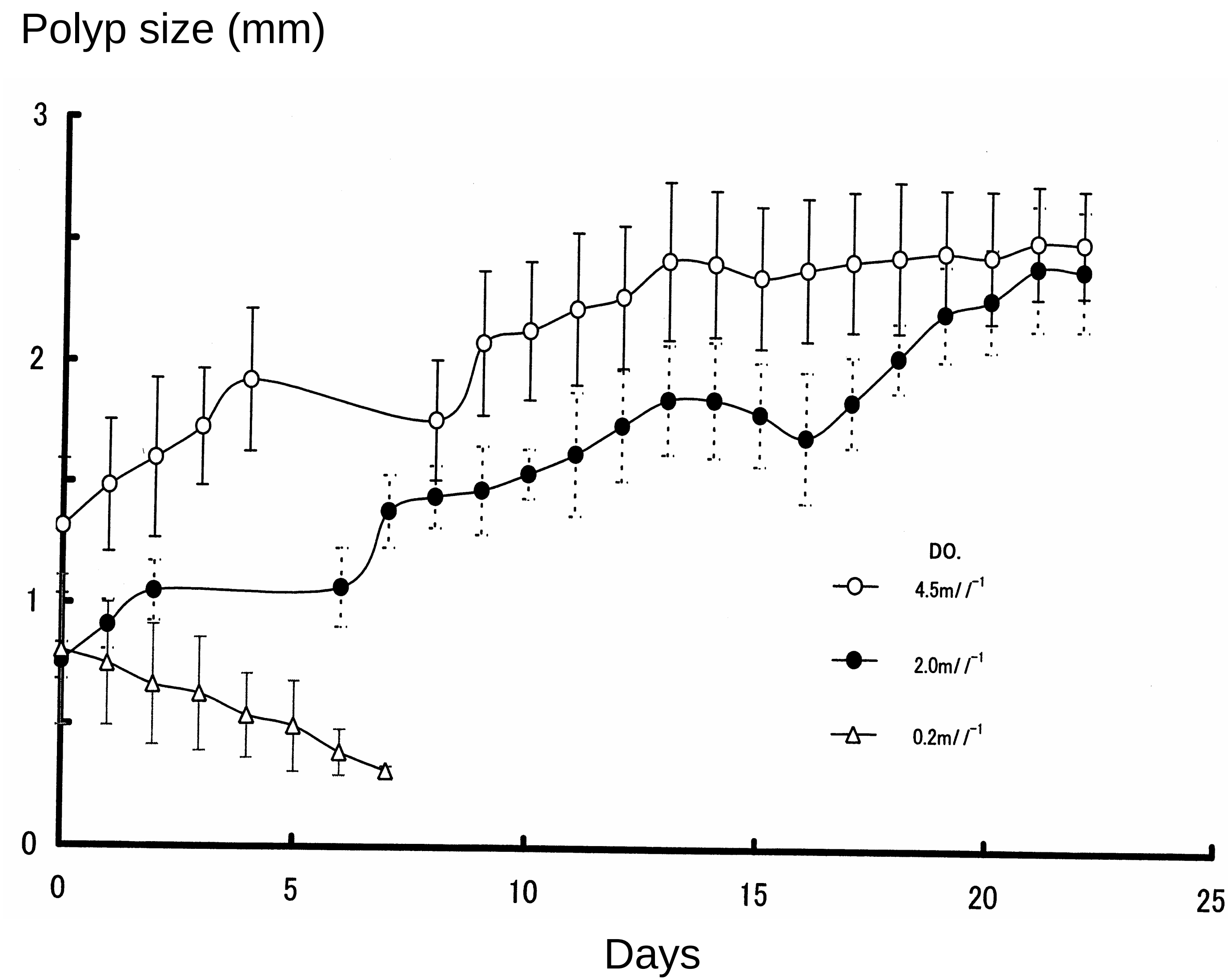
Seasonal changes in the concentration of D.O. (ml O_2 l^{-1}) in the innermost part of Tokyo Bay.

Polyps of *A. aurita*

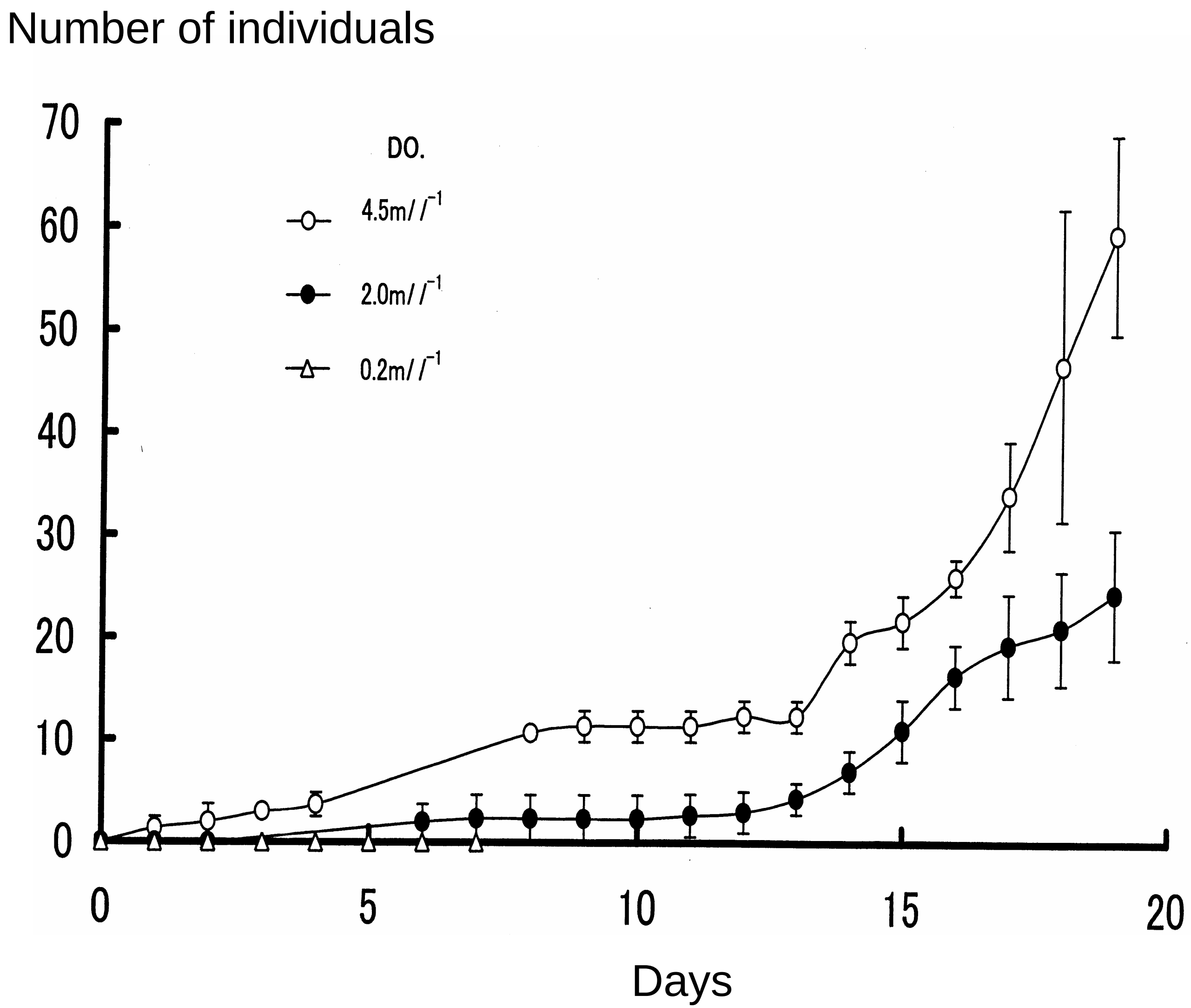


M. galloprovincialis





Growth of polyps in the different D.O. concentration waters



Increase of daughter polyps by asexual budding in the different D.O. concentration waters

Polyp stage

When the D.O. concentration increased, strobilation and ephyra release are also observed even in the polyps cultured in hypoxic waters.

We still need to understand the relationship between the abundance of polyps with various jellyfish in eutrophic coastal waters and their adaptation to dysoxic bottom-layer waters resulting from eutrophication.

Guideline to prevent the mass occurrence of jellyfish

1. Recover from hyper eutrophicated bay

Decreasing the nutrient (N and P) concentration
→ Disappearance of red tide event and bottom dysoxic waters

2. Balance of Si / N ratio in waters

Reconsideration of dam construction, river improvement, and coastal reclamation
→ Increasing the size in phytoplankton (diatoms) and zooplankton (mesozooplankton) community
→ Decreasing the polyp settling substrate

Since we cannot control the jellyfish biomass by top down method (no dominant predator), bottom up control will be effective.

Transition of Ecosystem

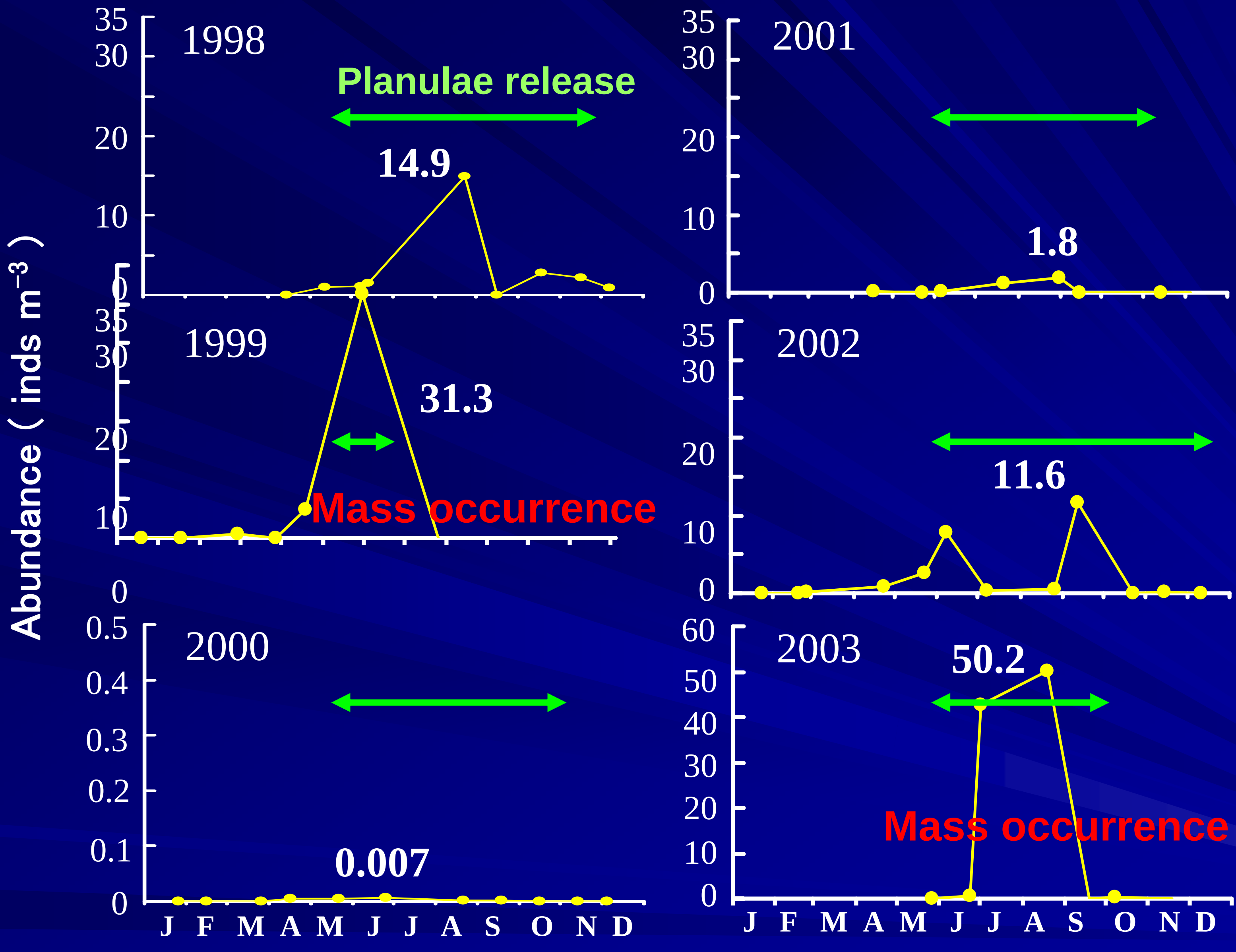
Muscle Food Chain (Fish) → Jelly Food Chain

Mass occurrence of gelatinous plankton including jellyfish with environmental changes is a symbolic event decreasing the biodiversity in marine ecosystem

Study:

・Construction of the simulation model including various parameters in relation to environmental changes; climate, river water, economic activity in the city, development of coastal region, eutrophication, and jellyfish biomass

・Prediction of the mass occurrence of jellyfish and control of the transition to jelly-ecosystem



Abundance of jellyfish, *A. aurita* in Tokyo Bay (1998～2003)