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Climate-induced habitat suitability variations of chub mackerel *Scomber japonicus* in the East China Sea

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ABSTRACT

Chub mackerel *Scomber japonicus* is an economically important fish species, extensively distributed in the East China Sea, the Yellow Sea and the Sea of Japan. Climate variability has strong impacts on its habitat. In this study, an integrated habitat suitability index (HSI) model was constructed to examine habitat suitability of *S. japonicus* in the East China Sea, and evaluate the relationship with the El Niño and La Niña events, with three crucial environmental variables (sea surface temperature (SST), sea surface height (SSH) and net primary production (NPP)) as predictors. The HSI model was developed using data over 2006–2013 and validated using data in 2014 and 2015. Results showed that the HSI model with the best model performance yielded robust predictions of habitat suitability for *S. japonicus*. The decreasing catch and CPUE (catch per unit effort) of *S. japonicus* during 2006–2015 were highly consistent with substantial shrinkage of suitable and optimal habitats, and enlargement of normal and poor habitats. Similar movement pattern was also found between the latitudinal gravity centers of fishing effort for *S. japonicus* fishery and the gravity centers of potential habitat. In addition, spatial correlation analysis indicated that the HSI value was significantly positively related to the SST anomaly (SSTA) and negatively correlated with the SSH anomaly (SSHA) and NPP anomaly (NPPA), on the main fishing ground between 25°–30 °N and 120°–130 °E. Furthermore, various intensity of the El Niño and La Niña event may lead to different variations in the habitat suitability of *S. japonicus*. Comparing to the very strong El Niño, the moderate El Niño events would yield rising SSTA and lowing SSHA and NPPA, leading to dramatically enlarged suitable habitat of *S. japonicus*. The habitat quality in La Niña events with different intensity depended on the local environmental variability on the fishing ground. Our findings suggested that the El Niño and La Niña events prominently affected the habitat suitability of *S. japonicus* in the East China Sea. However, the impacts varied with the intensity of each anomalous climatic event.

1. Introduction

Chub mackerel *Scomber japonicus* is a coastal-pelagic fish species, which is widely distributed in temperate and subtropical zones throughout the world ocean (Yatsu et al., 2005). In the Northwest Pacific Ocean, *Scomber japonicus* is divided into two stocks: Pacific stock and Tsushima Current stock (Watanabe et al., 2002). The Pacific stock of *S. japonicus* is extensively distributed in the waters off Kyushu Island to the Pacific coast of northeastern Japan, which is largely exploited by Japan (Watanabe and Yatsu, 2006). However, the latter stock prefers to inhabit in the East China Sea, the Yellow Sea and the Sea of Japan. Due to its highly economic values, this stock has been an important commercial fishing target by the large light-purse seine fisheries of China (including Taiwan province), Korea, Japan and Russia (Li et al., 2008). *Scomber japonicus* stock in the East China Sea and the Yellow Sea annually makes a seasonal south-to-north migration. Generally, *S. japonicus* moves northward into the north region of the East China Sea and the south Yellow Sea in spring for spawning, then it migrates southward to the south East China Sea in summer (Shiraishi et al., 2008). Thus, from July to September in summer, the south East China Sea becomes a very important fishing ground and attracts large amounts of international chub mackerel fishing vessels in this area (Chen et al., 2009). According to previous studies, it is observed that catches of *S. japonicus* fluctuate from year to year for many countries.

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One critical factor causing the fluctuant stock size of *S. japonicus* may source from the climate-driven environmental variability on the fishing ground (Hiyama et al., 2002).

In order to achieve rational exploitation and management of fish resources, many studies have paid attention to the impacts of climate variability on climate-related habitat suitability variations and relationships with the fish distribution and abundance as well as catches (Silva et al., 2016; Tanaka and Chen, 2016). It is well recognized that the El Niño and La Niña events, one of the most important climate changes, are large-scale oceanic warming and cooling, respectively, in the tropical Pacific Ocean with interannual variations, which have significant impacts on fish species in the oceans (Anderson and Rodhouse, 2001). In general, an El Niño or a La Niña event occurs, environmental conditions in original habitat will change, leading to poor or good habitat quality (Su et al., 2011). Fish will quickly respond, either concentrating in this region or moving to more suitable habitats. For example, previous studies reported that the habitat quality of winter-spring cohort of neon flying squid *Ommastrephes bartramii* in the Northwest Pacific Ocean would significantly decline in El Niño years (Yu et al., 2015). Squid shifted its distribution to southern regions (Chen et al., 2007). As with the most marine living resources, *S. japonicus* stocks is strongly affected by climatic and environmental conditions (Li et al., 2014). However, at present, relatively little research has been conducted to investigate the changes in abundance and distribution of *S. japonicus* associated with climate-induced habitat suitability variations in the coastal waters of China.

Habitat suitability index (HSI) modeling approach is initially used for evaluating wildlife-habitat relationships based on limited data or expert knowledge (Gong et al., 2011). With increasingly applications, it is extensively applied to assess the impacts of climatic and environmental conditions on fish stock dynamics (Su et al., 2011; Silva et al., 2016; Lan et al., 2017). Fish species have strict environmental requirements (Li et al., 2017). Through quantifying the relationship between environmental variables and fish abundance indicators by statistical analysis, HSI model can capture the habitat characteristics, evaluate the habitat conditions and further identify the habitat preferences under different climatic and environmental conditions (Alabia et al., 2016). For example, Guan et al. (2017) have developed an integrated HSI model to link the reduced abundance and contracted spatial distribution of Atlantic cod *Gadus morhua* in the Gulf of Maine (GOM) with large spatio-temporal variation in their habitat quality. They found that the declined cod recruitment may be caused by the low HSI quality. However, positive influences of environmental conditions might result in high-quality habitat and catch rates. Yen et al. (2017) have constructed a HSI model to illustrate the difference in the effects between two types of El Niño events on the skipjack *Katsuwonus pelamis* resources in the Western and Central Pacific Ocean. Their findings demonstrated that the Central Pacific El Niño events tended to yield more negative influences on relative abundance of skipjack than the Eastern Pacific El Niño events.

In recent years, the North Pacific Fisheries Commission (NPFC) has formally managed *S. japonicus* stock for long-term conservation and sustainable exploitation of this fishery. Thereby, it is urgent to address the causes and consequences of changing climate on *S. japonicus* habitat. In the present study, in order to examine the habitat suitability of *S. japonicus* in the coastal waters of China and relate them to different types of the El Niño and La Niña events, an integrated habitat suitability model was constructed. In the model development, two environmental variables including sea surface temperature (SST), sea surface height (SSH) and net primary production (NPP), which showed crucial influences on distribution and abundance of *S. japonicus* stock, were employed as the predictors. The HSI model was developed using available fisheries and environmental data over 2006–2013 and cross-validated using data in 2014 and 2015. Such a study can help better understand variations in the climate-related habitat suitability of *S. japonicus* stock in the East China Sea and better fisheries management.

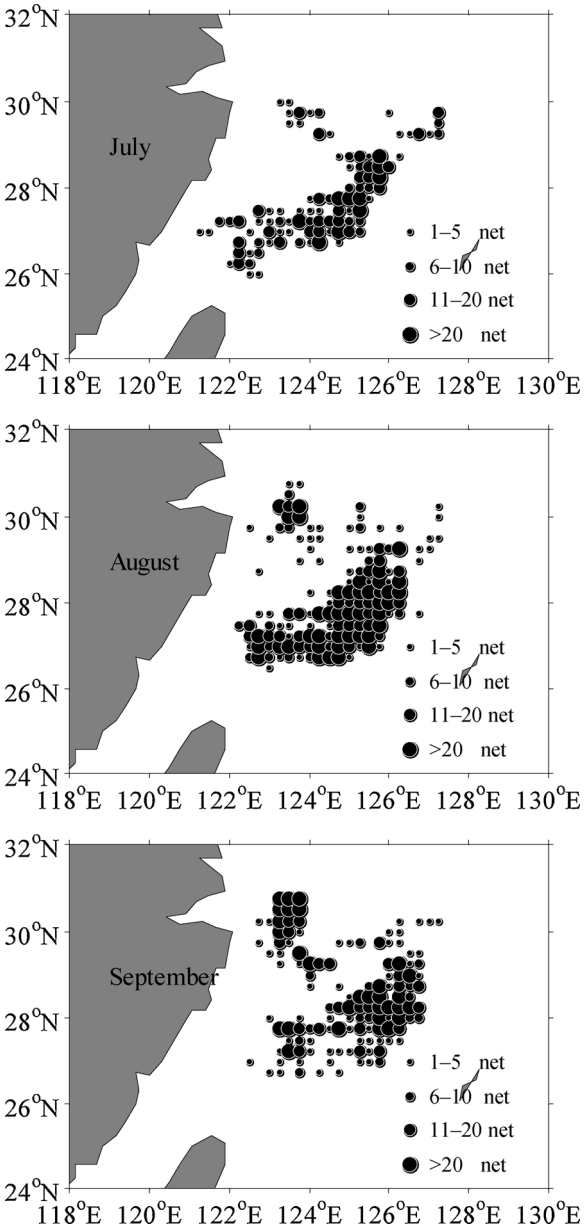

Fig. 1. Spatial patterns of fishing effort for the Chinese chub mackerel fishery from July to September during 2006–2015 in the East China Sea.

2. Materials and methods

2.1. Fisheries data

Commercial fisheries data from the Chinese large light-purse seine fishery for *S. japonicus* in the East China Sea were obtained from the Data Center of Chinese distance-water fisheries, Shanghai Ocean University. The data were grouped by 0.25° × 0.25° grid cell and by month, covering the main fishing months from July to September over 2006–2015. Data information included fishing date (year and month), fishing location (latitude and longitude), catch (unit: tons) and fishing effort (nets-haul number). Fig. 1 showed spatial pattern of fishing effort from July to September during 2006–2015 for the Chinese *S. japonicus* fishery in the East China Sea. The CPUE (catch-per-unit-effort) within a 0.25° × 0.25°grid cell was calculated by the catch/effort relationship as the following equation: