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Effective longline effort within the yellowfin habitat and standardized CPUE

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Introduction

The SPC Oceanic Fisheries Programme (OFP) has developed a length-based age-structured model for yellowfin tuna in the western and central Pacific Ocean (WCPO, Hampton & Fournier 1999). Longline catch and effort data are a critical input to the assessment model as both yellowfin and bigeye are actively targeted by most longline fleets in the Pacific; however trends in nominal longline effort may differ from trends in actual effort in the yellowfin or bigeye habitat because of gear modifications over the fishery (>35 yr) time-series.

At SCTB11, the OFP reported (Hampton et al. 1998) on an application of the Hinton and Nakano (1996) method to bigeye tuna in order to standardize longline effort and CPUE using habitat preferences and constraints, in combination with environmental data. This paper applies the similar method to standardize longline effort and CPUE for yellowfin tuna.

Spatio-temporal trends in nominal CPUE

Pacific yellowfin tuna are thought to be composed of two stocks, separated at 150°W. This analysis only considers the western and central Pacific (WCPO) stock, which is to the west of 150°W. Nominal CPUE in the Japanese longline fishery remained stable in the 1960s and 1970, but declined since the mid-980s (Figure 1). A spatial representation for each decade indicates high nominal CPUE in tropical waters (20°S–20°N) in the western Pacific (west of 180°). Within the western Pacific, EEZs with high yellowfin catch rates include Papua New Guinea, Federated States of Micronesia, Solomon Islands and the Marshall Islands (Figure 2). Since the 1980s there has been a general decline in CPUE and a decline in areas fished partly attributable to declining EEZ access (e.g. Hawaii, PNG, Guam, CNMI).

Model inputs

Essential elements in the effort standardization model are the specification of the depth distribution of the longline gear inferred from hooks-between-floats (HBF) information and the species depth distribution based on habitat preferences from acoustical tracking and oceanographic information.

- **Longline fishery data** - Two analyses were conducted using different spatial scales of fishery data.
    1. A fine-scale (1°) analysis was conducted using Japanese longline data to provide information on spatial trends. The data were aggregated by quarter. Data encompass the period from 1966 to 1996 and most of the time-series has information on gear configuration (i.e. HBF). Strata with missing HBF information (1967–71) were substituted according to the method described in a similar paper on bigeye tuna (Bigelow et al. 1999).
    2. A coarser scale (5°) analysis was conducted with the three distant-water fleets (Japan, Korea and Taiwan) to provide trends of effective effort in the bigeye habitat. In the future, these estimates may be extrapolated to the remaining longline fleets in order to generate total effective effort for inclusion in stock assessment models.

- **Depth distribution of longline gear** – Our preliminary standardization results (Hampton et al. 1998) used HBF information as a proxy for the targeted fishing depth of the longline gear. Depth zones of 100 m in the range of 0–600 m were defined. The present analysis uses finer-scale depth strata (40 m instead of 100 m) to specify fishing depth and bigeye depth distribution. Thus there are 15 vertical layers considered in the model. Assumed depth distribution profiles for the distant-water fleets are illustrated in Table 1.

Table 1. Proportion of hooks by depth zones for different longline gear types. Gear type is defined according to the number of hooks between floats (HBF).

Depth strata	Gear type = Regular (3-6 HBF)	Gear type = Intermediate (7-9 HBF)	Gear type = Deep1 (10-11 HBF)	Gear type = Deep2 (12-15 HBF)	Gear type = Deep3 (16-20 HBF)	Gear type = Deep4 (>20 HBF)
0-40 m	0.10	0.05	0.05	0.05	0.05	0.05
40-80 m	0.20	0.15	0.10	0.05	0.05	0.05
80-120 m	0.20	0.20	0.15	0.10	0.10	0.05
120-160 m	0.30	0.25	0.20	0.20	0.15	0.10
160-200 m	0.20	0.25	0.30	0.25	0.20	0.20
200-240 m		0.10	0.20	0.20	0.25	0.20
240-280 m				0.15	0.15	0.20
280-320 m					0.05	0.10
320-360 m						0.05
360-400 m						

- **Habitat preferences and yellowfin depth distribution** – Hypotheses regarding habitat preferences are different for yellowfin and bigeye. Bigeye are hypothesized to be vertically distributed in the water by absolute temperature perferences. In contrast, yellowfin are vertically distributed by temperature differences in relation to the mixed layer, similar to blue and striped marlin. Daytime yellowfin habitat preferences were constructed from time-at-temperature data from an acoustical tracking study (Brill et al. 1998), in which six adult yellowfin were tracked off the Kona coast of the island of Hawaii. Time-at-temperature data indicated that yellowfin spent 57% of their time in the surface layer (defined as the depth of the water column within 1°C of sea surface temperature, SST). At cooler temperatures in relation to the surface layer, yellowfin spent lesser amounts of time. Temperature information was used in relation to oxygen data to distribute yellowfin in the water column. A dissolved oxygen (DO) preference index was constructed such that yellowfin decline sharply at DO < 4.0 ml l^{-1} and that no yellowfin exist when DO < 2.5 ml l^{-1}.

- From 1980 to 1996, an Ocean Global Circulation Model (OGCM, Ji et al. 1995) and climatological dissolved oxygen values (Levitus & Boyer 1994) were used to develop a time-series of yellowfin depth distribution for each 1°-quarter–40 m stratum. Prior to 1980, the OGCM was used to make a quarterly temperature climatology (i.e. all 1st quarter temperature values from 1980 to 1997 were averaged to represent 1st quarter values for 1966 to 1979). Yellowfin depth distribution was a product of the yellowfin temperature and dissolved oxygen values. The temperature*dissolved oxygen data were then normalized to describe the relative depth distribution of yellowfin in each 1°-quarter stratum.

  An east to west section at 1° resolution along 10°N of the daytime yellowfin habitat suggests that the yellowfin population in the Pacific is largely confined to the upper 120 m of the water column (Figure 3). Due to the oxygen constraints, the vertical distribution of yellowfin is shallower in the EPO (80 m) than in the WCPO (160 m).

Spatio-temporal trends in standardized CPUE

Standardized CPUE in the Japanese longline fishery (Figures 4–5) display different spatio-temporal patterns than nominal CPUE (Figure 2). Values of the standardized series were scaled to the mean of the nominal series to allow comparison.

The yellowfin stock is divided into seven sub-areas by the Yellowfin Research Group (Figure 4). Yellowfin are mainly exploited in the tropics, where CPUE is highest (sub-areas 3–5, Figure 4). Trends in standardized CPUE are similar to nominal CPUE for all sub-areas except sub-areas 3 and 4, where standardized trends are approximately 20% higher since 1985. The standardization model does not alter trends at higher latitudes (sub-areas 1,2, 6 and 7) as there has been little change in gear configuration. Spatial plots of standardized CPUE indicate little change over the last four decades (Figure 5). Through standardization, the 20% increase in sub-areas 3 and 4 during the 1980s effectively removed the decline that was evident in the nominal CPUE.

In the tropics, effective effort in the yellowfin habitat as a percentage of total effort has decreased from 17% in the 1960s and 1970s to about 6% in the 1990s (Figure 6). The reduction in the percentage of effective effort reflects the change in gear configuration from shallow to deeper deployment in the water column. There is little change in targeting of the yellowfin habitat at higher latitudes.

Temporal changes in effective effort

Temporal changes in effective effort or standardized hooks in the yellowfin habitat were calculated for the three distant-water fleets (Japan, Korea and Taiwan) using 5°–quarterly data (Figure 7).

At higher latitudes, annual effective effort has remained stable. In the tropics, annual effective effort is larger than at higher latitudes, but has decreased since the 1980s. In the 1990s, sub-areas 4 and 5 have the largest amount of effort deployed in the yellowfin habitat, 8 and 6 million hooks, respectively.

Conclusions

1. Nominal CPUE indicate a decline in the 1980s and 1990s; however, standardized CPUE trends appear stable in areas 3, 4 and 5, but have declined in areas 4 and 5 after a peak in 1978.
2. Effective effort in the yellowfin habitat has decline since 1980 in the tropics where most of the yellowfin are exploited.

Future work

Refinements to the yellowfin standardization model are similar to those described for the bigeye model (Bigelow et al. 1999).

- Habitat and gear depth assumptions in the model are based on one published study, yet a more rigorous analysis of the sensitivity to our assumptions should be performed. For example, a Monte-Carlo analysis could be applied by constructing the probability distributions of the three (temperature, oxygen, gear depth) model inputs. This would provide confidence limits around the trends of the standardized CPUE and effective effort.
- Toward this end, time-at-temperature and time-at-oxygen estimates from the published studies as well as from acoustical tracking results of the French Polynesian ECOTAP programme could be used to develop probability distributions of habitat preferences.
- Similarly, longline gear monitoring with time-depth-temperature-recorders has been undertaken in recent years by the NRIFSF, ECOTAP and others. These results could also be summarized so that probability distributions of hook depths for the six gear types could be constructed.
- The yellowfin CPUE trends by sub-area assume each 1° cell has equal weighting. As outlined in Hinton & Nakano (1996), it may be informative to weight each 1° square by longline effort to produce effort-weighted CPUE trends.

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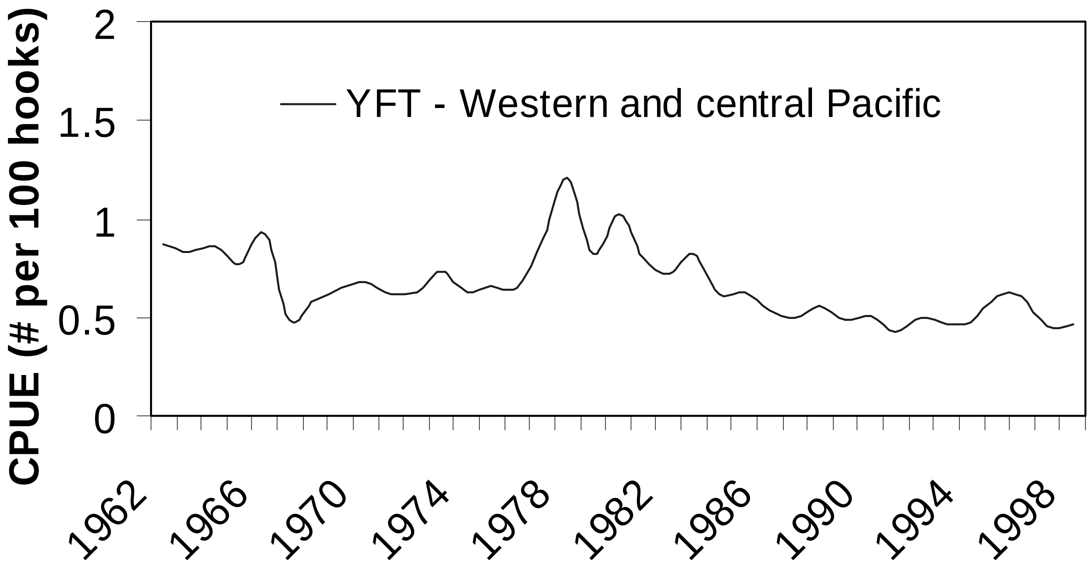

Figure 1. Nominal yellowfin CPUE (ΣCatch/ΣEffort) for the Japanese longline fishery in the western and central Pacific Ocean.

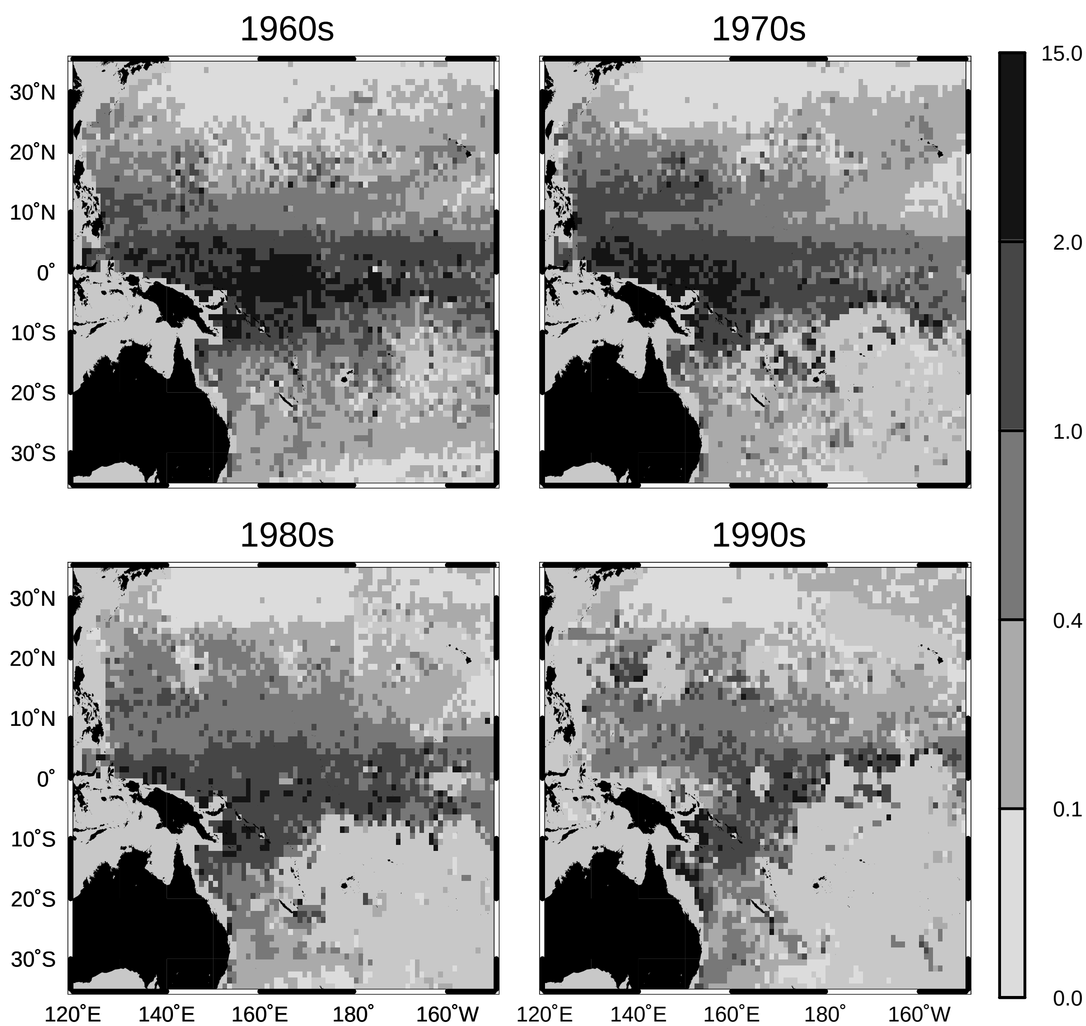

Figure 2. Comparison of nominal yellowfin CPUE in the Japanese longline fishery during the last four decades.

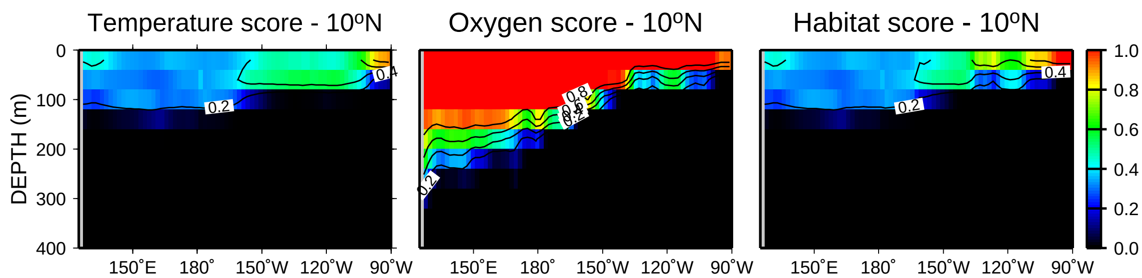

Figure 3. Zonal section at 10°N of yellowfin habitat indices for temperature, oxygen and normalized habitat quality. Indices are represented for 1980.

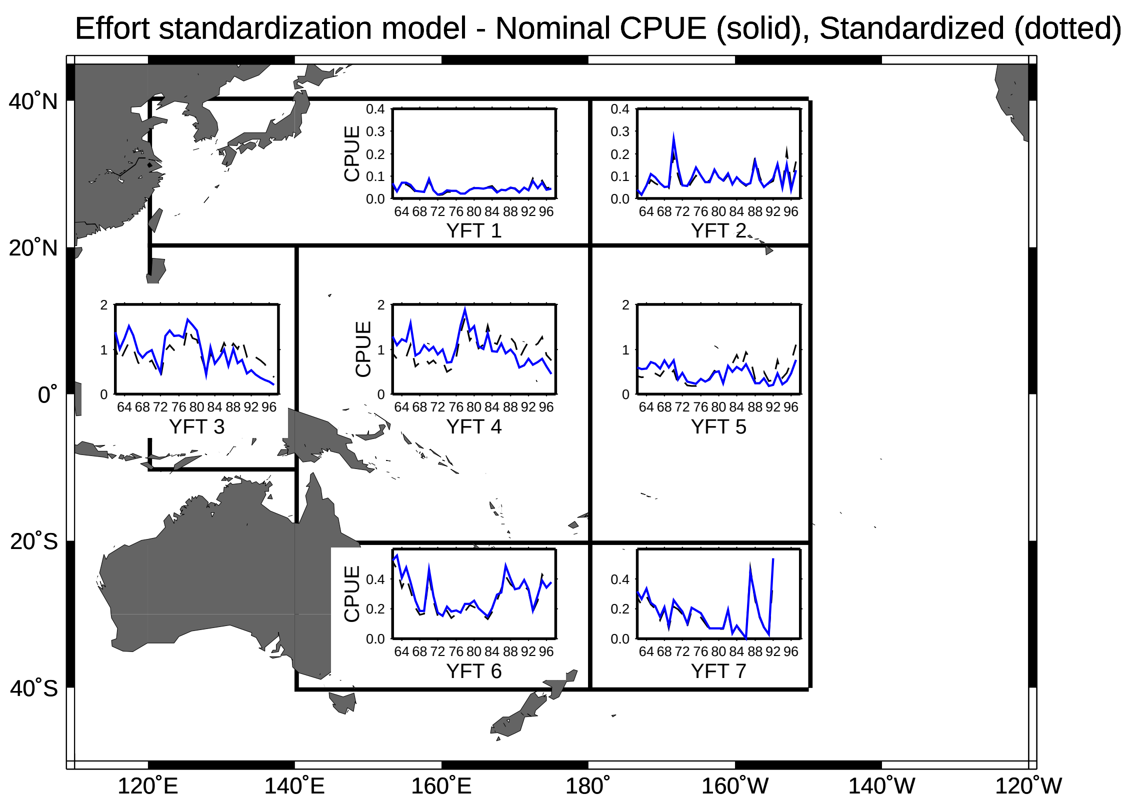

Figure 4. Comparison of nominal (solid) and standardized (dotted line) yellowfin CPUE in the Japanese longline fishery for the western and central Pacific (WCPO).

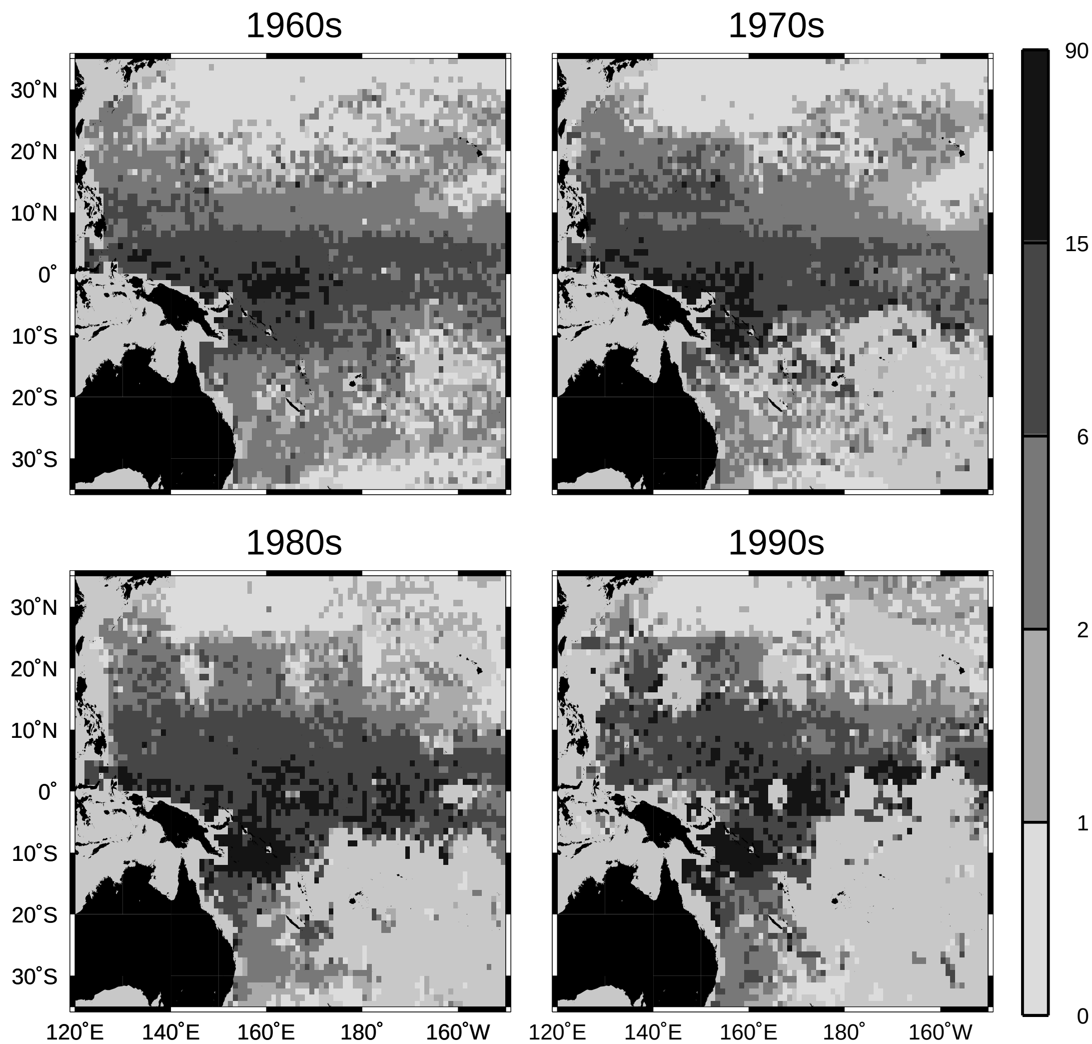

Figure 5. Comparison of standardized yellowfin CPUE in the Japanese longline fishery during the last four decades.

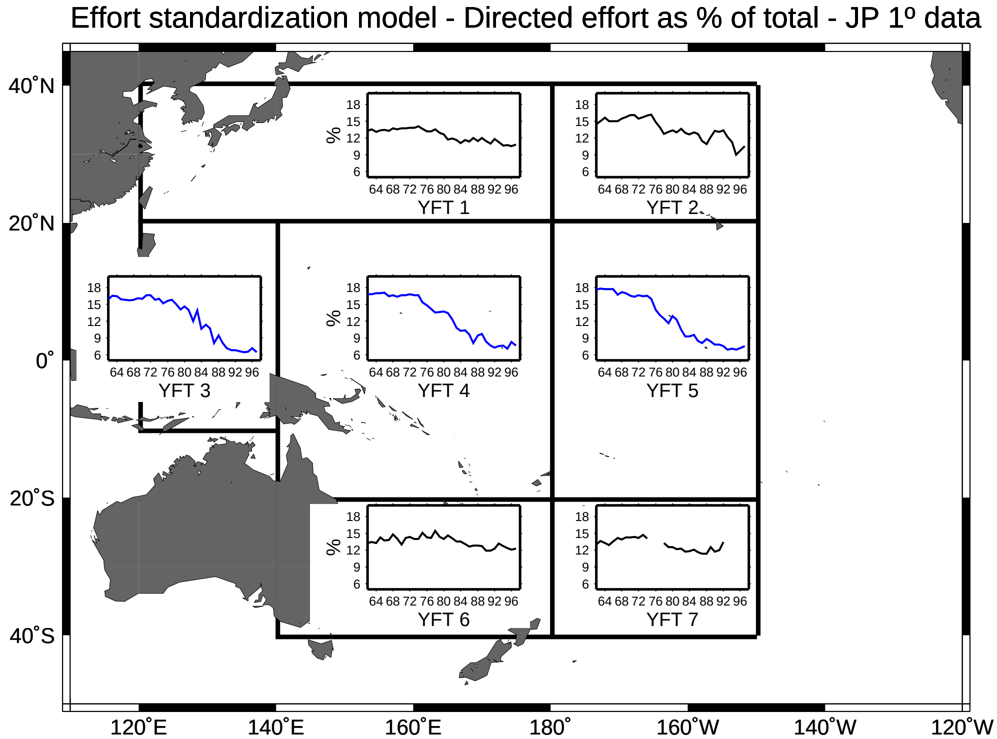

Figure 6. Effective effort in the yellowfin habitat as a percentage of total effort in the western and central Pacific Ocean.

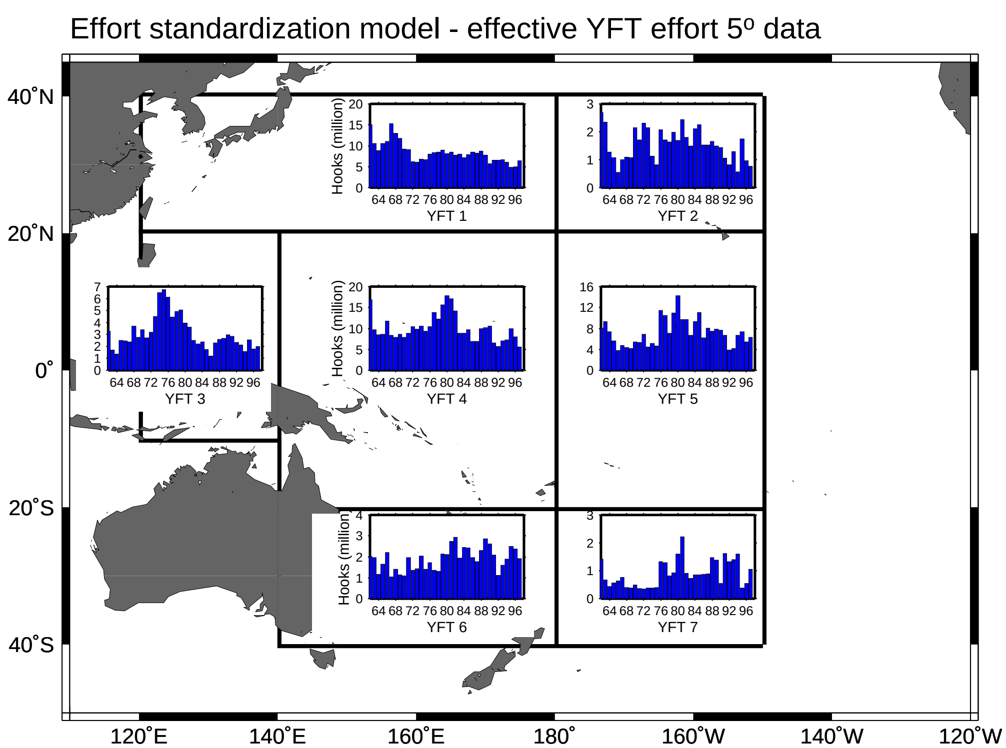

Figure 7. Total effective effort in the yellowfin habitat for the three distant-water fleets in the western and central Pacific Ocean.