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Spatio-temporal variation in the higher trophic level community structure of the western North Pacific pelagic ecosystem

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ABSTRACT

There are increasing demands for evaluation of the current status of marine ecosystems and impacts of environmental change and anthropogenic activities, but for the open ocean available data are quite limited. The Japanese driftnet survey dataset of Hokkaido University was used to analyze the spatio-temporal variations in the higher trophic level (HTL) community structure in the western North Pacific. The analyses were conducted by using subset of the data that was collected along four regularly surveyed transect lines at 155°E, 170°E, 175°E and 180°E spanning from 36 to 48°N and from 1982 to 1996. Non-size-selective multiple mesh driftnets were used in the survey. Total number of individuals, species richness and Simpson index of species diversity indicated a longitudinal gradient with a lower abundance and diversity in the eastern area. Latitudinal gradient was clear for numerical abundance and species richness, but no trend for Simpson diversity index. Temporal patterns in the HTL community structure were not consistent among the three metrics: numerical abundance showed a significantly decrease and increasing fluctuations in later years, species richness was increased along years, and Simpson index did not show any clear temporal trends. The inconsistency in the temporal patterns of community metrics was considered to arise from the effects of the sampling scheme on community measurements and/or complex structural changes such as the emergence of dominant species related to regime shifts. These results suggest the importance of proper consideration of temporal changes in the sampling scheme when analyzing long-term data.

1. Introduction

There is increasing demand for the evaluation of the current status of marine ecosystems and the impacts of climatic and anthropogenic factors on them. While the oceans cover 71% of the Earth's surface, our understanding of marine ecosystems has lagged behind that of terrestrial ecosystems (Hoegh-Guldberg and Bruno, 2010). The situation is particularly true for oceanic ecosystems: in contrast to benthic and planktonic communities in neritic waters (Angel, 1997) even mere description of spatiotemporal patterns of biodiversity is challenging for the open ocean pelagic community. Long-term data on open ocean ecosystems are of particular importance in evaluating the impacts of climate change and/or anthropogenic activities such as commercial fisheries.

Several data sources have provided information on changes in open oceanic ecosystems. Some studies used logbook data derived from commercial fisheries to evaluate long-term changes of higher trophic level (HTL) species in oceanic ecosystems (e.g., Baum et al. (2003) and Myers and Worm (2003)), others analyzed data collected by scientific observers onboard commercial fishing vessels (e.g., Morato et al. (2010)) or both of these fishery-related data sources (e.g., Worm et al. (2003, 2005)). Unfortunately, commercial fishery data often do not allow a true assessment of the magnitude of ecosystem changes because their focus is concentrated on commercially important species and do not collect sufficient information relevant to analyze ecosystem changes such as abundance, species and size composition of non-target species (Jackson et al., 2001). Moreover, even if scientific observers collected substantial scientific data for a variety of ecosystem components, fishery-related data are inevitably affected by changes in fishing technology and fleet dynamics, which can also be influenced by socioeconomic factors (e.g., Salas and Gaertner (2004) and Cinner et al. (2008)). On the other hand, some long-term scientific surveys, which were originally aimed at monitoring fishery resources and the marine environment, can also provide supplementary information on oceanic ecosystems. For example, Japanese long-term survey data on oceanic plankton, fish and marine mammals have been analyzed to detect ecosystem changes (Shiomoto et al., 1997; Sugimoto and Tadokoro, 1998; Chiba et al., 2006; Yonezaki et al., 2008, this issue).

In this study, we used Japanese driftnet survey data in the western North Pacific Ocean. The main purpose of the driftnet

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survey was to monitor the distribution and abundance of commercially important species such as salmonids and squids, but the survey also collected data on other incidentally-caught species. We analyzed the data to find out whether the driftnet survey data can reveal spatio-temporal variations in the pelagic HTL community structure with respect to abundance, species diversity, and species composition. We focused following three aspects of the large scale spatio-temporal variation of community. As the large scale temporal pattern, we tested the linear trend of community structure along years, which would be associated with climate change like as the regime sifts between Japanese sardine and Japanese anchovy around the late 1980s (Kawasaki, 2013). As the large scale spatial pattern, we examined the latitudinal and longitudinal trends of community structure. In the former case, latitudinal gradient of species diversity which indicates a higher diversity in lower latitudes is generally well known both in terrestrial and marine communities (e.g., Roy et al. (1998), Willig et al. (2003) and Hillebrand (2004)). The longitudinal pattern of HTL community would be influenced by the oceanic currents around Japan. In the western North Pacific Ocean off northern Japan, two major current systems, the warm Kuroshio current and the cold Oyashio current, form a front where water masses, materials, and biota originating from both subtropical and subarctic regions intermix and give rise to a highly productive and diverse ecosystem (Kawai, 1972; Sugimoto and Tameishi, 1992). And then, the Kuroshio extension generates the predominant flow to east that would cause longitudinal variation of HTL community.

2. Methods

2.1. Data

The open access database of the long-term driftnet survey conducted by Hokkaido University in the western North Pacific Ocean (HUFO-DAT volume 2) was used in this study. The survey was conducted from 1953 to 2007 to obtain biological data on salmonids and other commercially important fishery resources. From the dataset, we extracted a subset of data ($n=491$) collected along four regularly surveyed transect lines at 155°E, 170°E, 175°E and 180° spanning from 36°N to 48°N from 1982 to 1996 (Fig. 1). In this period, the driftnet survey was conducted annually from June to early August. At each monitoring site, 49–137 net panels (tans) were deployed in the evening and submerged in the water overnight. Each net panel was 50 m in horizontal length and 6 m in vertical height. The research driftnet was composed of nylon monofilament gillnet of commercial mesh size (stretched mesh size: 112–130 mm) and non-size-selective multiple mesh sizes (stretched mesh size: 19–233 mm; Takagi, 1975; Yatsu et al., 2000). From 1982 to 1996, although net panel composition varied through years, spatial arrangement and sampling date did not bias among years.

In the database, the date and location of sampling, mesh size and number of driftnet panels used, and species and number of individuals collected were recorded for each survey haul. Unfortunately, the sampling gear used was not consistent throughout the study period. The number of net panels used in a research haul was gradually reduced from 1984 (mean ± SD: 129.75 ± 12.53 panels) and the number halved by 1993 (mean ± SD: 49.77 ± 0.43 panels). Mesh size composition was also changed. Large mesh size nets (130 mm, 179 mm, 204 mm, and 233 mm) were not used after 1993 (Table 1). In addition, for 1988 the mesh size composition data were not accurate: many driftnet operations did not record the number of net panels for each mesh size and recorded only the total number of net panels in a haul.

Major components of the driftnet samples were neon flying squid (*Ommastrephes bartramii*), Pacific pomfret (*Brama japonica*), Pacific saury (*Cololabis saira*), Japanese sardine (*Sardinops melanostictus*), blue shark (*Prionace glauca*), skipjack tuna (*Katsuwonus pelamis*) and albacore tuna (*Thunnus alalunga*) as well as salmonids in the northern sampling points. Salmonid catches were recorded for each mesh size, while other fish and squid species were recorded not by mesh sizes but as the sum of individuals caught in a haul.

To assess whether the temporal change of net panel composition (i.e., sampling effort) caused sampling bias, we constructed the species accumulation curve, which relates sampling effort (i.e., cumulative number of plots) to the cumulative number of species, for each year (Fig. 2). Average species accumulation curve for each year was obtained from a total of 1000 curves that were constructed by arranging all the sites (the number of sites vary among years) in random order. Species accumulation curves almost approached asymptotes in all years and the shapes of curves did not show obvious differences among years. Furthermore, no clear decreasing trends of catch amount were not observed in the small and large sized fishes when the mesh size composition of the driftnet changed with decreasing number of small net panels and the disappearance of the largest net panels from 1993 to 1996 (Fig. 3). These facts imply that the temporal change of number of net panels of each haul would affect the

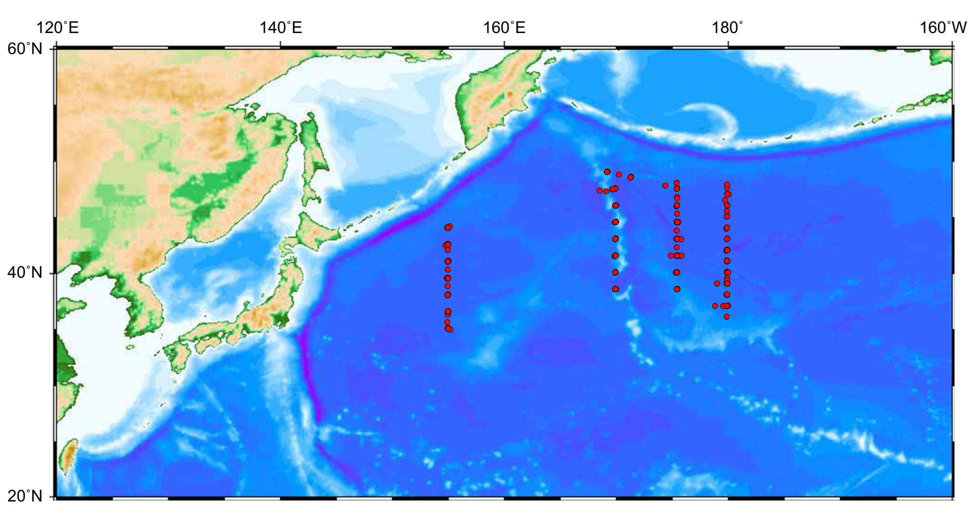

Fig. 1. Map showing the sampling locations of the drift net survey along the four transect lines analyzed in this study (red circles) (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article).