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Effective longline effort within the bigeye 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 in the western and central Pacific Ocean (WCPO, Hampton & Fournier 1999) and will soon construct a similar model for Pacific bigeye with the assistance of collaborating agencies (IATTC, NRIFSF). Longline catch and effort data are a critical input to these models 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 standardize longline effort and CPUE using habitat preferences and constraints, in combination with environmental data.

Since SCTB11, additional data have been acquired as model inputs. Model improvements include:

1) incorporation of fine-scale (1°) Japanese longline data
2) additional information on gear configuration from the Japanese fleet
3) increased vertical resolution (40 m) in the model and
4) inter-annual characterization of the bigeye thermal habitat with an Ocean Global Circulation Model (OGCM).

Using these additional model inputs an update of the trends in effective effort and CPUE is presented.

Spatio-temporal trends in nominal CPUE

Though bigeye stock structure is not well understood, the analysis was stratified at 150°W into western and central Pacific Ocean (WCPO) and eastern Pacific Ocean (EPO) stocks. Nominal CPUE in the Japanese longline fishery has remained stable since the early 1960s (Figure 1). Nominal CPUE in the EPO has been about 50% greater than the WCPO, due in large part to yellowfin targeting in the WCPO.

A spatial representation for each decade indicates high nominal CPUE in tropical waters (20°S–20°N) throughout the Pacific and subtropical waters in the EPO (20°–35°N, 20°–30°S), low CPUE in the far eastern tropical Pacific (ETP) due to low oxygen concentration and low CPUE in the northwest Pacific to the west of the Emperor seamounts (Figure 2). The number of 1° cells fished by the Japanese fleet has consistently declined in each decade due to at least three factors: 1) cessation of albacore fishing at high (temperate) latitudes, 2) declining EEZ access (e.g. Hawaii, PNG) and 2) increasing fishing knowledge whereby the fleet now targets the best fishing areas.

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 in the following manner:
     A) For a 1°-quarterly stratum, the stratum was substituted with the average (1966 & 1972) HBF composition from a similar 1°-quarterly stratum.
     B) If no corresponding strata exist, then the stratum was substituted with the average (1966 & 1972) HBF composition from a 10°x10°-quarterly area around the stratum.
     C) If no strata exist in a 10°x10° area, then the yearly average (1966 & 1972) HBF composition was applied.

  If missing HBF strata occurred in other years (1966 or 1972–96), substitution followed the above criteria of B and C, but only applied HBF composition from the same year in which substitution was required.

  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 bigeye depth distribution –** Daytime bigeye habitat preferences were constructed from time-at-temperature data from tracking and longline monitoring studies (Boggs 1992, Holland et al. 1990). Our hypotheses regarding habitat preferences remain unchanged since the initial analysis. Other researchers have recently conducted acoustical tracking (ECOTAP) and archival tagging research (NMFS Honolulu), but these data have not been incorporated into the preference hypotheses. 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 bigeye 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). Bigeye depth distribution was a product of the bigeye temperature and dissolved oxygen values. The temperature*dissolved oxygen data were then normalized to describe the relative depth distribution of bigeye in each 1°-quarter stratum.

  An east to west section at 1° resolution along 10°N of the daytime bigeye habitat suggests that the bigeye population in the EPO is largely confined to the upper 160 m of the water column (Figure 3). In comparison, the majority of the population is distributed at moderate depths at the dateline (160–280 m) and deeper in the western Pacific (200–320 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 (Figures 1–2). Values of the standardized series were scaled to the mean of the nominal series to allow comparison. Since a peak in 1977, there has been a long-term decline in standardized trends in the WCPO (Figure 4). In comparison, the standardized time-series in the EPO is stable over the time-series, similar to nominal CPUE, but has declined from a peak in the mid-1980s.

The north Pacific shows the greatest temporal changes with a substantial CPUE reduction in the subtropical (18–32°N) area during the 1980–90s (Figure 5). The subtropical south Pacific does not show a similar decline, but the interpretation is complicated because the Japanese fleet has not actively fished this area due to limited access arrangements and presumably because of the thermal profile, whereby bigeye are more difficult to catch.

There is a meridional transition in standardized CPUE from 5° to 10°N in the WCPO. Although not evident in the spatial plots of nominal CPUE, the area over 5°–10°N and 130°E–150°W has lower standardized CPUEs than areas to north and south. This area is characterized by a shallow thermocline (15°C isotherm in the upper 200 m) and moderate dissolved oxygen content (2.0 ml O_2 l^{-1} isopleth in the upper 200–300 m). These oceanographic features result in higher levels of effective effort and corresponding lower standardized CPUE in this region.

Standardized CPUE values are fairly consistent throughout time in the EPO, with the exception of a suggested decline to the north of 10°N. Similar to nominal CPUE, standardized CPUE is poor in the northern ETP due to the low oxygen. In the southern ETP there is no apparent trend in the spatial plots to suggest a decline in standardized CPUE.

Preliminary sensitivity analysis to model input assumptions

The robustness of model results are based on assumptions of habitat (temperature and oxygen) preferences and gear depth distribution. In our preliminary effort standardization (Hampton et al. 1998), we demonstrated that different interpretations of standardized CPUE could emerge when reasonable (but not very different) assumptions were made regarding temperature preferences. A preliminary analysis of the sensitivity of these assumptions was conducted by altering habitat preferences and gear depth. Alternative assumptions included:

- **Temperature** – Bigeye were assumed to prefer warmer waters in the alternative hypothesis.

Original hypothesis	Index value	Alternative hypothesis	Index value
>26°C	0.05	20–32°C	Linear decrease from 1.0 to 0.0
24–26°C	0.10	10–20°C	1.00
20–24°C	0.15	9–10°C	0.60
19–20°C	0.20	8–9°C	0.25
18–19°C	0.35	<8°C	0.00
17–18°C	0.60		
10–17°C	1.00		
9–10°C	0.60		
8–9°C	0.25		
<8°C	0.00		

- **Oxygen –** Bigeye were assumed to prefer more oxygenated waters in the alternative hypothesis.

Original hypothesis	Index value	Alternative hypothesis	Index value
>2.0 ml O_2 l^{-1}	1.00	>4.0 ml O_2 l^{-1}	1.00
1.5–2.0 ml O_2 l^{-1}	Linear increase from 0.0 to 1.0	1.5–4.0 ml O_2 l^{-1}	Linear increase from 0.0 to 1.0
<1.5 ml O_2 l^{-1}	0.00	<1.5 ml O_2 l^{-1}	0.00

- **Gear depth –** Gear was assumed to be deployed 20% deeper in the water column.

Preliminary results suggest that altering assumptions had little effect on trends in the EPO, but had larger effects in the WCPO (Figure 6). In the WCPO, effects were largest for temperature (Figure 6A), moderate for gear depth (Figure 6B), and small for oxygen (Figure 6C). Also, standardized CPUE is stable (less of a decline) in the WCPO when alternative temperature and gear depth hypotheses are considered.

Standardized CPUE estimates are a ratio estimator (Number of bigeye/effective effort). For the alternative temperature assumption, standardized CPUE is reduced for the early portion of the time-series (1966–1980) because bigeye are distributed shallower; consequently, effective effort would be greater, especially for the regular (shallowest) gear type.

Distributing the gear 20% deeper has a similar effect to assuming that bigeye prefer warmer temperatures. The regular gear would be distributed deeper in the water column; thus effective effort in the bigeye habitat would be greater.

Temporal changes in targeting and effective effort

Temporal changes in targeting and effective effort or standardized hooks in the bigeye habitat were calculated for the three distant-water fleets (Japan, Korea and Taiwan) using 5°–quarterly data (Figure 7). Effective effort as a percentage of total effort has increased about ~50% in the WCPO over the 35 yr time-series from 7% to 11%. In the EPO, effective effort as a percentage of total effort has declined slightly from 17% to 15%. Annual effective effort has increased in both the WCPO and EPO. In the WCPO, annual effective effort has increased from 15 million hooks in the 1960s and early 1970s to 30 million hooks in the 1980. This increase results from improved targeting of the bigeye habitat as well as an overall increase in total longline effort. Effective effort in the EPO has also increased, but only due to an overall increase in total longline effort.

Conclusions

Model inputs have been improved since the preliminary analysis presented at SCTB11 which allow insights into finer scale spatial trends. Future work will include the following:

- Habitat and gear depth assumptions in the model are based on a few published studies, 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 and one archival tag from NMFS Honolulu 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.

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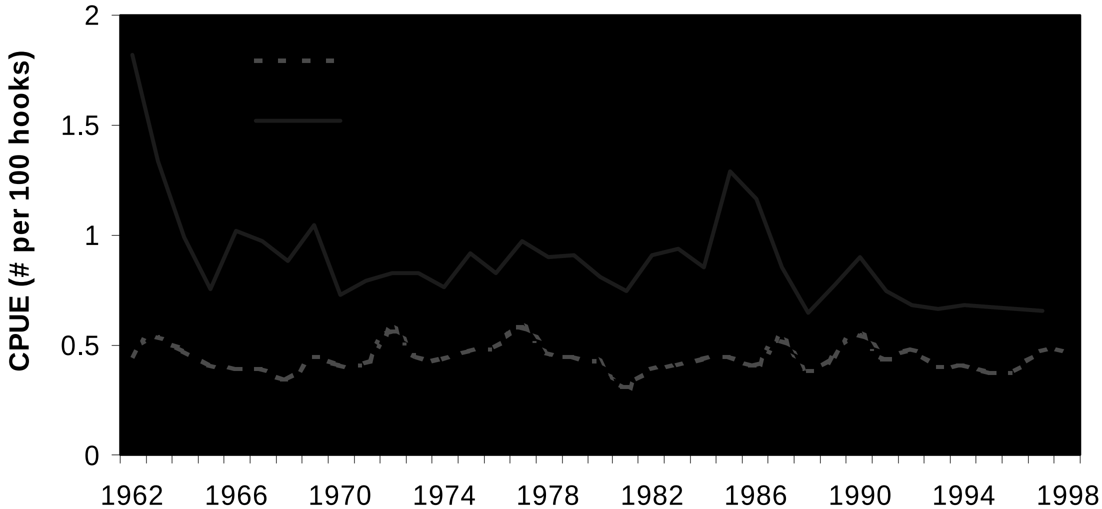


Figure 1. Nominal bigeye CPUE (ΣCatch/ΣEffort) for the Japanese longline fishery in the western and central Pacific and eastern Pacific Ocean.

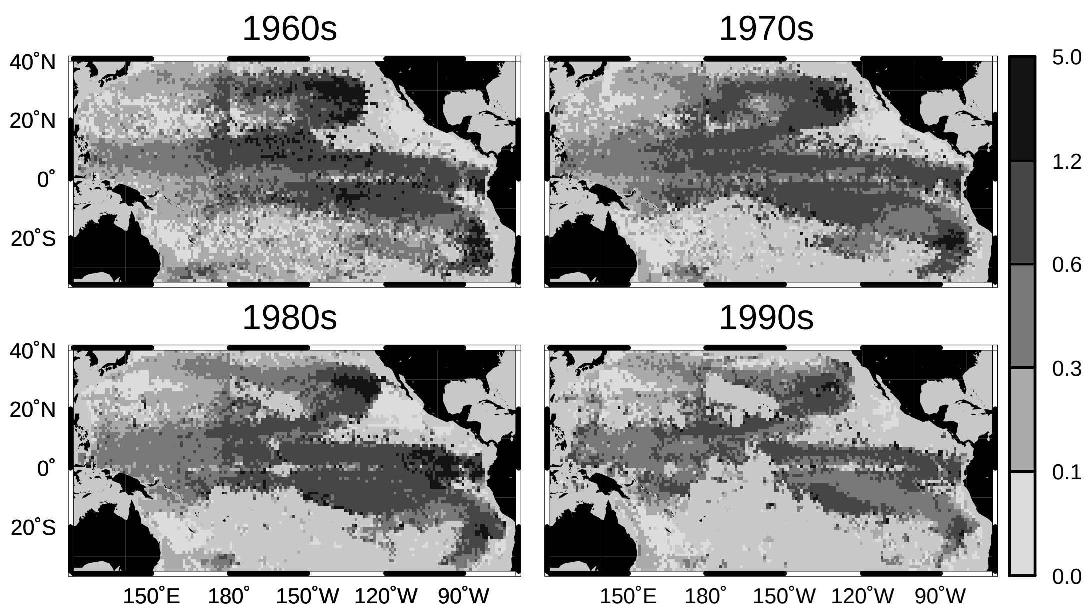


Figure 2. Comparison of nominal bigeye CPUE in the Japanese longline fishery during the last four decades.

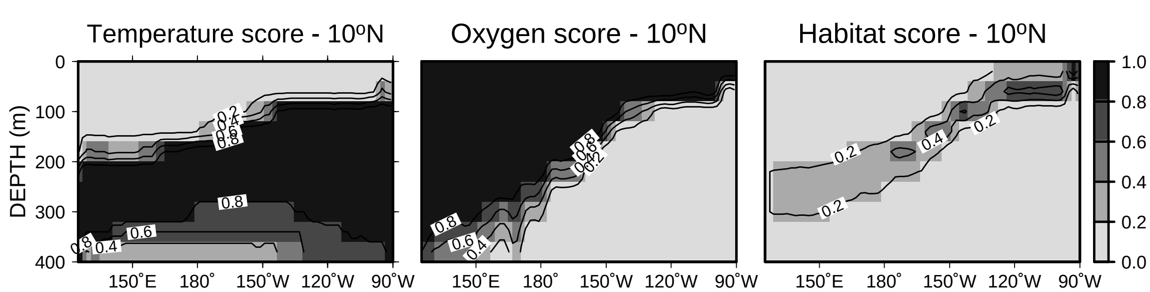


Figure 3. Zonal section at 10°N of bigeye habitat indices for temperature, oxygen and normalized habitat quality. Indices are represented for 1980.

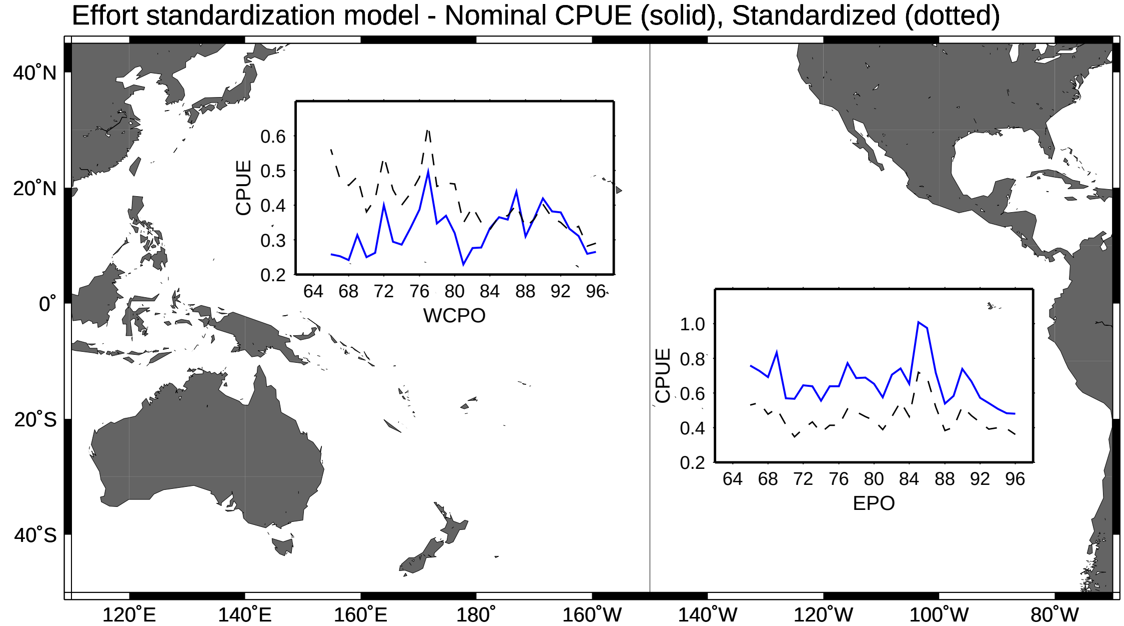


Figure 4. Comparison of nominal (solid) and standardized (dotted line) bigeye CPUE in the Japanese longline fishery for the western and central Pacific (WCPO) and eastern Pacific Ocean (EPO).

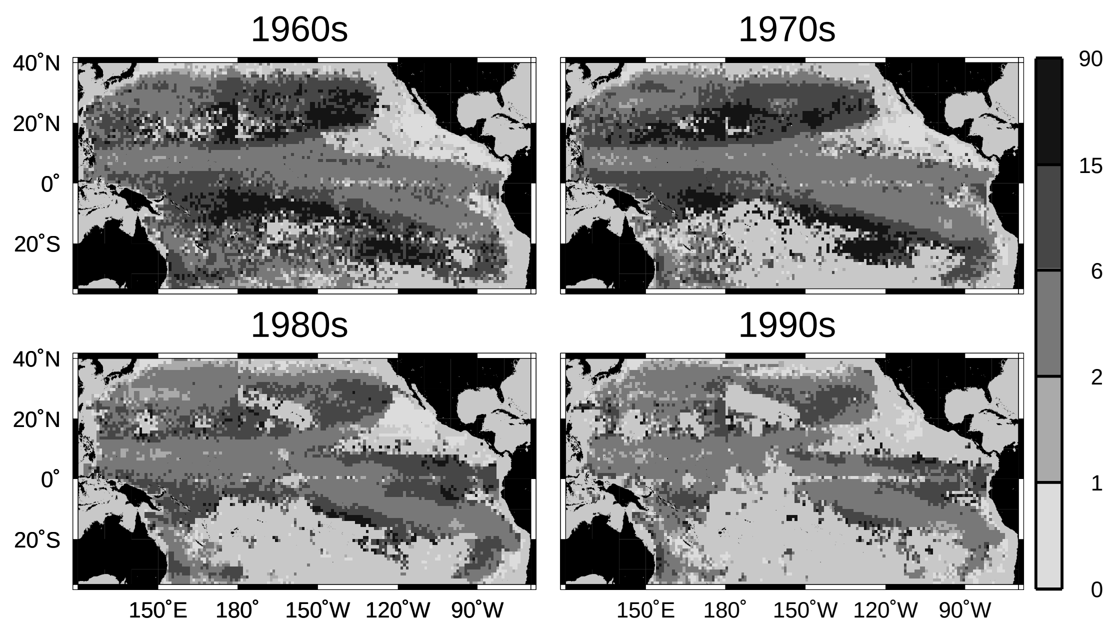
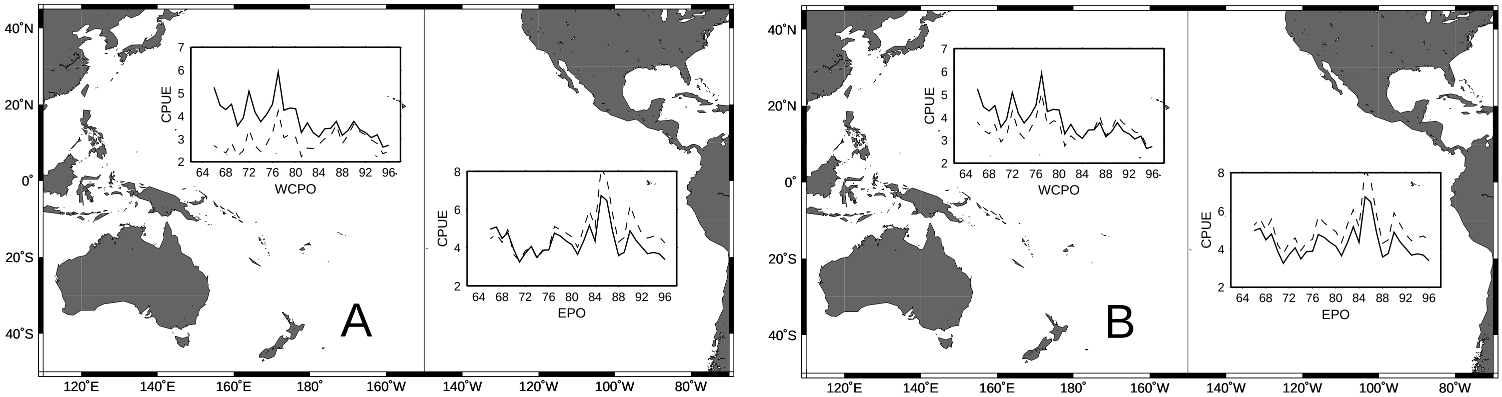


Figure 5. Comparison of standardized bigeye CPUE in the Japanese longline fishery during the last four decades.



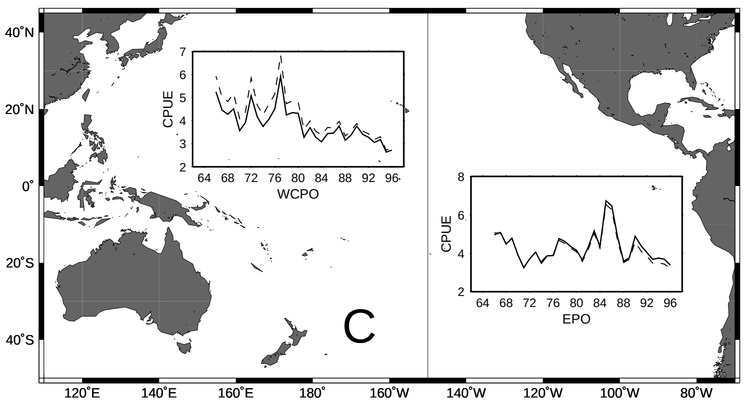


Figure 6. Comparison of standardized bigeye CPUE with various temperature (A), hook depth (B) and oxygen (C) hypotheses. Solid line indicates original hypothesis, dotted line indicates alternative hypothesis.

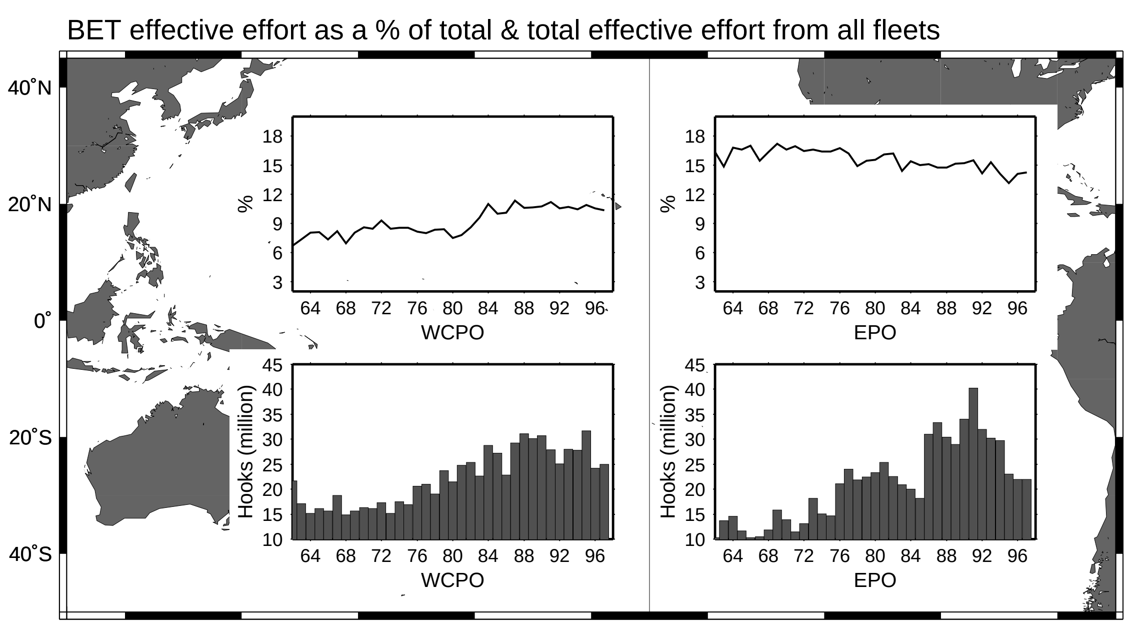


Figure 7. Effective effort in the bigeye habitat as a percentage of total effort (top) and total effective effort (bottom) for the WCPO and EPO.