Seasonal and year-to-year variations in the surface copepodid population and egg production rate of *Eucalanus californicus* (Copepoda: Calanoida) in Sagami Bay, Japan

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Introduction

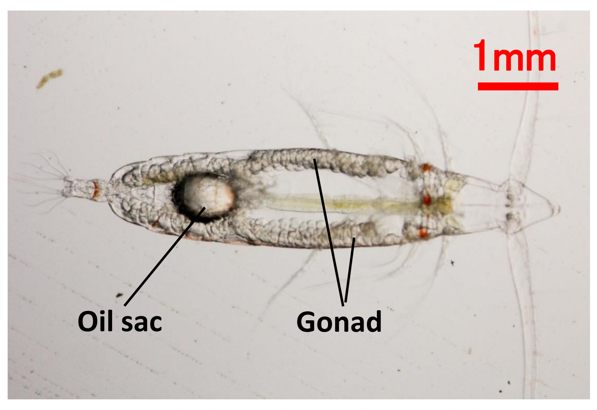

Fig. 1. Adult females of *E. californicus* (Gonad state 4).

E. californicus (Fig. 1) is one of the major secondary producers and performs seasonal ontogenetic vertical migration (Seasonal OVM) in the mid latitude area of the North Pacific Ocean. The species appears in the surface layer during spring phytoplankton bloom for feeding and reproduction, and diapauses in the deep depth (> 500 m) from summer to winter (Shimode et al., 2012, Fig. 2).

In this study, focusing on the relationship between the lengths of the surface occurrence periods and the surface environments, we investigated seasonal and year-to-year changes in the surface abundance and egg production rates (EPR) of *E. californicus*.

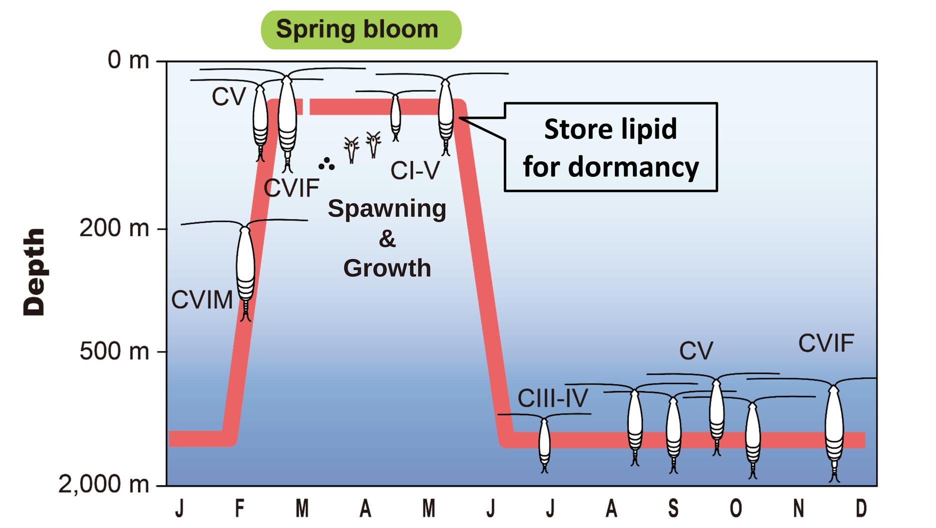

Fig. 2. Seasonal OVM of *E. californicus* in the mid latitude areas of the North Pacific Ocean (Shimode et al., 2012).

Material and methods

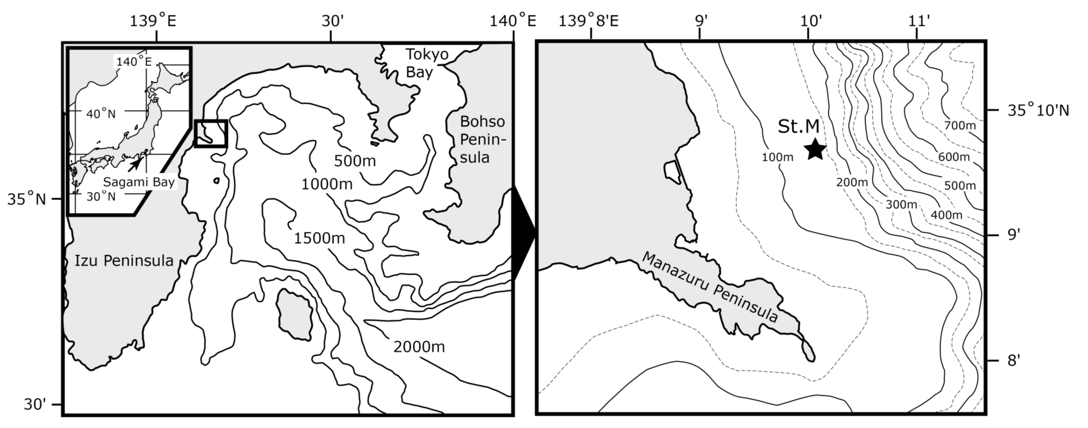

Fig. 3. Study area.

E. californicus was collected from 100 m depth to the surface at a coastal station (St. M, ca. 120 m depth, Fig. 3) during January 2012 to June 2016. Each copepodite stage was sorted and counted. Prosome lengths (PL) and sizes of an oil storage in the prosomes were measured.

EPR experiments were conducted in 2015 and 2016. Each adult female was incubated in a 250 ml bottle with false bottom of 250 µm mesh to prevent egg-cannibalism (Fig. 4). Eggs were counted after 24 hrs. Before starting experiments, gonad states (GS) of each adult female were examined.

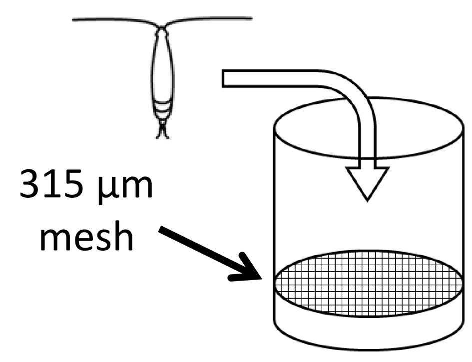

Fig. 4. An incubation chamber for EPR experiment.

Results & Discussion

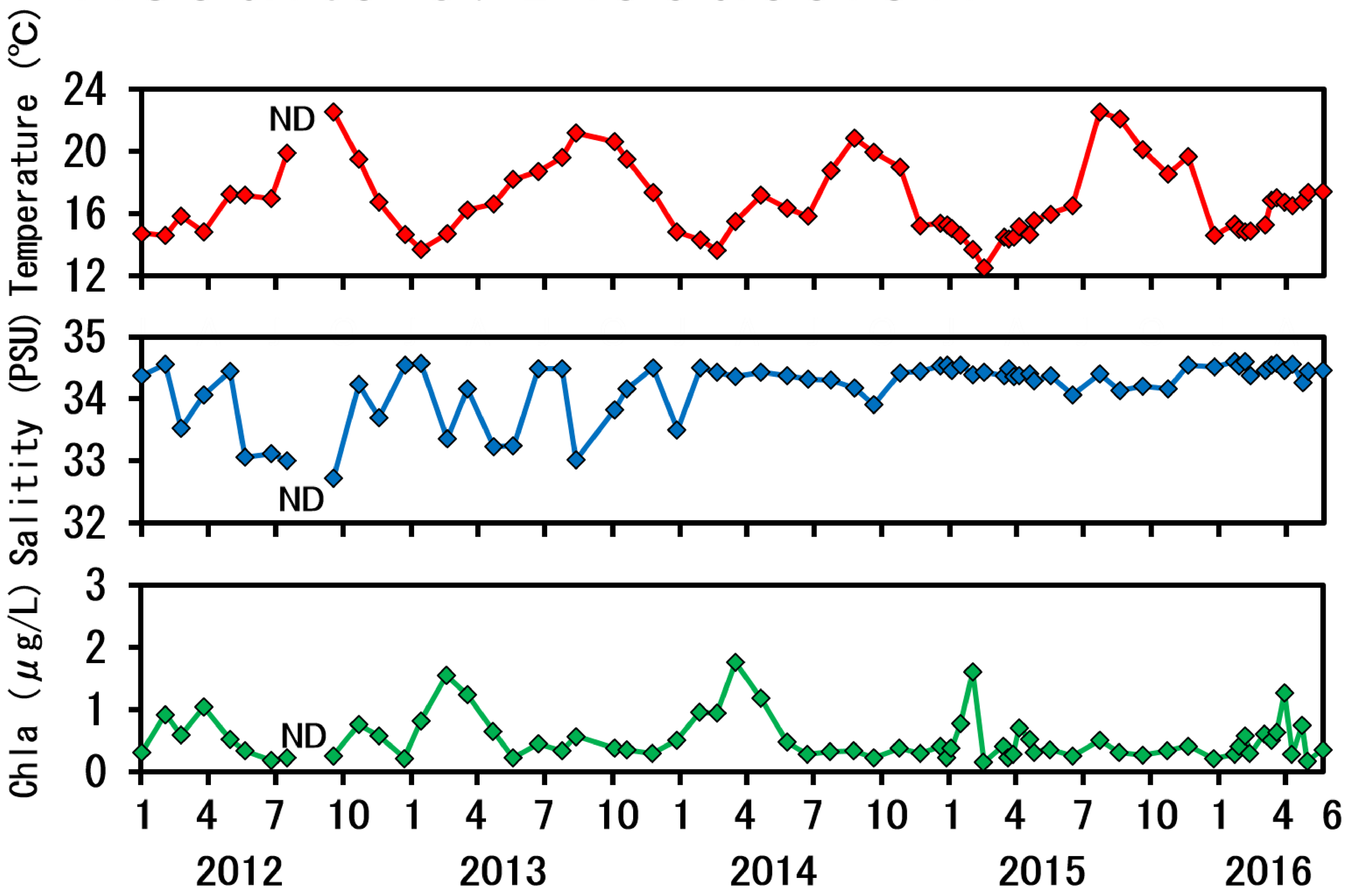

Fig. 5. 0-100 m means of temperature, salinity and chlorophyll *a* concentration from January 2012 to June 2016 at St. M in Sagami Bay.

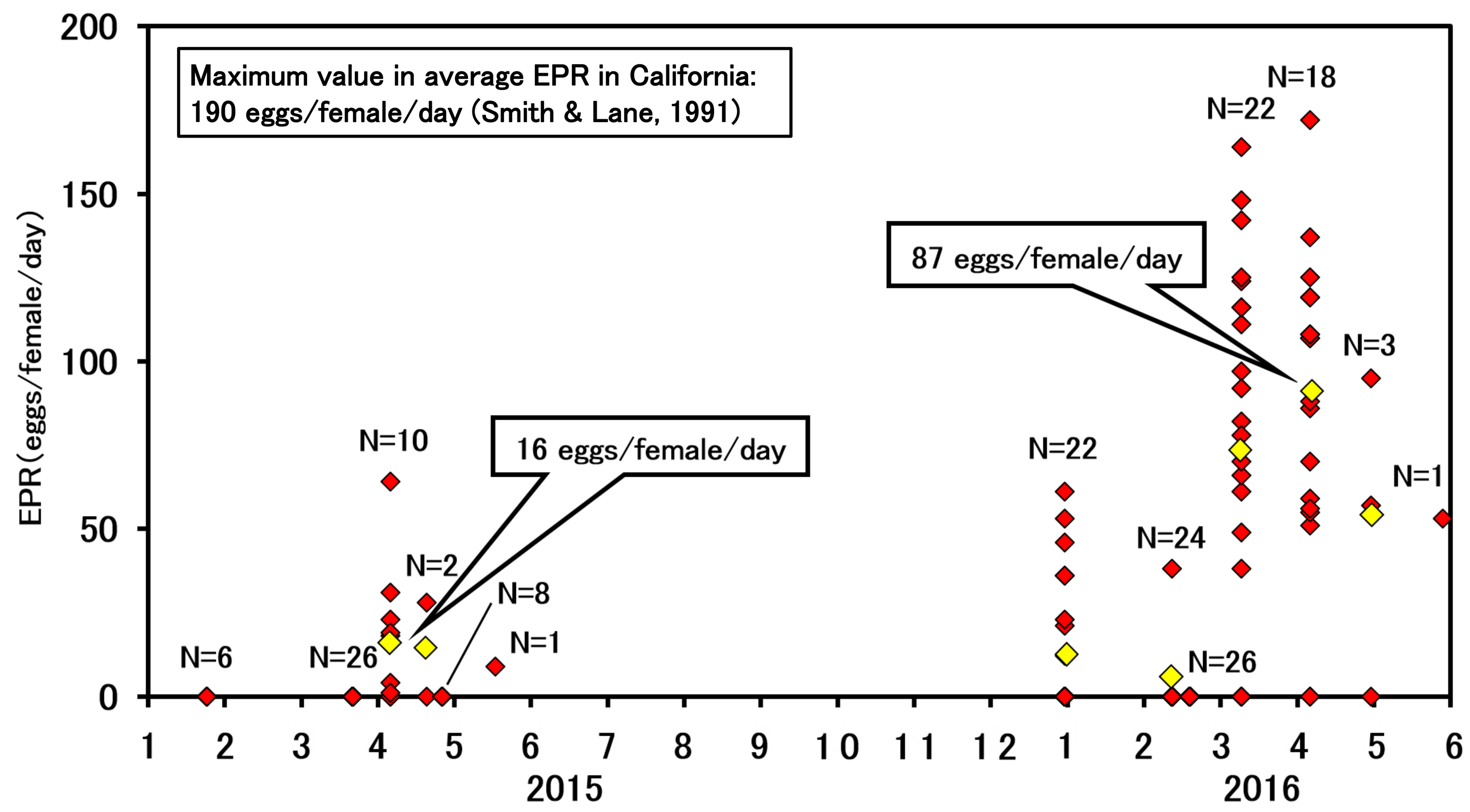

Fig. 8. EPR of adult females of *E. californicus* at St. M in Sagami Bay from February 2015 to June 2016. Yellow diamonds: averages in each month.

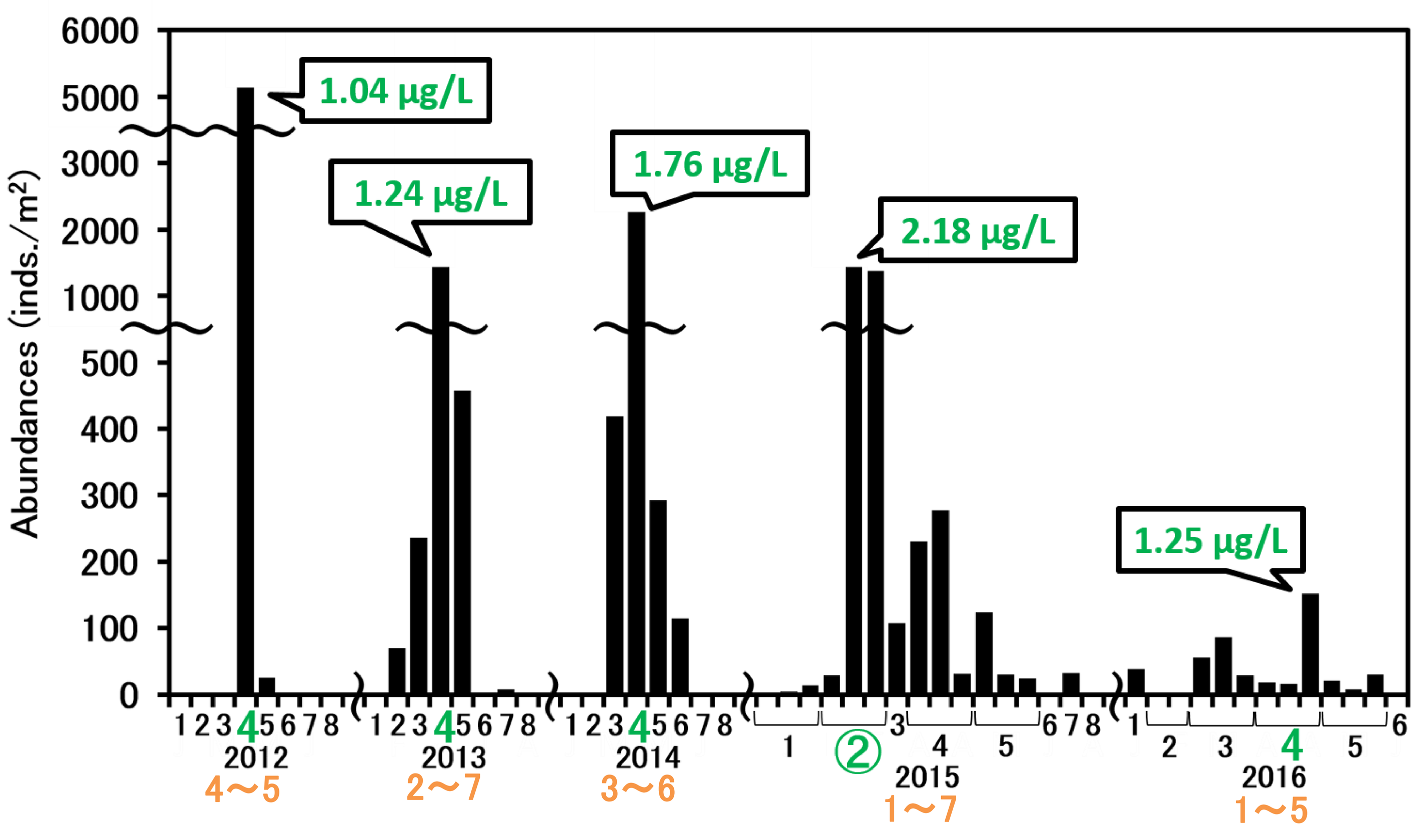

Fig. 6. Abundances of *E. californicus* at St. M in Sagami Bay from 2012 to 2016.

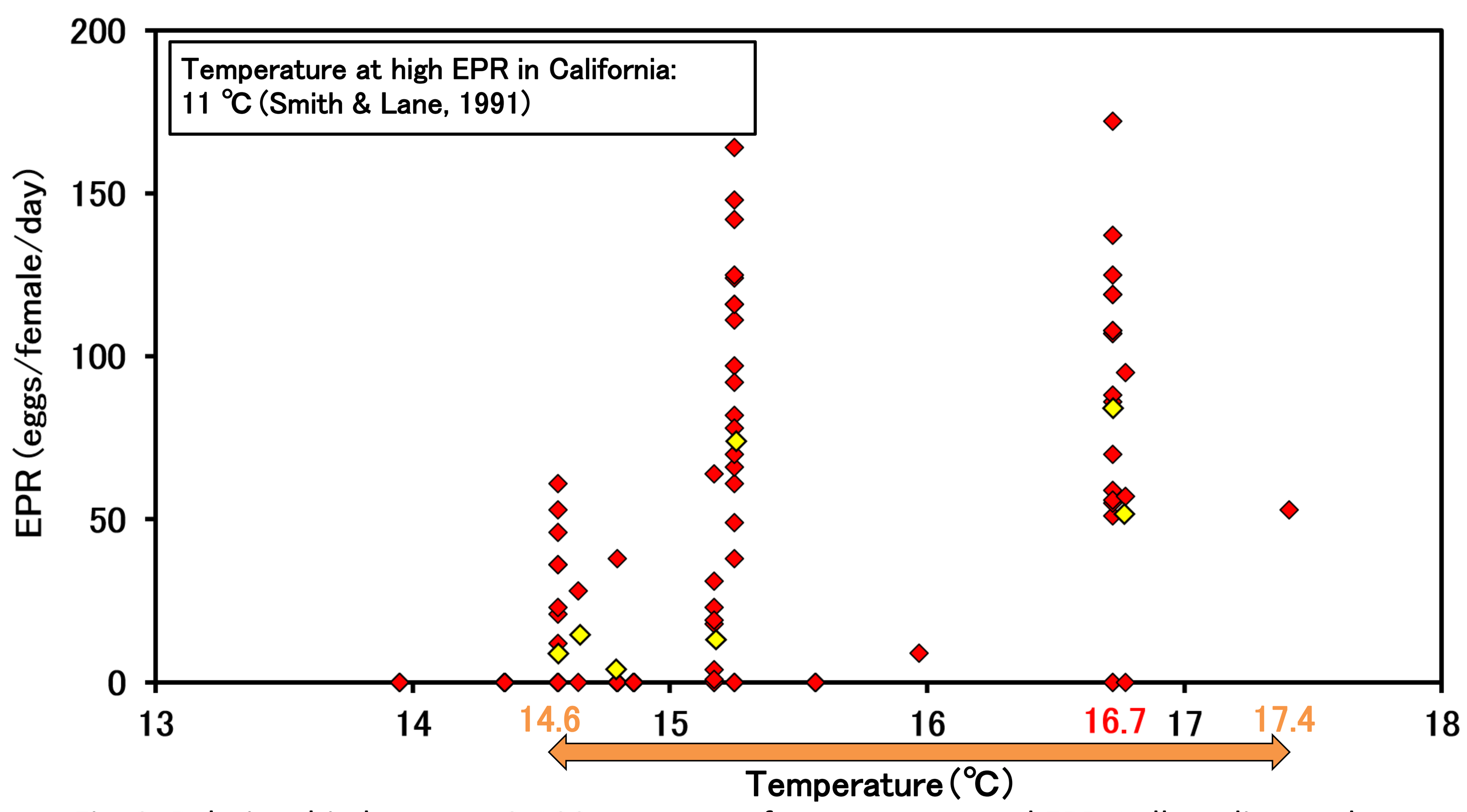

Fig. 9. Relationship between 0-100 m means of temperature and EPR. Yellow diamonds: averages in each temperature.

- *E. californicus* continued to feed, grow and reproduce during longer periods in the surface before starting deep dormancy in 2015.
- The cause of lower EPR in 2015 is considered to be lower chlorophyll *a* concentrations than those of the other years.
- This result implies the newly recruited population in 2015 might be limited.
- Our result suggests that year-to-year variations in the surface environmental conditions can regulate the population dynamics and recruitments of the species.

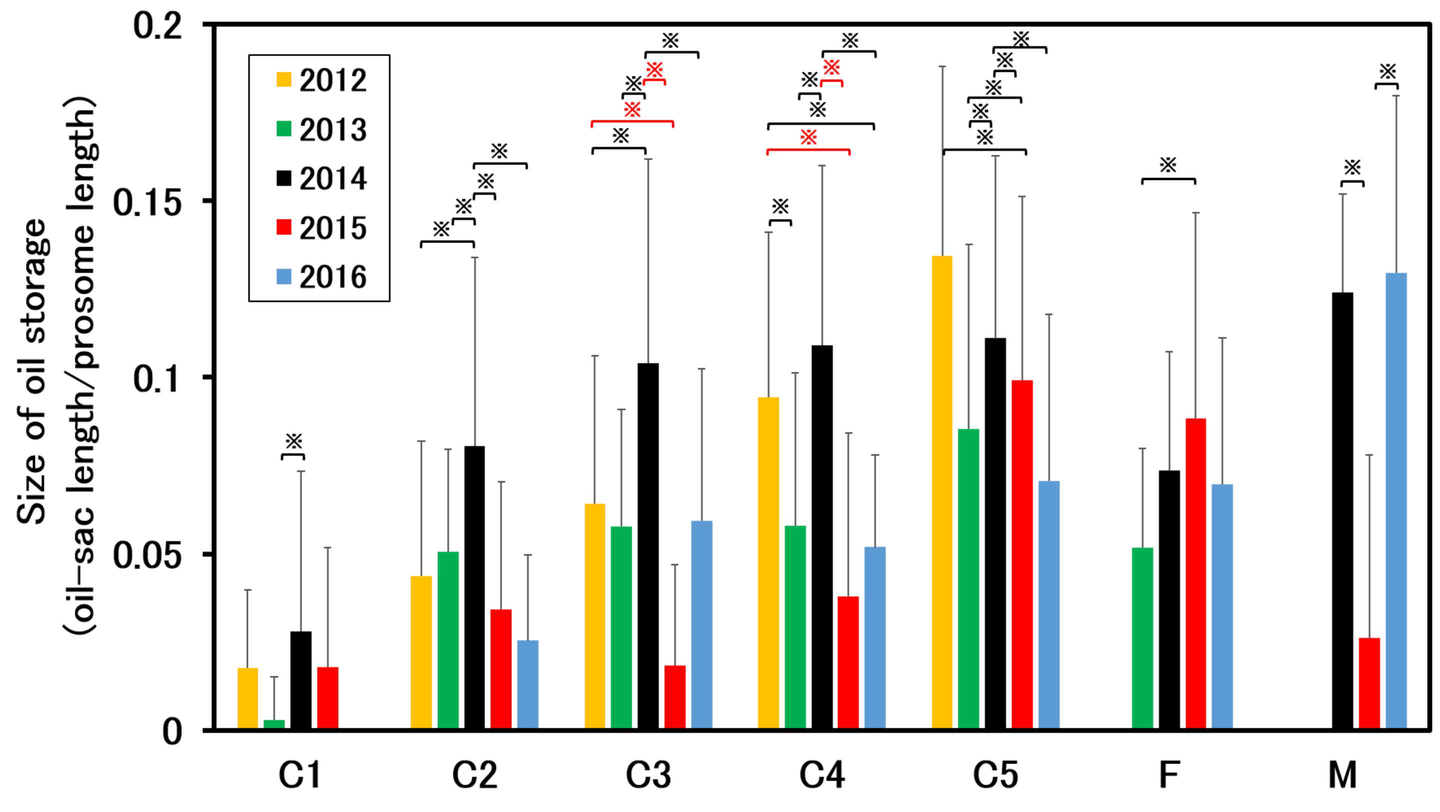

Fig. 7. Average size (± SD) of oil sacs of each copepodid stage of *E. californicus* at St. M in Sagami Bay from 2012 to 2016. *: $p < 0.05$ (Turky-HSD).

- Result of a multiple regression analysis (stepwise method), a model formula of EPR of *E. californicus* was proposed.

$$EPR = -328.2 + 24.4GS + 19.5T + 19.4Chla \ (R^2=0.62)$$

T: 0-100 m mean of temperature, Chla: 0-100 m mean of chlorophyll *a* concentration.

Table 1. Result of multiple regression. β: partial regression coefficient.

	β	*p*
GS	0.52	<0.0001
T	0.35	<0.0001
Chla	0.18	0.0009

- This result shows that GS is the most effective factor for controlling EPR.
- It might be possible that long-term and past EPR of *E. californicus* is restored from examination of GS of formalin-fixed female specimens in old monitoring samples.

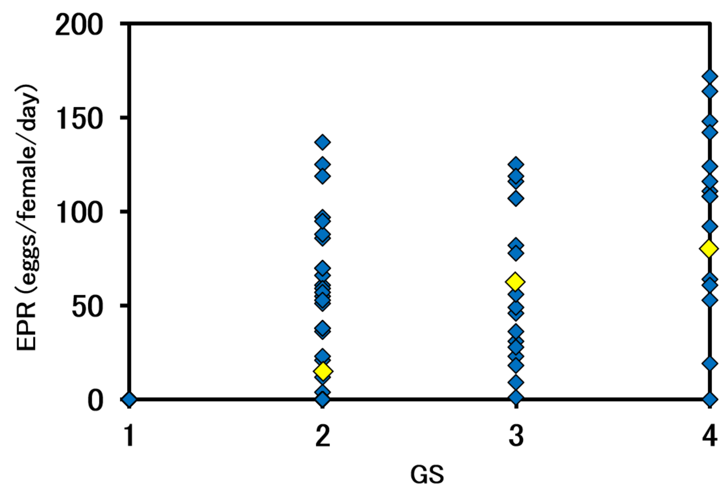

Fig. 10. Relationship between GS of adult females of *E. californicus* and EPR. Yellow diamonds: averages in each GS.