

# Stock Abundance and Size Compositions of the Neon Flying Squid in the Central North Pacific Ocean during 1979–1998

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## Introduction

The neon flying squid, *Ommastrephes bartrami*, is one of the most dominant nekton in the epipelagic subtropical and subpolar waters of the world oceans, and it undertakes extensive seasonal north–south migration (Seki, 1993). In the North Pacific Ocean, this species is composed of an autumn cohort and a winter–spring cohort, both having a one-year life span (Yatsu et al., 1997).

*O. bartrami* has been harvested in the North Pacific Ocean since 1974 until the present with an intensive fishing period by the international squid driftnet fishery during 1978–92, when the annual commercial catch fluctuated between 152,505 and 356,882 metric tons (Gong et al., 1993). The autumn cohort is abundant in the Central North Pacific and was the major target of driftnet fishery since 1979 (Yatsu et al., 1993).

The closure of the large-scale high seas driftnet fisheries was in effect by the end of 1992 according to the bycatch problem. Since 1993, fishing mortality of the autumn cohort has been derived only by jig fishing, whose annual catch has been estimated to be less than 10,000 tons for this cohort.

Since 1979, Hokkaido University (HU) and National Research Institute of Far Seas Fisheries (NRIFSF) have been conducting monitoring surveys for oceanographic and biological conditions by using research driftnets in the western and central North Pacific Ocean. Yatsu and Watanabe (1996)

indicated that these monitoring data would reveal stock abundance of *O. bartrami* since catch-per-unit-effort (CPUE) of this fishery was significantly correlated with that of the research driftnet surveys along 175°30'E in July, which coincided with the peak of the commercial fishery.

The purpose of this study is to examine interannual variability in research net CPUE, size compositions and growth of the autumn cohort until 1998 in relation to pronounced El Niño Events during 1997.

## Materials and Methods

### 1. Sea surface temperature (SST)

SST anomalies over the North Pacific Ocean were determined on the basis of Comprehensive Ocean Atmosphere Data Set (COADS) during 1978–97, which was supplied by the Japan Meteorological Agency as monthly means in two-degree latitude and longitude blocks.

Interannual variability in SST around the western feeding grounds of *O. bartrami* (both along 175°30'E and area of 40°–44°N, 170°E–180°) and around spawning grounds (30°–36°N, 150°–170°W) was also examined from COADS and HU monitoring data.

**Table 1.** Location and period of driftnet survey.

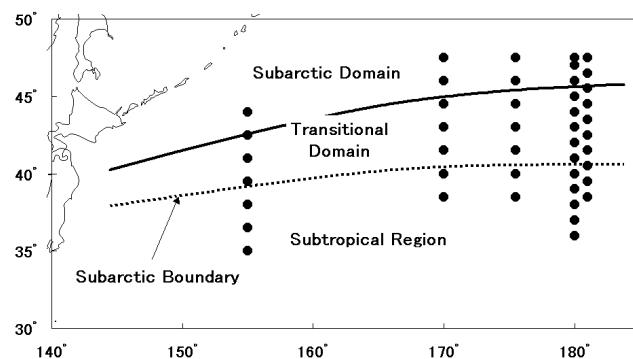
Vessel	Longitude	Year	Date	Latitude	Interval (nautical mile)
<i>Hokusei Maru</i>	155°E	1982–98	June 4–July 7	35°00'N–44°00'N	90
<i>Hokusei Maru</i>	170°E	1981–97	July 15–24	38°30'N–47°30'N	90
<i>Hokusei Maru</i>	175°30'E	1979–98	July 22–August 1	38°30'N–47°30'N	90
<i>Osyoro Maru</i>	180°	1979–98	June 8–19	36°00'N–47°00'N	90
<i>Wakatake Maru</i>	179°W/180°	1991–98	June 12–28	38°30'N–47°30'N	90

## 2. Driftnet monitoring

Monitoring operations by HU and NRIFSF have been carried out at almost fixed sites and dates along five transects, 155°E, 170°E, 175°30'E, 180° (HU) and 179°W (NRIFSF), from June to early August over the Subarctic Domain, Transitional Domain and Subtropical region. (Table 1, Figure 1). At 155°E, monitoring was repeated two times in early June and from late June to early July for each year.

The driftnets were composed of non-size-selective nets (Takagi, 1975) and commercial nets for squid and salmon (mesh sizes 112–130 mm). Each net panel was 50 m long and 6 m deep. A total of 49–134 net panels were connected to form a long net section and soaked over night.

CPUE is the number of animals caught per a 50-m net panel. We separated catch of *O. bartrami* into a autumn cohort with mantle length (ML) 30 cm and larger, and a winter–spring cohort with less than 30 cm ML according to Yatsu et al. (1997).



**Figure 1.** Oceanographic regions and location of monitoring sites.

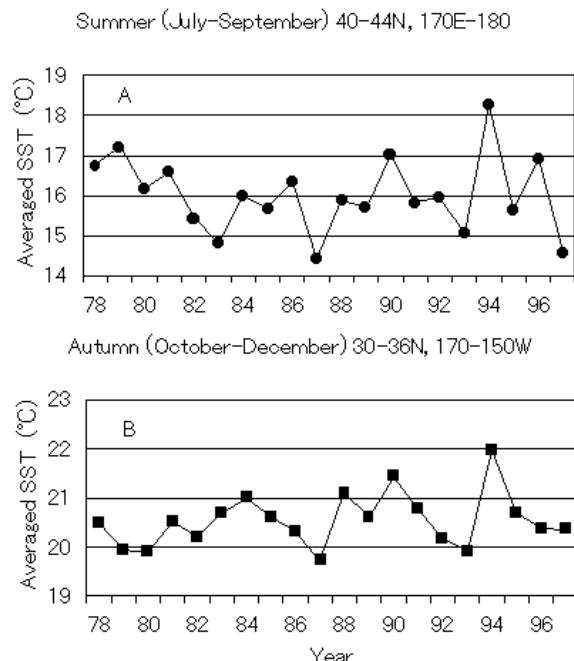
## 3. Size composition and age estimation

ML composition data were derived from these monitoring surveys and from jigging surveys during 1994–97. Ages of selected autumn cohort specimens obtained from 180° longitude during June, 1995–97, were determined with statolith microstructure, following the methods of Yatsu et al. (1997).

## Results and Discussion

### 1. SST conditions

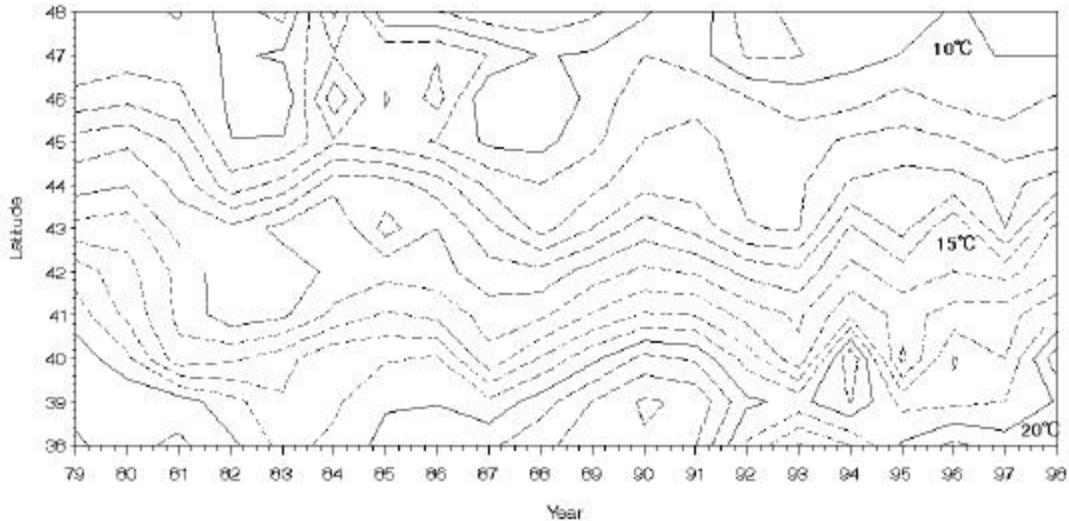
In the feeding grounds of *O. bartrami* around the Transitional Domain in summer, strong negative



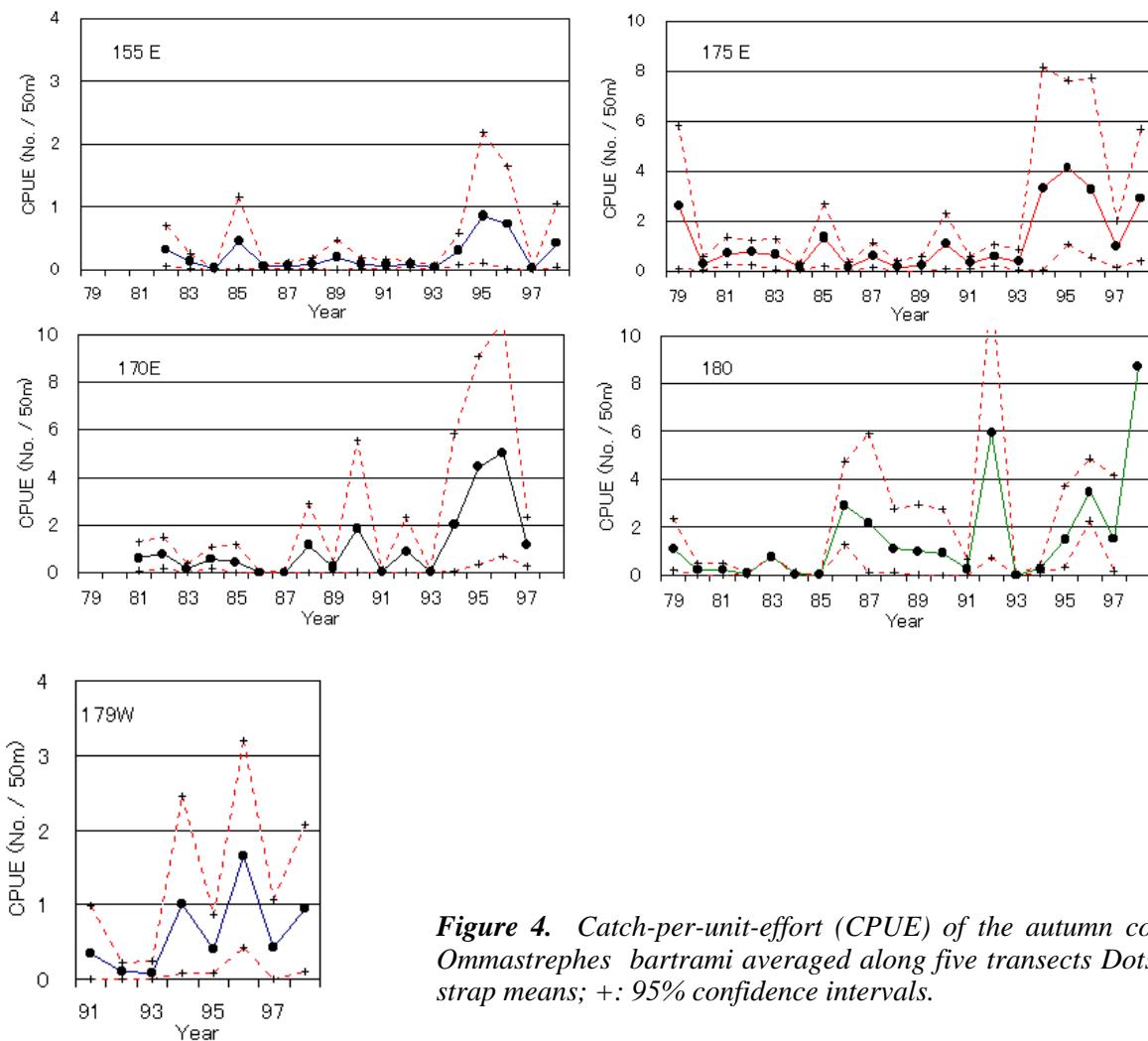
**Figure 2.** Averaged sea surface temperatures (SST) during 1978–97 around feeding grounds (A) and spawning grounds (B) of the autumn cohort of *Omnastrephes bartrami* in the North Pacific Ocean.

SST anomalies were detected in 1983, 1987, 1993, and 1997 (Figures 2A and 3), corresponding to El Niño years. In the spawning ground mainly located

north of the Hawaiian Islands ( $30^{\circ}$ – $36^{\circ}$ N) in autumn, low SSTs were also found in 1987 and 1993 (Figure 2B).



**Figure 3.** Interannual variation in sea surface temperatures during 1979-1998 at  $175^{\circ}30'E$  longitude



**Figure 4.** Catch-per-unit-effort (CPUE) of the autumn cohort of *Ommastrephes bartrami* averaged along five transects Dots: bootstrap means; +: 95% confidence intervals.

## 2. Distribution and CPUE

The autumn cohort was mainly distributed in the southern area of the Subarctic Domain and in the Transitional Domain, contrasting with the winter-spring cohort, which occupied subtropical waters, as in Yatsu and Watanabe (1996).

Averaged CPUE of the autumn cohort at each 5° longitude were generally low during 1980–93 and in 1997 and were high during 1994–96 and in 1998 (Figure 4). Low CPUE during 1980–93 could be attributed to high fishing rates derived from driftnet fisheries. After the moratorium of the fishery, *O. bartrami* stock seemed to quickly recover.

Stock abundance of the autumn cohort was extremely low in 1993 and in 1997, the most prominent El Niño year in this century. For these year-cohorts, spawning ground SST (autumn, 1992 and 1996) were also low (Figure 2).

## 3. Size compositions, age and growth

ML ranges and modes of the autumn cohort in July indicate that squid were considerably larger in 1997, and smaller in 1996 compared to other years (Figure 5).

The ML-age relationship (Figure 6A) indicates that squid collected in 1997 were larger than in 1995 and 1996, yet estimated hatching months were mostly between November and December of previous years with slight year-to-year variation (Table 2). ML-statolith length relationships did not seem to depend on sampling years (Figure 6B).

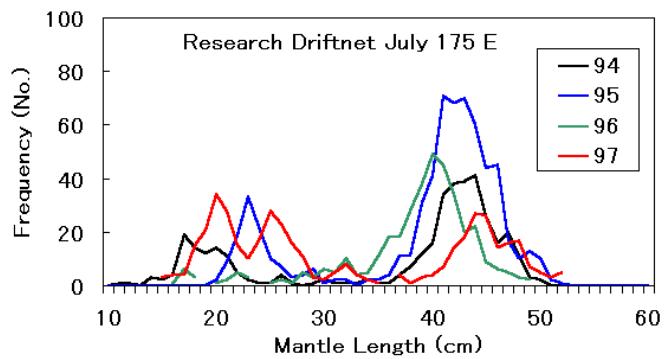
On the basis of statolith daily increment width, Yatsu et al. (1996, 1998) postulated that the most distal part of the broader increment area (increment width >3 µm) correspond to the end of juvenile stage. In the present samples, these ages were slightly younger in 1997 (Table 3).

Statolith growth rates during the juvenile stage seemed to be related to neither ML at capture nor year (Figure 6C). In contrast, statolith growth rates seemed to decrease with ML at capture and were slightly higher in 1997 samples (Figure 6D). Although sample sizes are very limited, this may indicate that higher somatic growth rates in the 1997 samples were derived mainly in the subadult stage.

## Provisional Conclusions

In El Niño years, summer SST around the Transitional Domain in the central North Pacific Ocean

(40°–44°N, 170°E–180°) had negative anomalies. Extremely low stock abundance in 1993 and 1997 might have been derived from negative SST anomalies around the feeding and nursery grounds (40°–44°N, 170°E–180°). An observed lower CPUE in 1993 than in 1997 can be explained by a lower abundance of spawning biomass in 1992 due to intensive driftnet fishing. Higher somatic growth rates in the 1997 samples may have been achieved during their subadult stage rather than juvenile stage.



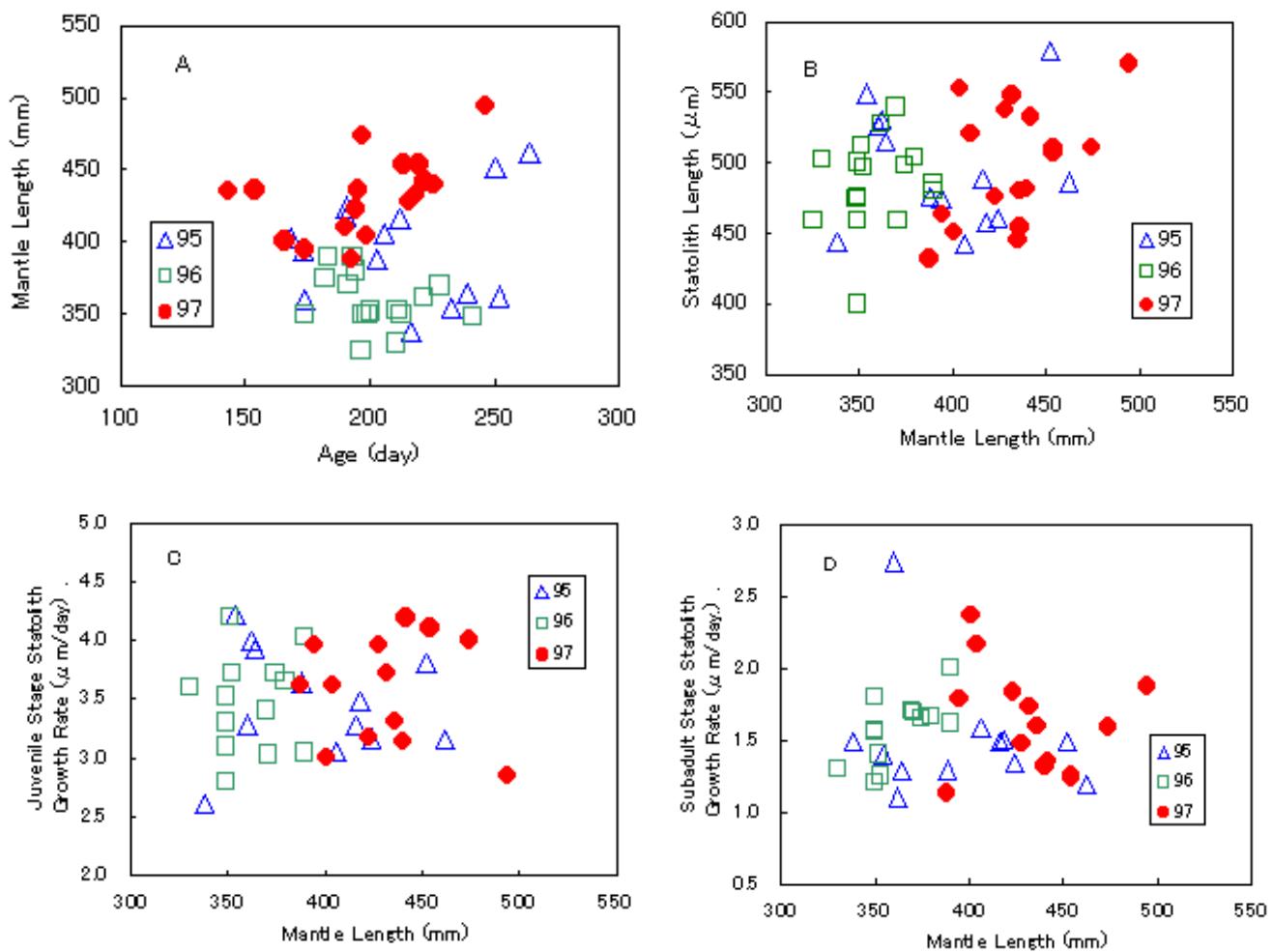
**Figure 5.** Mantle length compositions of *Ommatophterus bartrami* caught with non-size-selective-driftnet along 175° 30'E during July, 1994–97.

**Table 2.** Estimated hatching month by sampling year.

	Sep	Oct	Nov	Dec	Jan
1995	1	4	4	4	1
1996	–	1	7	8	–
1997	–	1	6	7	3

**Table 3.** Estimated age at the end of the juvenile stage by sampling year.

	N	Min	Mean	Max
1995	13	79	90.3	113
1996	13	76	92.9	107
1997	16	70	87.4	111



**Figure 6.** Relationships between mantle length (ML) and age (A), ML and statolith length (B), ML and juvenile statolith growth rates (C) and ML and subadult statolith growth rates (D) in the autumn cohort *Ommastrephes bartrami* collected during June, 1995–97 at 180° longitude.

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