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# Predicting the timing of Pacific saury (*Cololabis saira*) immigration to Japanese fishing grounds: A new approach based on natural tags in otolith annual rings

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ABSTRACT

Pacific saury, *Cololabis saira*, are widely distributed in the central Pacific Ocean during the pre-fishing season (June and July) and migrate westward to fishing grounds off the coast of Japan from August to December. This study clarified the relationship between pre-fishing distribution and immigration to the fishing grounds (i.e., the relationships among distribution during the pre-fishing season, immigration rate to fishing grounds, immigration date, and westward velocity) in age-1 (1 year old) Pacific saury using the radius of otolith annual rings (ROAs) as a natural tag to improve fishing predictions based on stock assessments via pre-fishing surveys. The ROAs of Pacific saury collected from 2003 to 2014 were measured to quantify their geographical variation during the pre-fishing season and temporal changes during the fishing season. Pacific saury with larger ROAs were distributed in the western area during the pre-fishing season and immigrated to the fishing grounds early during the fishing season. Differences in the relative proportions of each ROA size class between the pre-fishing and fishing seasons suggest that Japanese fishing fleets non-selectively caught fish immigrating from a broad area. Dates of immigration to the fishing ground were correlated with the longitude at which Pacific saury were distributed during the pre-fishing season ($r^2$ = 0.48). Furthermore, westward migration velocities estimated for this period (range: 0.087–0.410° longitude/d) were highly correlated with the longitude of their distribution during the pre-fishing season ($r^2$ = 0.80). This result suggests that the mean immigration date of age-1 Pacific saury found in each area during the pre-fishing season could be predicted based on their estimated westward velocities. In conclusion, our Pacific saury migration results provide important information to improve the management and sustainability of this important fishery stock.

## 1. Introduction

Pacific saury (*Cololabis saira*) are small pelagic fish distributed in the North Pacific Ocean (NPO) (Hubbs and Wisner, 1980), with a lifespan of 2 years (Suyama et al., 2006). Pacific saury are important commercial fish in Japan, Taiwan, Korea, Russia, and China. The fishing grounds for fishing fleets for these countries are mainly located in the western area of 165 °E (Huang et al., 2007; Tseng et al., 2013, 2014). Although the standing stock of Pacific saury has declined (TNFRI, 2017), total fisheries catches have recently increased; thus, international stock management is required to sustain this fishery resource. Because Pacific saury are widely distributed in the NPO, stock management is implemented through a regional fisheries management organization, the North Pacific Fisheries Commission (www.npfc.int), which aims to ensure long-term conservation and sustainable use of this fishery resource.

Pacific saury undergo long-distance migrations during their life history (Ito et al., 2004), and use the Kuroshio current, Kuroshio Extension, and Kuroshio-Oyashio transition areas as spawning grounds (Watanabe et al., 1997) (Fig. 1). The spawning season begins in September and continues until the following June. Previous studies have suggested that the primary spawning area of this species is in the Kuroshio region during winter (Watanabe and Lo, 1989). Subsequently, the larvae and juveniles are transported to the Kuroshio Extension area

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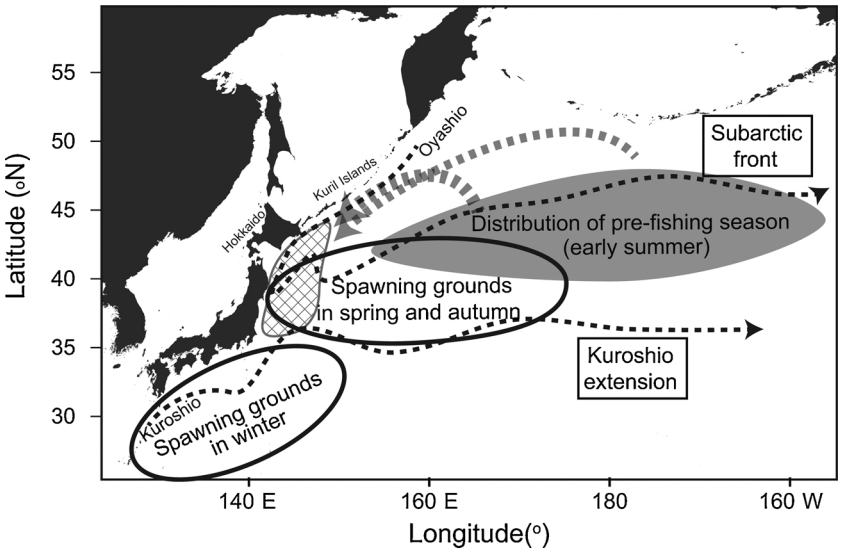


**Fig. 1.** Schematic migration map of age-1 Pacific saury (*Cololabis saira*) and the oceanographic structure of the North Pacific Ocean. Grey, cross-hatching, and oval areas represent distributions during the pre-fishing season (June and July), Japanese fishing grounds, and spawning grounds of Pacific saury, respectively. Thin black dashed arrows represent the Kuroshio and Oyashio currents. Bold grey lines show the estimated main migration routes of Pacific saury from the pre-fishing to fishing seasons based on Huang et al. (2007) and Suyama et al. (2012b).

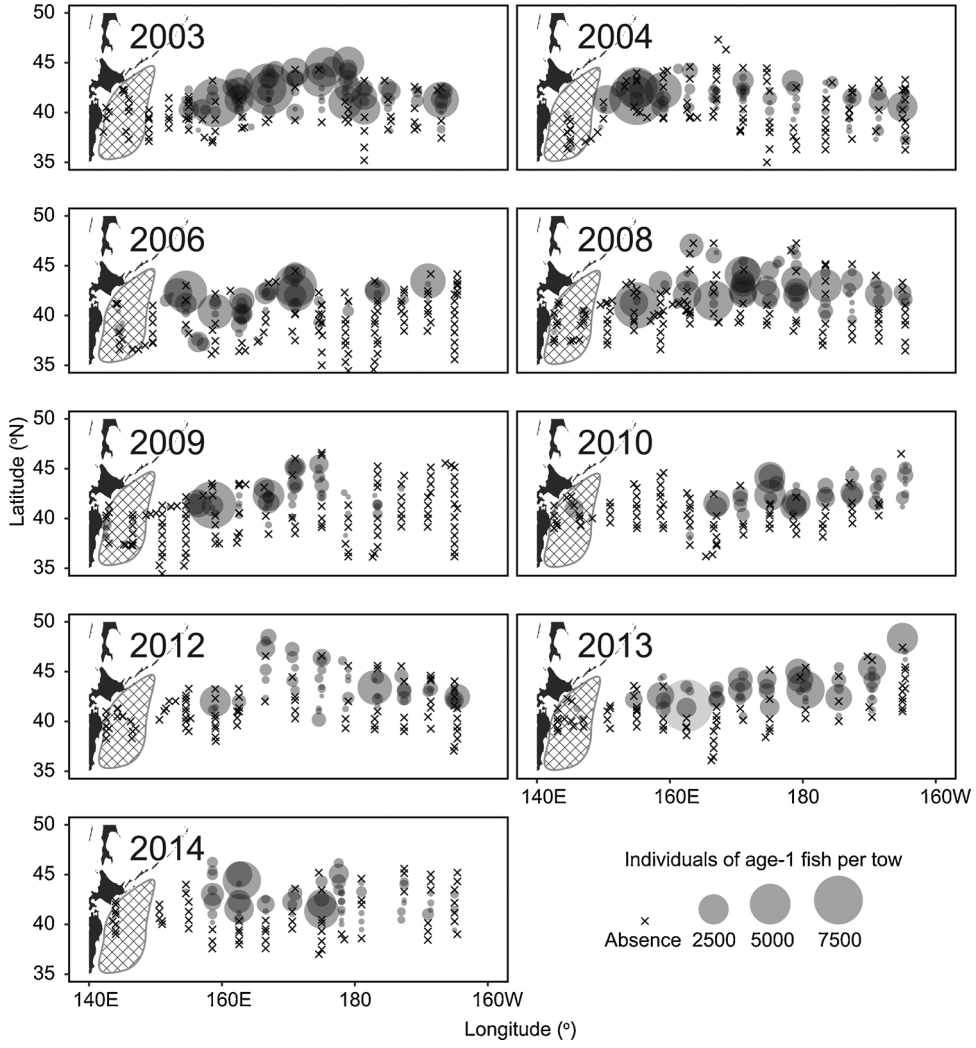


**Fig. 2.** Distribution of age-1 Pacific saury according to a stock assessment survey during the pre-fishing season (June and July), modified from TNFRI (2017). Cross-hatching represents the Japanese fishing grounds of Pacific saury.