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

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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 (Microflagellates) to fish

- Microflagellates $\rightarrow$ Small zooplankton $\rightarrow$ Gelatinous plankton

  Ciliates (Microzooplankton)

Jelly Food Chain

- Decrease of biodiversity

- No predation on large gelatinous plankton; Top down control 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

Surface aggregation of *Aurelia aurita* in Tokyo Bay
Transition of Ecosystem

Muscle Food Chain

Diatoms $\rightarrow$ Mesozooplankton $\rightarrow$ Fish

(Observed mainly in upwelling systems)

Jelly Food Chain

Microflagellate $\rightarrow$ Small zooplankton $\rightarrow$ 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

- **Winter**
  - North
  - Ephyra
  - Medusa
  - Dead medusa
  - South
  - Ephyra
  - Medusa
  - Dead medusa

- **Spring**
  - North
  - Ephyra
  - Medusa
  - Dead medusa
  - South
  - Ephyra
  - Medusa
  - Dead medusa

- **Summer**
  - North
  - Ephyra
  - Medusa
  - Dead medusa
  - South
  - Ephyra
  - Medusa
  - Dead medusa

- **Autumn**
  - North
  - Ephyra
  - Medusa
  - Dead medusa
  - South
  - Ephyra
  - Medusa
  - Dead medusa
Changes of the salinity and nutrient concentration in Tokyo Bay; 

1950s～2000s

Salinity decreasing (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**

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**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-**

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**Oithona**
- 515
- 470
- 600
- 1177
- 2045
- 1664

**Acartia**
- 28–38
- 23
- 13.2
- 1.9

Source:
- Yamaji (1955)
- Marumo & Murano (1985)
- Nishida (1974)
- Anakubo (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

- 26-May
- 23-Jun
- 1-Jul
- 19-Aug
- 18-Sep
- 7-Oct
- 18-Nov
- 9-Dec

Frequency

- Oithona davisae
- Nauplius larvae
- Other copepods
- Cladocerans
- Polychaeta larvae
- Bivalvia larvae
- Others
Prey composition in the stomach of medusae

19-Aug

22-Aug

2-Oct

Frequency

Oithona davisae
Acartia omorii
Nauplius larvae
Other copepods
Cladocerans
Cypris larvae
Bivalvia larvae
Others
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

Abundance (m⁻³)

25-Jun
29-Jul
28-Aug
12-Sep

M. galloprovincialis

Biomass (gDW m⁻³)
Growth of polyps in the different D.O. concentration waters

Polyp size (mm)

Days

Growth of polyps in the different D.O. concentration waters
Increase of daughter polyps by asexual budding in the different D.O. concentration waters
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) $\rightarrow$ 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