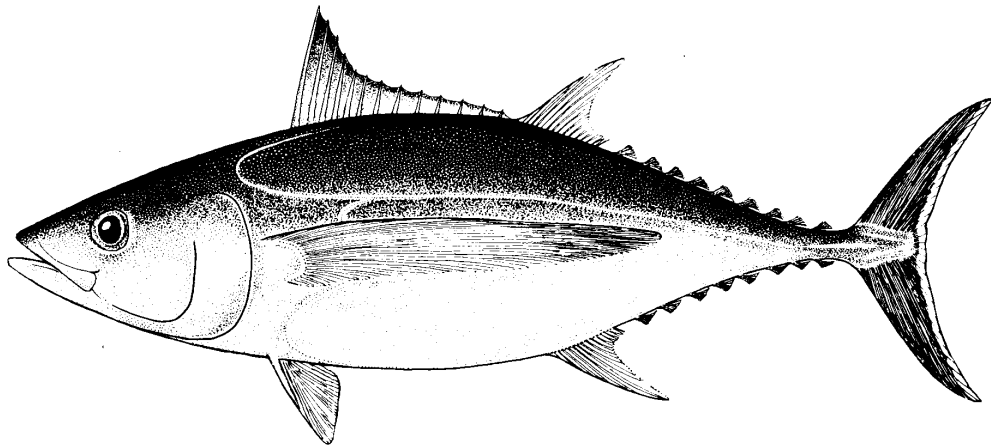




SCTB15 Working Paper

ALB-6

**Preliminary results of SEPODYM application to albacore
in the Pacific Ocean**



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Introduction

Tagging and fisheries data suggest that albacore's distribution in the Pacific Ocean shows separate concentrations north and south of the 5°N-5°S equatorial band, with a large extension to temperate latitude (45°N, 40°S) roughly delineated by the 15°C sea surface temperature (SST) isotherm (Figure 1). Comparatively to a tropical tuna like skipjack, albacore is characterised by a slower growth, lower natural mortality and long life spans (15-20 years), first maturity around 4-5 years of age (~ 90 cm), apparent seasonal spawning (with a peak in summer), and low production to biomass (P:B) ratio. Also, While the main skipjack spawning grounds appear associated to the warm pool, those of albacore are roughly extending through the tropical Pacific on each sides of the equator (Figure 1), and consequently under the influence of the productivity of the equatorial cold tongue.

However, as other tuna species, albacore have high fecundity, spawn in warm waters over wide areas and feed upon a similar large spectrum of prey species. Main concentrations of larvae occur in the sub-equatorial regions, between 5 and 25° of latitude with highest densities west of 160°W and west of 130°W respectively in the northern and southern hemisphere. That is roughly associated with water temperature above 24°C in surface. Though there is no observation of spawning in the equatorial waters, presence of juveniles (under 200 mm) between 0° and 10°S has been noted by Yoshida (1968, in Foreman 1980). The recruitment of juveniles occurs in the surface fisheries (troll and pole-and-line) in both north and south Pacific stocks at 2 years of age (~ 40 cm). These surface fisheries occur in subtropical waters (e.g., the Sub-Tropical Convergence Zone in the south) and are highly seasonal (during summer), while longline fisheries operate throughout the year in tropical and subtropical waters.

This paper presents the preliminary results of an application of the spatial environmental population dynamics model SEPODYM (Lehodey 2001a, 2001b, 2002) to the albacore in the Pacific Ocean.

Parameterization

Albacore biological parameters

The albacore population dynamics are described on a quarterly basis with a maximum number of 60 quarters (15 years), the last age class being a plus group where oldest fish are accumulated. Growth and mortality-at-age estimates are obtained from MULTIFAN-CL analyses (Hampton 2002). Recruitment occurs after 2 years and reproduction (mature fish) after 4 years. The movement is modelled as for skipjack (Lehodey 2002) but with a slightly higher diffusion. The total level of recruitment is adjusted, so that the stock biomass estimates for the southern stock are roughly equal to those obtained independently with MULTIFAN-CL (Fig. 2).

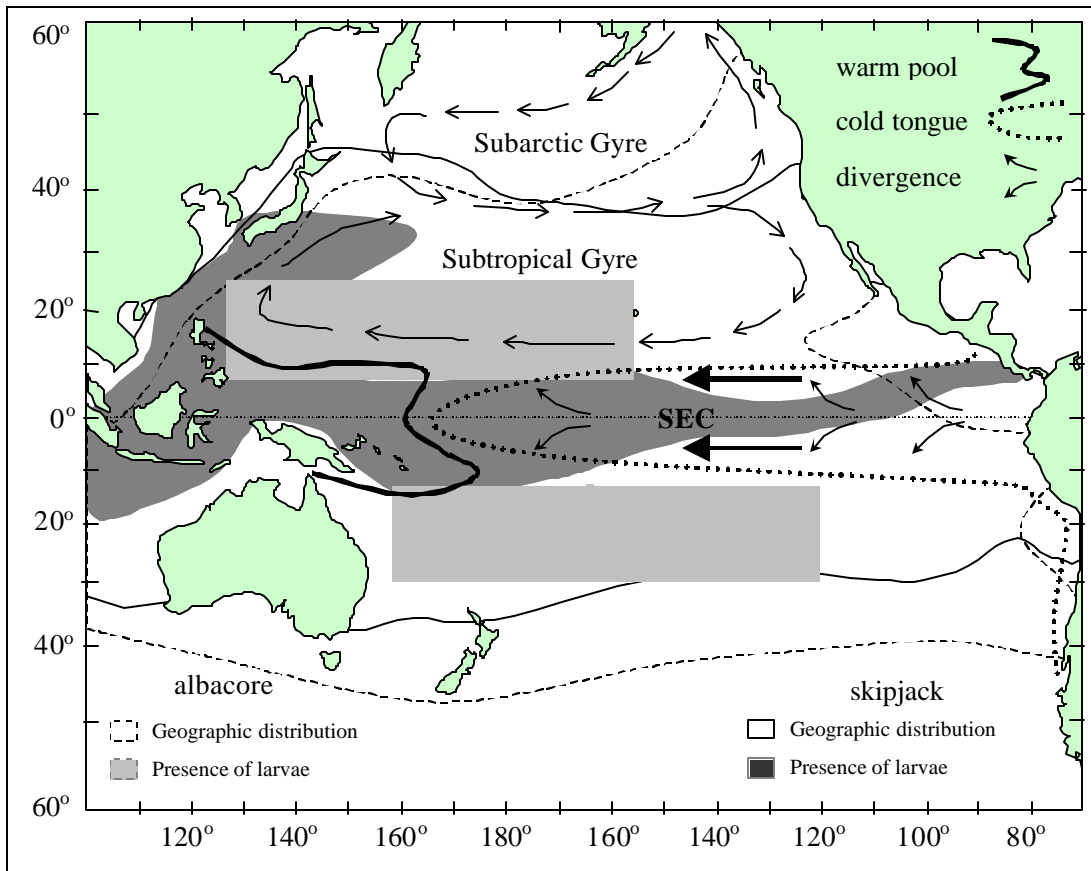


Figure 1. Schematic map of the Pacific Ocean comparing the main spatial characteristics of the albacore and skipjack populations (SEC= South Equatorial Current)

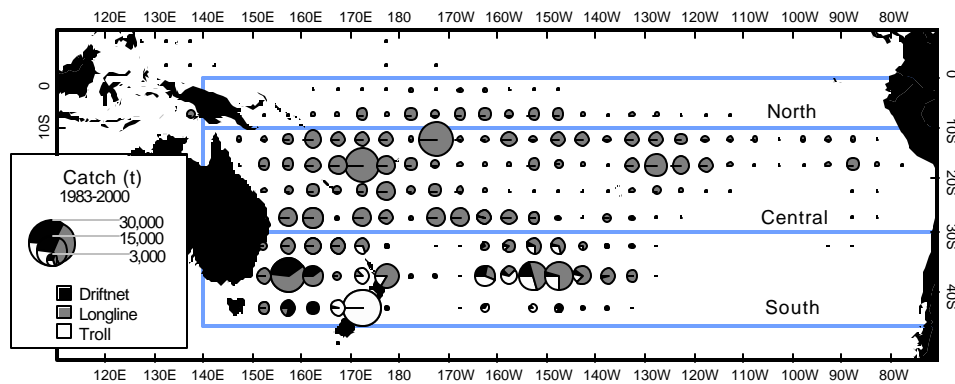


Figure 2. Albacore catch distribution (1983–2000) by fleet and spatial stratification used in the MULTIFAN-CL application (from Hampton 2002).

Habitat indices

The spawning habitat index (H_s) has been defined in the skipjack application (Lehodey 2002). Values of coefficient have been changed to allow spawning at lower temperature than for skipjack, that is above 26°C instead of 28°C.

The parameterization of the adult habitat index (H_a) differs from the skipjack application (Lehodey 2002) by the temperature function. Based on the literature related to the relationship between albacore tuna and temperature, juveniles and adults would be distributed between 15 and 25 °C. Therefore, a normal distribution with an optimum of 20 °C and a standard error of 4 °C $N(20, 4)$ would be appropriate in a first approximation to describe the habitat temperature index (Fig. 2). As the model integrates the vertical dimension, this normal function has been replaced by a function following the slope of the normal function but with a constant maximum after the optimal value. This is to take into account the possibility that fish can always swim deeper to find the optimal temperature when temperature of the surface layer is above this value. In addition, to better reflect the vertical temperature habitat of this species, the same function is applied with temperature distribution at three different depths: surface, 100 and 200 m and the index is the average on these three levels.

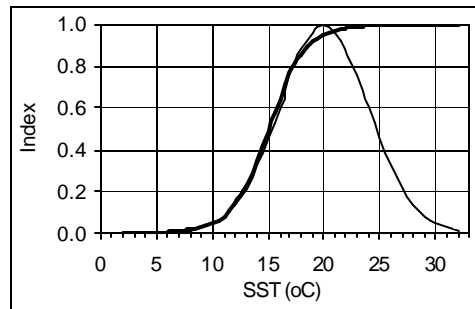


Figure 2. Temperature function used in the definition of the albacore adult habitat index (thick curve). The thin curve represent the corresponding normal distribution that would be used in a true 3D environment.

Preliminary simulations have shown an unrealistic tendency of the adult population to be concentrated in the equatorial eastern Pacific, where maximum temperature index and high forage production produce the highest habitat values. This bias is likely due to the oxygen constraint in the habitat definition. The minimum oxygen requirement is about 2 ml/l (Foreman 1980), and the distribution of this environmental parameter is likely determinant in the eastern Pacific where minimum concentration is found (Fig. 3).

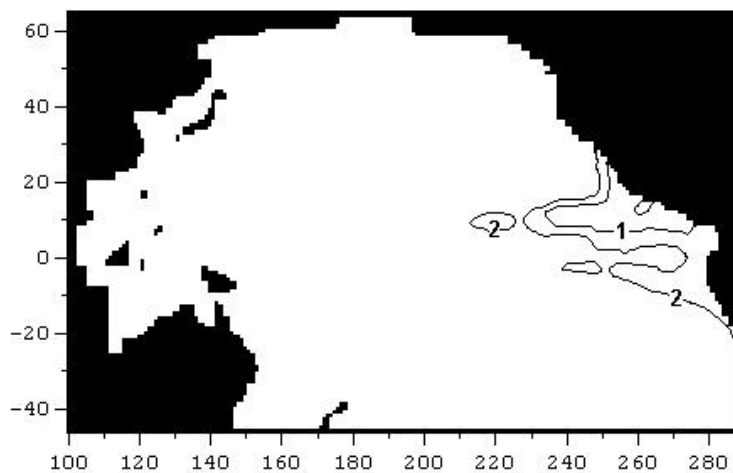


Figure 3. Dissolved oxygen concentration below or equal to 2 ml/l at depth = 100 m in the Pacific for first quarter (from Levitus' climatology).

Therefore, in addition to temperature and forage, the adult habitat index is also proportional to an oxygen index (1). The quarterly climatology of dissolved oxygen concentration is used in absence of other more detailed dataset.

$$I_{O_2} = 1 / (1 + e^{(-0.06(z - 100))}) \quad (1)$$

with z the depth of the 2 ml/l dissolved oxygen concentration.

Results

Habitat

Compared to skipjack, change in the temperature function of the albacore adult habitat produces a very different overall distribution. Because of an increased tolerance to lower temperature, the habitat extends to the sub-tropical and temperate regions where there are high level of forage biomass (Fig. 4). The oxygen constraint limits the habitat in the eastern Pacific and there is a natural separation of favourable habitat between north and south hemispheres, with central regions of less favourable habitat due to lower biomass of forage. However, the seasonal signal produces north-south displacements of the subtropical fronts of high forage biomass that attenuate this average distribution. Although these large bands of favourable habitat could provide natural path of migration for long-living species like albacore tuna, its population dynamic and the seasonal variability of production in the sub-tropical and temperate regions do not necessarily allow following this simple scheme.

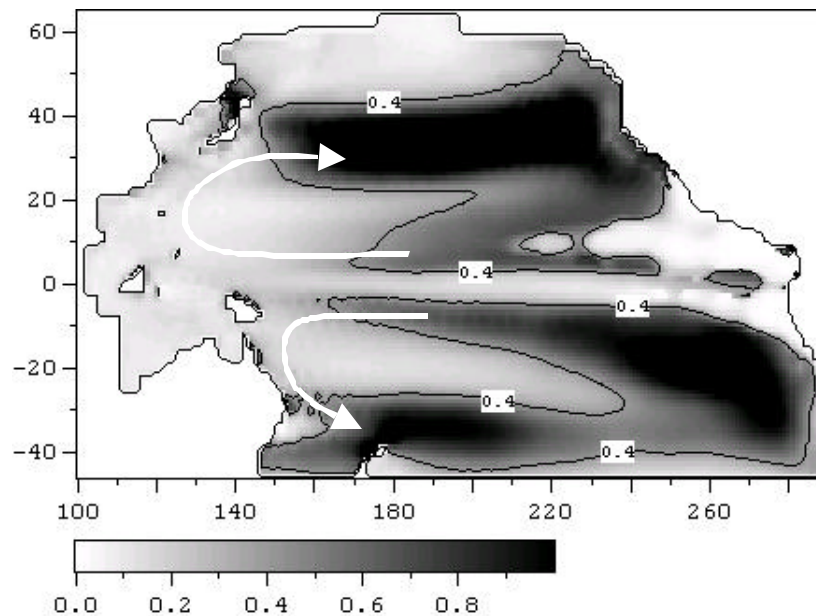


Figure 4. Mean spatial distribution of the adult habitat defined for albacore tuna. White arrows indicate the general circulation of the western boundaries of subtropical gyres.

Larvae and juveniles

The predicted spawning grounds are mainly concentrated on both sides of the equator. As larvae are drifting passively with currents during their first quarter of life, the resulting distribution for the first age class (0 to 3 months) shows a clear separation between north and south regions of concentration. However, results are sensitive to relatively small changes in the habitat parameters and initial conditions (Fig. 5), and the parameterization requires further detailed analyses.

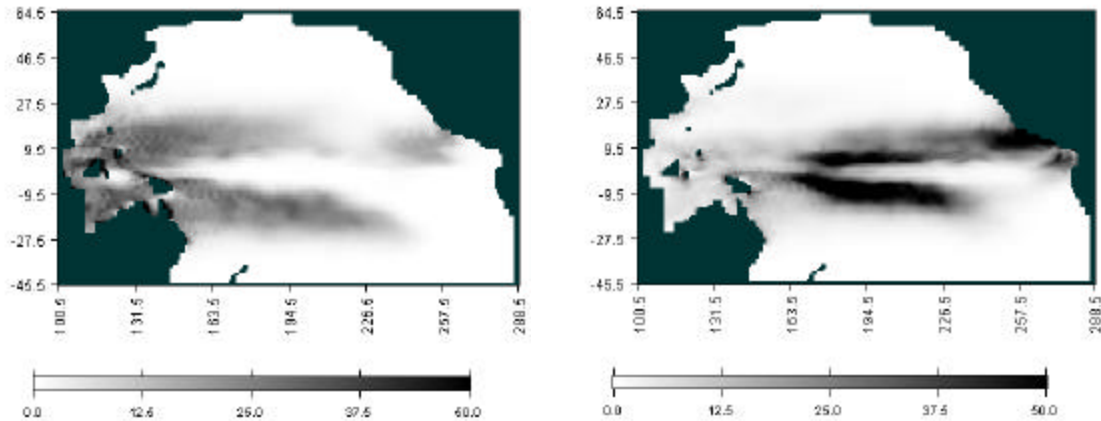


Fig. 5. Two examples of predicted distribution of juvenile albacore (0-3 months) with two different parameterization of the spawning habitat index.

Adults

The overall distribution of adult albacore is sensitive to small changes in both spawning and habitat indices. In particular, some combinations of oxygen constraint in adult habitat with temperature constraint in spawning habitat produce unstable conditions to maintain the population.

These first simulation were based on a spawning habitat index only constrained by temperature ($\alpha = 0$). As expected in this case, the recruitment and biomass series presented very limited fluctuations (Fig. 5). The corresponding adult biomass appears reasonably well distributed (Fig. 6) and the average recruitment and biomass by region for the southern stock are in agreement with MULTIFAN-CL estimates (Fig. 7).

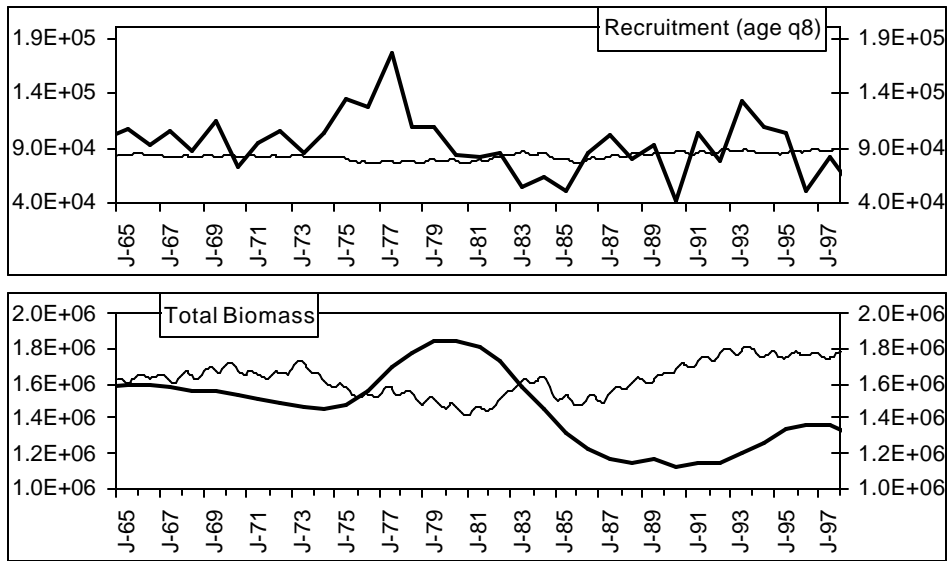


Figure 5. Total recruitment and biomass of south Pacific albacore predicted by MULTIFAN-CL () and SEPODYM (thin curve) with $\alpha = 0$.

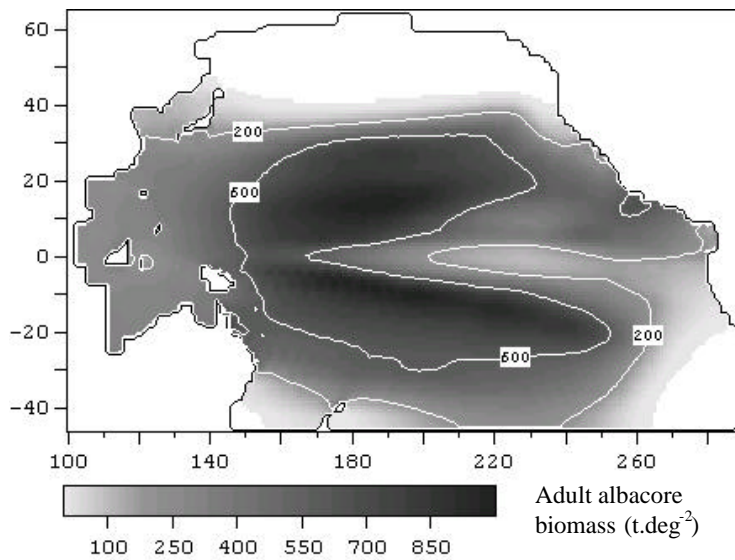


Figure 6. Average distribution of the predicted biomass of adult albacore

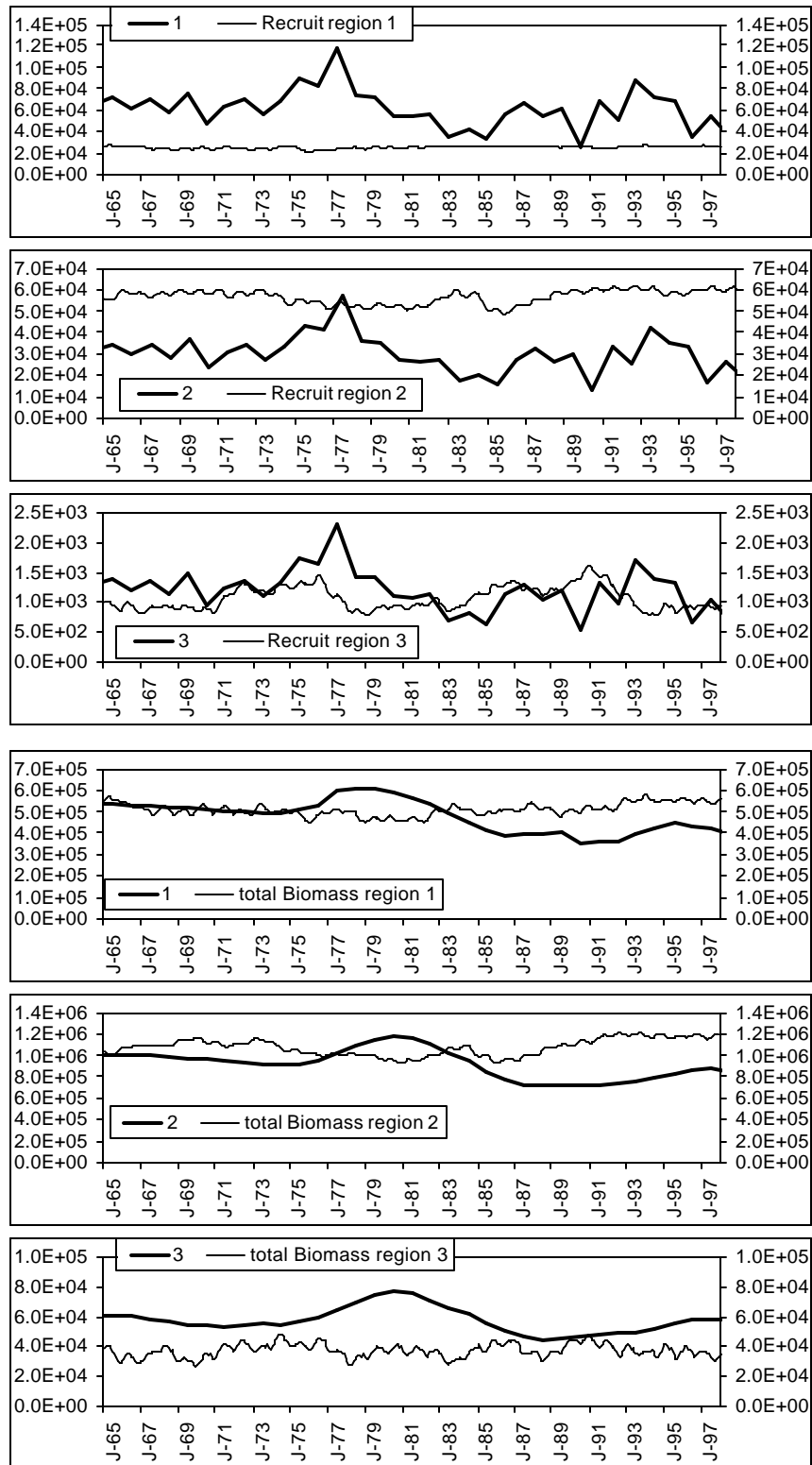


Figure 7. Recruitment and biomass of south Pacific albacore predicted by MULTIFAN-CL (thick curve) and SEPODYM (thin curve) with $\alpha = 0$ and by region as shown on Fig. 2 (region 1= north; region 2 = central; region 3 = south).

Conclusion

This preliminary study suggests that the modelling approach developed for skipjack can be adapted for long living species like albacore. This requires an appropriate parameterization to consider the different biological characteristics and the integration of the vertical habitat. Parallel modelling development for these two species should be very helpful for understanding mechanisms of recruitment and movement dynamics as they have different and sometimes opposite characteristics. It will be also particularly interesting to run the model with both species together to study potential interactions or competitions.

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