Impact of climate variability on the neon flying squid (Ommastrephes bartramii) winter-spring cohort stock

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Life history of winter-spring cohort of the neon flying squid

Paralarvae stay in spawning grounds until May and feed on zooplankton.

**OUR HYPOTHEISIS**

Autumn-winter MLD interannual variation affects on the neon flying squid stock through zooplankton availability in the early life stage.

Significant positive correlation between the CPUE and Chl-a density in the spawning grounds (Nishikawa et al., submitted)

CPUE: calculated by Japanese jigging vessels data
Chl-a: satellite data
MLD and plankton: output of ecosystem model

Autumn-winter MLD controlled phytoplankton and zooplankton density through nutrient supply from deep layer

MLD and plankton: output of ecosystem model
Purpose of this study

Clarify the underlying climate impact on autumn-winter MLD interannual variation

Bottom-up process

Climatic change? → Mixed layer depth → Nutrient

Phytoplankton → Zooplankton → Neon flying squid Winter-spring cohort

Clarification of bottom-up process will be helpful to predict the squid stock. Because zooplankton variation is a direct cause for stock variation but it is difficult to obtain.
Methods

Averaged MLD in the spawning grounds
- October–February
- 135–170°E and 20–27°N
MLD data is derived from 4D-VAR data assimilation system (Masuda et al, 2006).

Autumn-winter MLD in this area depends on entrainment

We use Bulk mixed layer model (Qiu and Kelly, 1993) to separate contributions of Wind friction, Shortwave radiation and Heat flux to the entrainment.

\[
\frac{1}{2} \alpha g h_m \Delta T \cdot \text{We} = m_0 u^3
\]

Wind friction

\[
+ \frac{\alpha g}{\rho_0 c} \int_0^{h_m} q(z) dz \quad \text{Shortwave radiation}
\]

\[
- m_e \frac{\alpha g h_m}{4 \rho_0 c} (|Q_{net}| - Q_{net}) - \frac{\alpha g h_m}{2 \rho_0 c} (Q_{net} + q_d)
\]

Heat flux
Results

Cause of Entrainment

Anomaly of entrainment and each components (1994–2006)

Autumn-winter Entrainment interannual variation depends on Wind friction and Heat flux

Wind friction: $28.8 \pm 6.1 \text{m}, r = 0.89$
Heat flux: $56.0 \pm 4.7 \text{m}, r = 0.77$
When wind friction/heat flux deepens Mixed layer?

Correlation coefficient between wind friction induced entrainment and autumn-winter entrainment in each month (1994–2006)

Time series of Oct-Nov wind friction and heat flux induced entrainment and autumn-winter entrainment (anomaly)

Heat flux induced entrainment and autumn-winter entrainment

October and November wind friction and heat flux explain almost autumn-winter MLD interannual variation

High correlation coefficients are shown in October and November.
What controls heat flux?

- Wind friction
- Wind speed
- Heat flux
- Latent heat flux

Possible control factor:
- Wind speed
- Humidity

Bulk formula of latent heat flux:

\[ Q_{LA} = -\rho_a L C_E U_{10} (q_s - q_a) \]

Density of air, Latent heat of evaporation and Transfer coefficient are nearly constant.

Difference between specific humidity at the sea surface and specific humidity of air at 10m.

What controls latent heat flux interannual variation?
What controls heat flux?

Estimation of Latent heat flux according to bulk formula

Obviously, latent heat flux interannual variation is controlled by wind speed.

October–November wind speed determines autumn-winter MLD
Summary

**Wind speed, MLD and CPUE**

*Time-series of the neon flying squid CPUE corresponds to autumn wind speed in the spawning grounds two years ago.*

**Hypothesis**

*Strong autumn wind in the spawning grounds induced deep mixed layer that causes high plankton density and links to good catch of the neon flying squid.*

**e.g.**

- Autumn of 2004: Windy
- Winter of 2005: Deep mixed layer
- Spring of 2005: High plankton density
- Winter of 2006: Good catch

**Stock prediction may be possible**
Why wind speed varies interannually?

We focused that high SST was shown in El Niño year in the south of spawning grounds.

Neon flying squid CPUE tends to be high after two years of El Niño (Chen et al., 2007).
Why wind speed often increased?

**Possible scenario**

- High SST in the south of spawning grounds
- Rising air on the south of spawning grounds
- Convergence zone on the south of spawning grounds intensify wind on the spawning grounds

Wind blows on the spawning grounds due to convergence zone

**Colored background:** Correlation coef. between Precipitation rate/CPUE

**Arrows:** Regression coef. between Wind speed/CPUE (Vectors are intensified in high CPUE year)

- High precipitation rate confirms that **rising air** formed clouds
Schematic diagram of climate-squid relation

- Wind convergence
- Rising air
- Warm SST
- Spawning grounds
- Cooling
- Vertical mixing
- Bottom-up effects
- Squid
- Zooplankton
- Phytoplankton
- Nutrient
- East
- West
- North
- South
Cause of ML deepening

\[
\frac{\partial h_m}{\partial t} = E \ w_{mb} \ u_{mb} \ \nabla h_m
\]

E: instant entrainment rate
W and u is vertical and horizontal velocities of the mixes layer.

dMLD: 60.1 ± 5.3m
ENT: 42.3 ± 3.7m, r = 0.80
wMLD: 18.7 ± 3.0m, r = 0.69
Adv: 0.85 ± 0.27m, r = -0.51
Content of Heat flux
Monthly wind

(a) Oct. Deep MLD/Strong Wind
(b) Oct. Shallow MLD/Weak Wind
(c) Oct. Difference
(d) Nov. Deep MLD/Strong Wind
(e) Nov. Shallow MLD/Weak Wind
(f) Nov. Difference