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Proposal of alternative spatial structure for skipjack stock assessment in the WCPO

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Summary
In this document, alternative spatial structure for the skipjack stock assessment in the WCPO were proposed based on previous research such as tagging or larvae surveys. We also review briefly with respect of previous skipjack research as well. It will be necessarily to verify its appropriateness for improving stock assessment accuracy such as biomass estimates or movement rates in the WCPO.

Introduction

Spatial structure for the skipjack stock assessment has been changed in last three assessments. The assessment model area in 2005 contains six spatial regions (Fig.1 (a)) as used in CPUE standardization study and enlarged to include the domestic fisheries of the Philippines and eastern Indonesia. The assessment model area in 2011 comprises three regions (Fig.1 (b)), with a single region north of 20°N, and two equatorial regions 20°S to 20°N, with the western equatorial region from 120°E to 170°E, and eastern equatorial from 170°E to 150°W. The assessment model area in 2014 comprises five regions (Fig.1 (b)), with a single region north of 20 °N (Region 1), and four equatorial regions between 20°S to 20°N with consideration for recent tagging project in this region. One issue of the model results is that skipjack movement among areas especially from tropical to norther area were not occurred in the model. This is unrealistic results when considering skipjack movement in the WCPO and it needs to be reeamined. In this document, we briefly review previous research regarding skipjack distribution, migration, larvae distribution based on ship surveys and propose alternative spatial structure for skipjack stock assessment.

Skipjack distribution and migration

Skipjack distribution in the Pacific Ocean is wider in western side relative to eastern side along with their thermal habitat. Tropical area is believed to be main spawning areas and larger size skipjack likely to be distributed, while smaller skipjack (approximately age 1 and around 40cm) shows seasonal migration to near Japanese water where is margin of skipjack distribution. Fujino (1972) first represented a schematic map of skipjack distribution and migration and there are two main route near Japanese water. One is along Kuroshio in the East China Sea and another is along Izu-Ogasawara Islands (Fig.2).

To describe skipjack movement or migration in qualitative and quantitative manner, fisheries data and tagging data has been used. Recently, electronic tagging data has been employed to understand not only their horizontal movement but vertical behaviour more in detail (*e.g.* Schaefer and Fuller, 2007). For example, skipjack released in the tropical area exhibits east-west movement and not many skipjack were caught near Japanese waters (*e.g.* Fonteneau and Hallier, 2015) . On the other hand, skipjack release in the subtropical area likely migrate to around Japan (*e.g.* Tashiro and Uchida,1989; Aoki et al., 2016; Fig.3).

Historical skipjack larvae distribution

Skipjack spawning area are estimated by larvae distributions from ship survey (Ueyanagi, 1969) and matured fish (Naganuma, 1979), and those area are believed to be formed between 35°N and 24°S with SST is more than °C. Kayama (2006) concluded that the skipjack migrated near the Japanese water are from the North Equatorial Current in March - May using by otolis daily increment. Although spawning areas are estimated from larvae and matured adult distributions, there still remains unknown regarding spawning season or habitat.

Clarifying the seasonality of skipjack tuna larvae distribution would be very important to understand spawning habitat and recruitment process of these species in the WCPO (Kiyofuji et al., 2015). Fig.4 shows quarterly and spatial distribution of tropical tuna larvae from Nishikawa et al (1985). Significant occurrences of skipjack larvae (blue) were identified in quarter 2 (Apr.-Jun.) especially in western area (0°N-20°N, 120°E-170°E) and quarter 4 (Oct.-Dec.) between 20°S and 20°N, mainly around PNG and Solomon Islands. Overall skipjack larvae distribution tends to be distributed in the western Pacific Ocean. Taking growth of skipjack into account (Tanabe *et al*., 2003), larvae in quarter 2 in subtropical area would contribute to recruit to near Japanese water.

Based on brief review on skipjack distribution and movement described above, we propose alternative stock assessment areas shown in Fig.5. It is worth noting that subtropical area (area 6 in Fig.5) is an important with taking into account skipjack movement. Fig.6 shows number of recaptured skipjack with origin of released area. Pie charts in each area represent relative number of recaptured skipjack and colors in each pie chart are the origin of skipjack. Increased number of recapture from the subtropical area (area6) was identified in all areas.

Followings are summary of this document and list of research items should be addressed to improve stock assessment results in near future.

- Brief review on area definitions of skipjack stock assessment in the WCPO
- Brief review on skipjack spawning area and movement and in the WCPO
- Propose alternative area definitions for skipjack stock assessment in the WCPO
- Conduct collaborative tagging research to verify and improve area definition
- Investigate skipjack tuna spawning habitat in the WCPO

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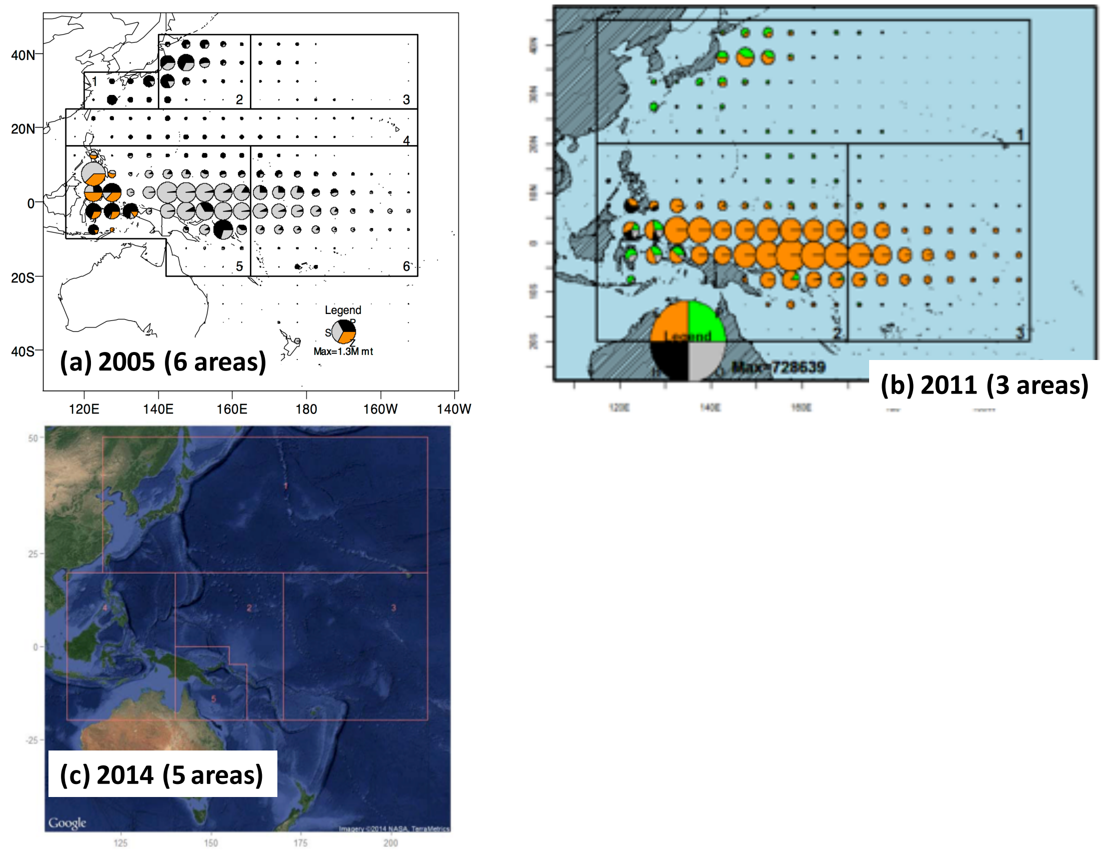

Figure 1. Spatial structures for skipjack stock assessment in the WCPO. (a) 2005 (6 areas), (b) 2011 (3 areas) and (c) 2014 (5 areas).

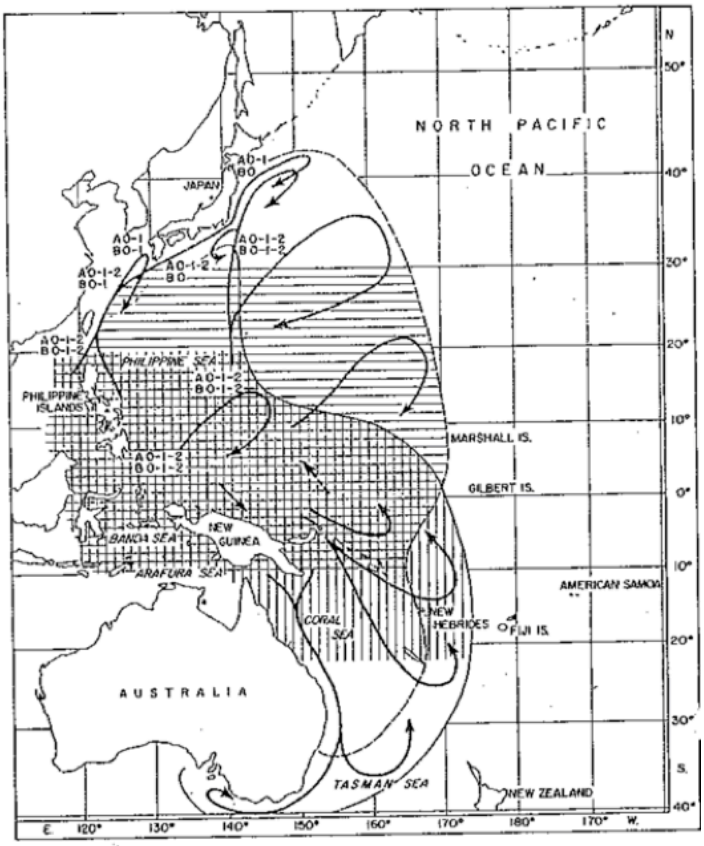

Figure 2. Distribution and migration routes of the western Pacific skipjack tuna subpopulation proposed by Fujino (1972). Eastern limits of distribution during northern winter and summer are indicated by a solid line and a broken line, respectively. Intensive spawning grounds are shown by horizontal and vertical hatching and migration routes are indicated by curved lines with arrows.

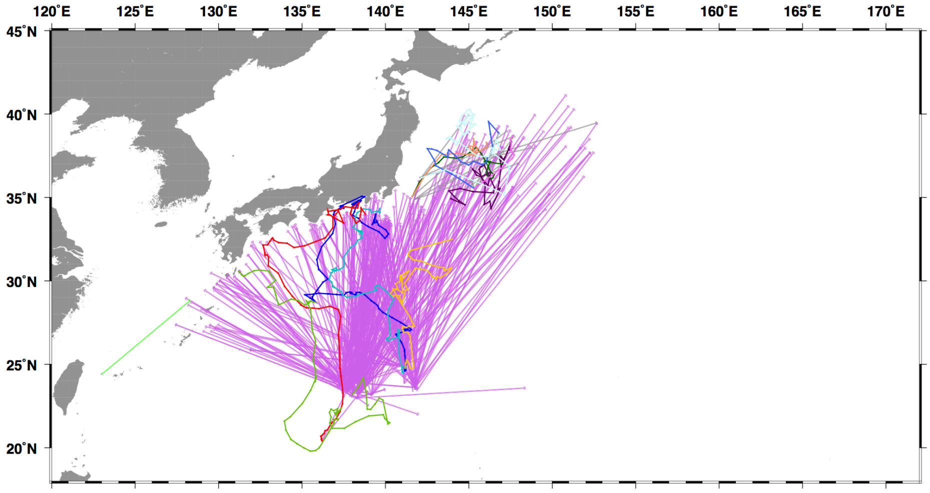

Figure 3. Trajectory of tagged skipjack released in the subtropical area.

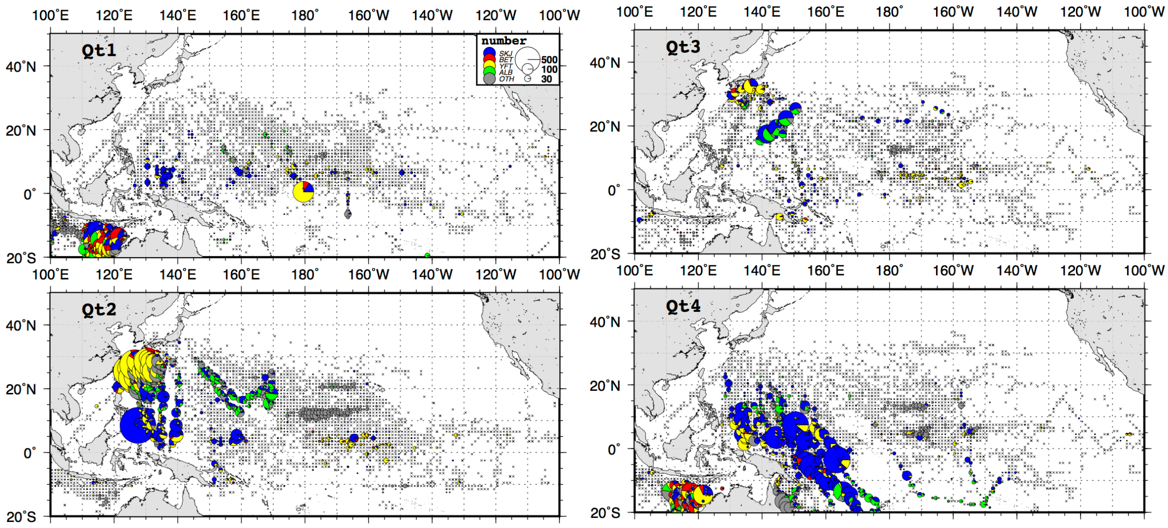

Figure 4. Historical larvae distribution in the Pacific Ocean (modified from Nishikawa *et al*., 1985). Blue: Skipjack, Red: Bigeye, Yellow: Yellowfin, Green: Albacore and Gray: Others.

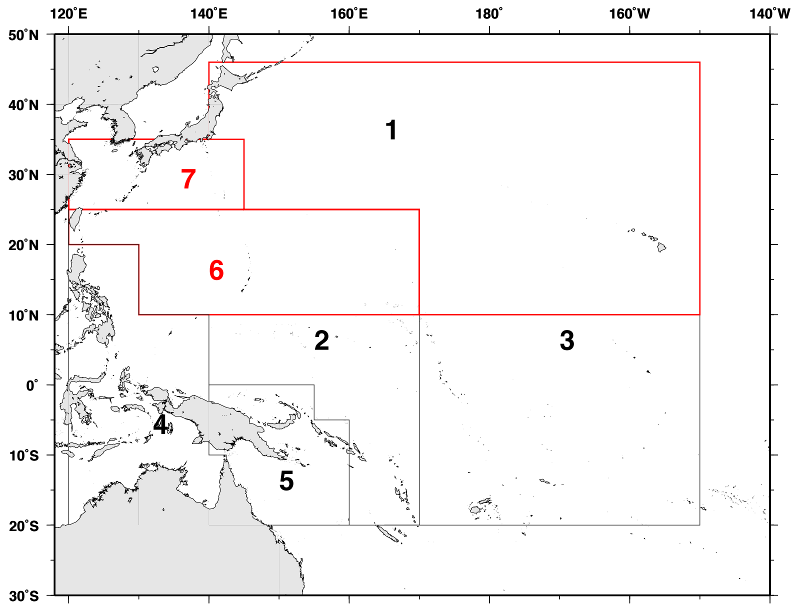

Figure 5. Proposed spatial structure for the skipjack stock assessment in the WCPO.

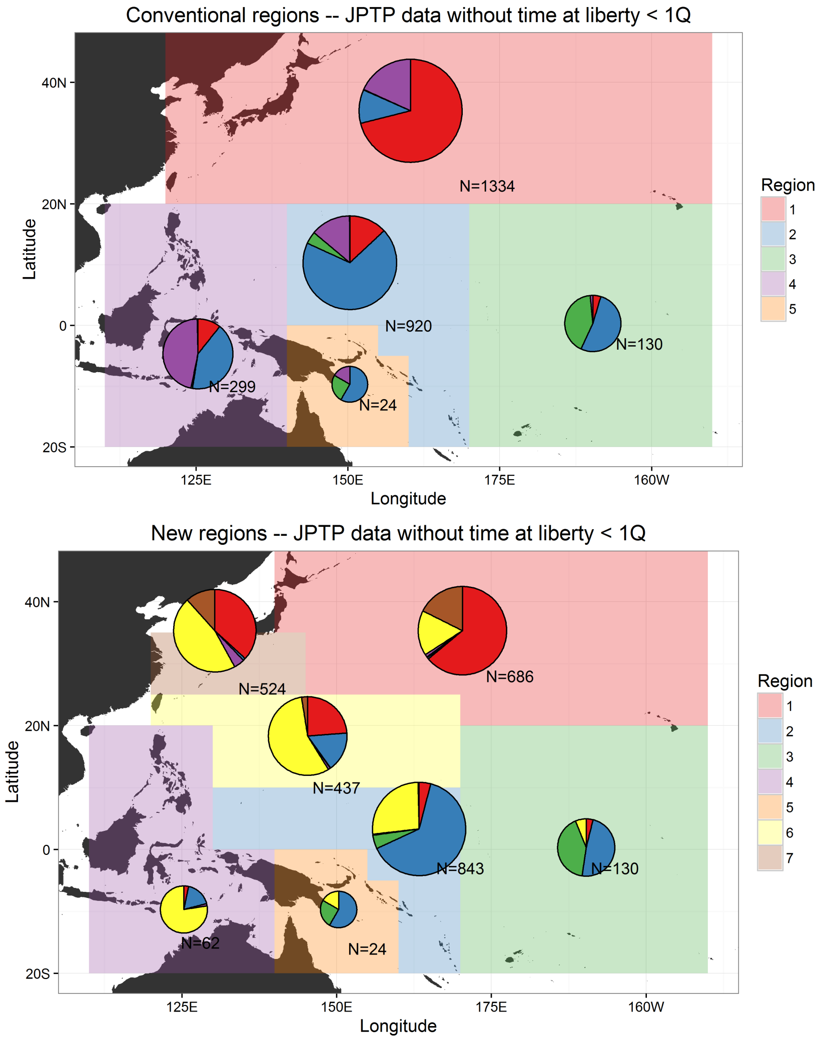

Figure 6. Recaptured skipjack aggregated by release area both area definitions in 2014 (upper) and in alternative area of 2016 (lower). Note that colors in pie chart is origin of release.