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# Interannual Variability in the Neon Flying Squid Abundance and Oceanographic Conditions in the Central North Pacific Ocean during 1979-1997

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**Abstract** The neon flying squid, *Ommastrephes bartrami*, was the target species of the Japanese squid driftnet fishery in the Central North Pacific Ocean during 1979-1992. Interannual variation in the neon flying squid catch-per-unit-effort (CPUE) in this fishery was highly correlated with that of the Hokkaido University's research driftnet surveys since 1979 along 175° 30'E in July which coincided with the peak of the commercial fishery. While productivity in the northern North Pacific Ocean was high during the 1970's and declining to the present days, the research net CPUE of *O. bartrami* was higher in 1979 and in 1994-97 than in other years, suggesting effect of fishing on the stock abundance. The distributions and CPUE variability in *O. bartarmi* were also affected by water temperature and salinity structures around the Subarctic Boundary. During the intensive driftnet fishing, three squid species (*O. bartrami, Gonatopsis borealis and Onchoteuthis borealijaponica*) may have, to some extent, filled throphic niche that was occupied by pelagic fishes.

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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 autumn cohort and winter-spring cohort, both having a one-year life span (Yatsu et al., 1998).

*O. bartrami* has been harvested in the North Pacific Ocean since 1974 until present days with an intensive fishing period by the international squid driftnet fishery during 1978-92, when 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, 1994).

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 less than approximately 10,000 tons for this cohort. Absence of such large mortality in the former squid driftnet fishing grounds in the Central North Pacific Ocean could then be a good 'experiment' to evaluate effect of fishing on target and non-target species. The research area is composed of three oceanographic regions: Subarctic Domain, Transitional Domain and Subtropical region (Favorite et al., 1976).

## Material and Methods

The Hokkaido University has been conducting oceanographic observations and driftnet operations at almost fixed locations and dates along longitudes 155° E, 170° E, 175° 30'E and 180° from June to early August since 1979 (Table 1, Fig 1). The driftnets are composed of nonsize-selective nets (Takagi, 1975) and commercial nets for squids and salmons (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.

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

*Table 1. Location and period of driftnet survey by the Hokkaido University*

| Longitude | Year | Date | Latitude |
|---|---|---|---|
| 155° E | 1982–98 | June 4 – July 7 | 35°00' N – 44°00' N |
| 170° E | 1981–97 | July 15 – 24 | 38°30' N – 47°30' N |
| 175°30' E | 1979–98 | July 22 – August 1 | 38°30' N – 47°30' N |
| 180° | 1979–98 | June 8 – 19 | 36°00' N – 47°00' N |

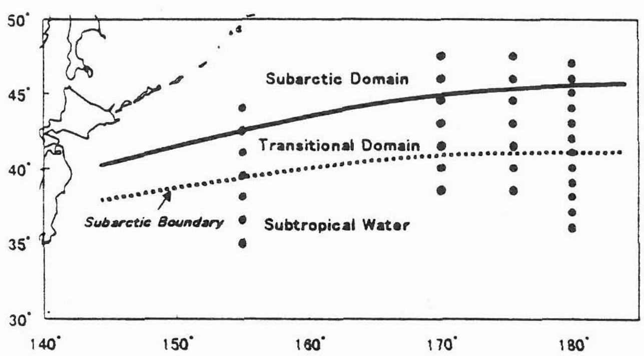


*Fig. 1. Oceanographic regions and location of stations*

## Results

### 1. Oceanographic conditions

Location of southern boundary of the Subarctic Domain (represented by 4℃ at 200m) is fairly stable during the research period, that of the Transitional Domain (34.0 psu) located at lower latitudes during 1986-89 than in other years.

### 2. Distribution and size compositions of *Ommastrephes bartrami*

The autumn cohort is distributed south of the Subarctic Domain with higher CPUEs in the Transitional Domain. In contrast, winter-spring cohort occupies mainly sub-tropical waters beyond the research area.

At longitudes 170° E and 175° E, the averaged CPUE of the autumn cohort were usually less than 2 during 1980-83 and in 1997 and were 2-5 during 1994-96 (Fig. 2). Although CPUE is low along 155° E, average CPUE were considerably higher in 1994-96 than other years. Averaged CPUE along 180° had three peaks at 1986, 1990 and 1995. Three-year running means of the averaged annual CPUE along the four longitudes indicate higher CPUE level in 1994 and after (Fig. 2).

### 3. Chronological CPUE fluctuation of the major species

CPUE trends of major fish and squid species taken by the research driftnet along 175° 30'E are shown in Fig. 3.

CPUE of Blue shark (*Prionace glauca*) was extremely low during 1982-92 than other period. CPUE of salmon shark (*Lamna ditropis*) declined throughout the study period in the Transitional Domain. These two shark species was very few (only 4 blue and 3 salmon shark) in the Subarctic Domain during 1979-96.

While CPUE of salmonid fishes was almost stable in the Subarctic Domain, it drastically increased from 1979 to 1993-96 in the Transitional Domain. The major component of this increment is chum salmon (*Onchorynchus keta*). Pomfret (*Brama japonica*) CPUE in the Subarctic Domain declined since 1980-81, whereas in the Transitional Domain it declined in 1993-96. CPUE of albacore (*Thunnus alalunga*) continuously increased since 1979 in the Transitional Domain. Sardine (*Sardinopos melanostictus*) was very abundant during 1980-92 in the Transitional Domain and was almost absent in 1979 and in 1993-96. Absence of sardine in 1979 may be caused by the lack of small meshed (19 mm and 22 mm) nets. CPUE of anchovy (*Engraulis* *japonicus*) continuously increased since 1979 until 1993-96. CPUE of saury (*Cololabis saira*) was difficult to interpret because of the mesh size history and highly variable CPUE in the Subarctic Domain.

CPUE of the neon flying squid (two cohorts combined) in the Transitional Domain declined from 1979 to 1982-92 and increased in 1993-96 as previously described for the autumn cohort. Eight-armed squid (*Gonatopsis borealis*) CPUE increased since 1980-81 in the Subarctic and Transitional Domains. Boreal club-hook squid (*Onchoteuthis boreali-japonica*) is increasing since 1979 in the Transitional Domain, whereas CPUE was considerably variable in the Subarctic Domain.

## Discussion

Owing to the above zonal distribution of the autumn cohort, together with good correlation between CPUE of research nets and commercial fishery (Yatsu and Watanabe, 1996), we assume that their CPUE represent annual abundance of the autumn. While productivity in the northern North Pacific Ocean was high during the 1970's and probably declining to the present days (Sugimoto and Tadokoro, 1997), the research net CPUE of *O. bartrami* was higher in 1979 and in 1994-97 than in other years, suggesting effect of fishing on the stock abundance.

Such effect of fishery is considered to be variable depending on a number of biological parameters, such as stock size, natural mortality, life span and reproduction rates, as well as amount of the bycatch.. Among the 11 species described in this study, estimated amount of bycatch are so small for salmonids, sardine, anchovy, saury and eight-armed and boreal club-hook squids, that the fishery can not have directly affected their stock abundance. Rather, CPUE fluctuation of these small pelagic fishes may have been caused from long-term environ-mental effects known as regime shift (Brodeur and Ware, 1995; Francis et al., 1998), recruitment failure (Watanabe et al., 1995), or stock enhancement in the case of salmonids.

There is a potential of negative effect of fishing mortality on the other four species: *O. bartrami*, pomfret, blue shark and salmon shark obviously decreased during the intensive fishing period. IN contrast, albacore, eight-armed squid and boreal club-hook squid had become abundant.

These contradictory trends in CPUE among species are considered to represent primarily different fishing mortality, which in turn is a function of (1) degree of matching (overlap) in geographic and seasonal distributions between the fishing grounds and these animals, and (2) mesh size selectivity (cf. Yatsu et al., 1994). Eight-armed squid and boreal club-hook squid have slightly more northern habitat and small body than the neon flying squid; albacore inhabits slightly more southern area and has larger body than the neon flying squid (Pearcy, 1991).

Since squids, albacore, pomfret, blue and salmon sharks are all opportunistic nekton/micronecton-feeders (Laurus and Lynn, 1991; Pearcy, 1991; Pearcy et al., 1993; Seki, 1993), there could be competition of food resources in the Transitional Domain among these species. For blue and salmon sharks, Transitional Domain is a nursery ground where they feed on myctophid fishes, sardine, saury and gonatid squids (Seki, 1993; Nakano and Nagasawa, 1996).

Difference in life span and in fecundity may explain the different CPUE recovery trends after the moratorium of the fishery in 1992 between squids and pomfret, and between blue shark and salmon shark. Owing to generally broad trophic niche and shorter life span of cephalopods, it is considered that where fish populations have been overexploited cephalopods may have filled vacant niche (Caddy, 1983; Rodhouse and Nigmatullin, 1996). We suspect this also holds true in the former squid driftnet fishing grounds in the Transitional Domain of the Central North Pacific Ocean.

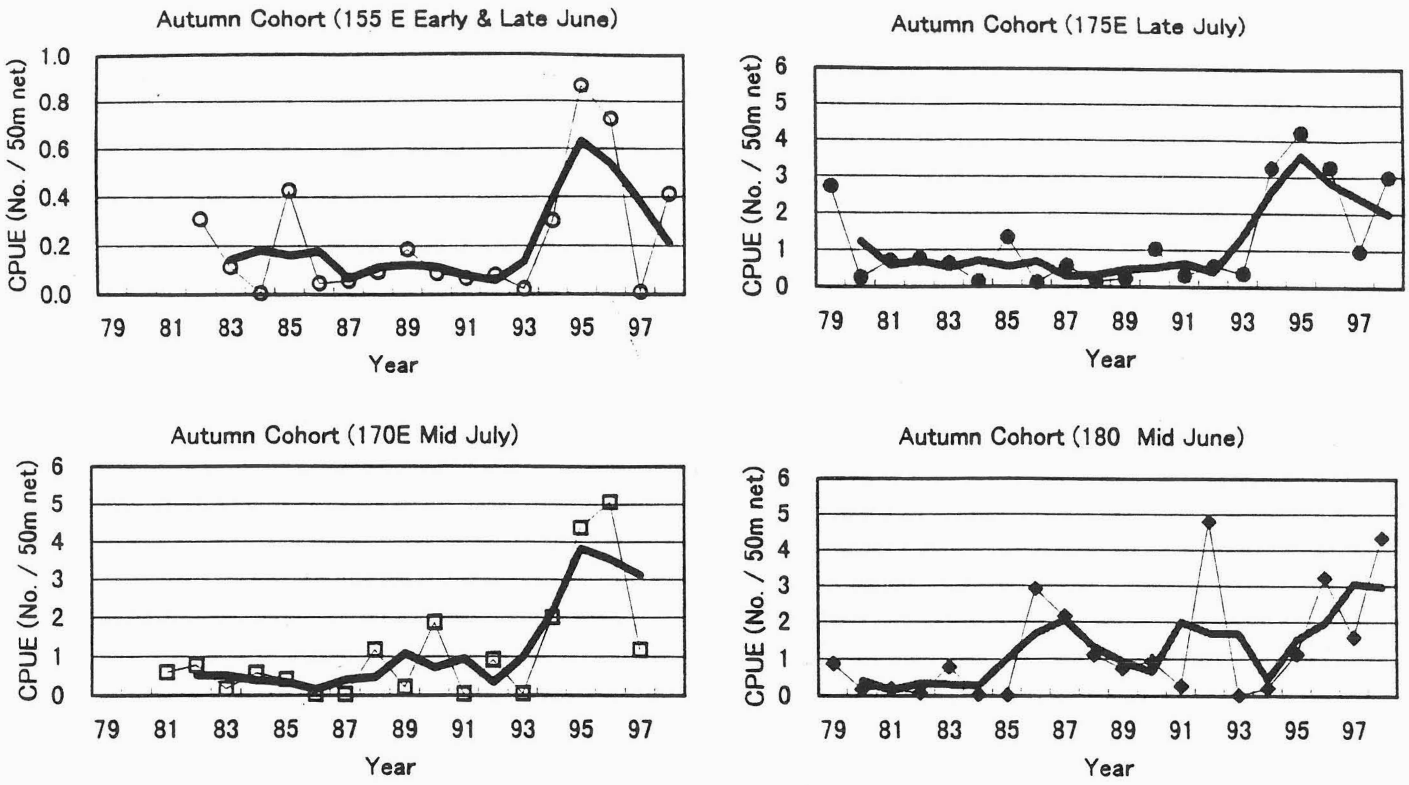


*Fig. 2. Interannual variation of average CPUE of neon flying squid (autumn cohort) at longitudes 155 ˚E, 170 ˚E, 175 ˚30'E and 180 ˚. Thick lines indicate 3-year running means.*

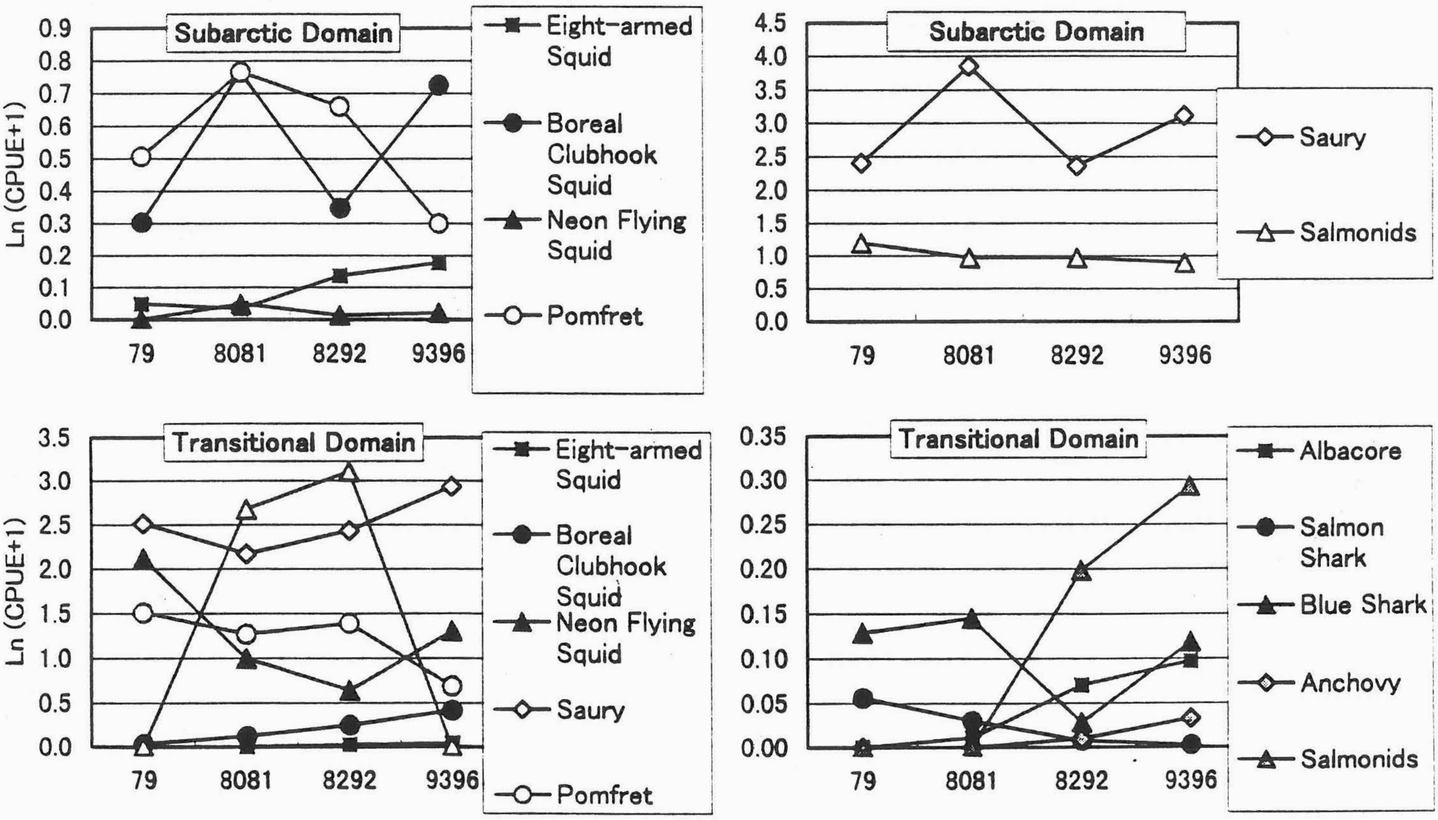


*Fig. 3. CPUE fluctuation of major species from onset of driftnet fishery (1979), intensive fishing (1982-92) to after the moratorium of the fishery (1993-96) in the Subarctic and Transitional Domains along 175 ˚30'E.*