THE WESTERN AND CENTRAL PACIFIC TUNA FISHERY: 2006 OVERVIEW AND STATUS OF STOCKS

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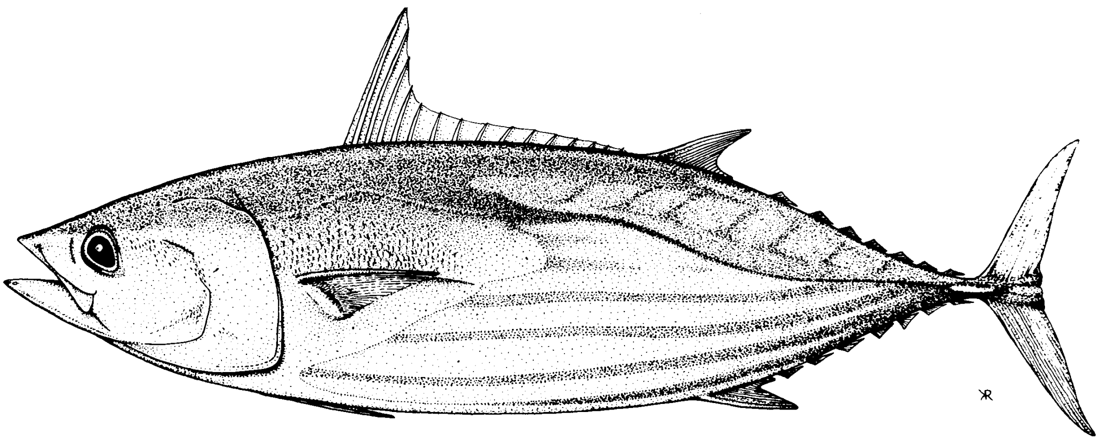

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Preface

Tuna Fisheries Assessment Reports provide current information on the tuna fishery of the western and central Pacific Ocean and the fish stocks, mainly tuna, that are impacted by them. This report focuses on the main tuna stocks targeted by the fishery – skipjack tuna (*Katsuwonus pelamis*), yellowfin tuna (*Thunnus albacares*), bigeye tuna (*T. obesus*) and South Pacific albacore tuna (*T. alalunga*).

The report is in three main parts: the first section provides an overview of the fishery, with emphasis on developments during the past few years; the second summarises the most recent information on the status of the stocks; and the third summarises information concerning the interaction between the tuna fisheries and the environment. The data used in compiling the report are those which were available to the Oceanic Fisheries Programme (OFP) at the time of publication. The fisheries statistics presented will usually be complete to the end of the year prior to publication; however, some minor revisions to statistics may be made for recent years from time to time. The stock assessment information presented is the most recent available, and is updated periodically for each species as new analyses are completed.

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For further information, including a complete online French version of this report, see the OFP web page: http://www.spc.int/oceanfish/.

Préface

Les rapports d'évaluation de la pêche thonière donnent des informations d'actualité sur la pêche thonière dans le Pacifique occidental et central et ses répercussions sur les stocks de poisson, principalement de thon. Le présent rapport braque le projecteur sur les principaux stocks de thon ciblés par cette activité : bonite (*Katsuwonus pelamis*), thon jaune (*Thunnus albacares*), thon obèse (*T. obesus*) et germon (*T. alalunga*).

Ce rapport comprend trois grandes parties. La première fait un tour d'horizon de la pêche thonière et met l'accent sur l'évolution intervenue ces dernières années ; la seconde fait le point sur l'état des stocks, et la troisième reprend succinctement les informations disponibles sur l'interaction de la pêche thonière et de l'environnement. Les données utilisées pour établir ce rapport sont celles dont le programme Pêche hauturière avait connaissance au moment de la publication. Les statistiques halieutiques présentées sont généralement complétées à la fin de l'année qui précède la publication. Quelques modifications mineures peuvent parfois être apportées aux statistiques pour les années récentes. Les informations concernant l'évaluation des stocks qui sont présentées ici sont les plus récentes dont on dispose et sont actualisées périodiquement pour chaque espèce, au fur et à mesure que l'on procède à des analyses.

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Des informations complémentaires, notamment une version française intégrale de ce rapport, peuvent être consultées sur le site Web du Programme pêche hauturière : http://www.spc.int/oceanfish/.

Abstract

Overview of the western and central Pacific tuna fishery

The tuna fishery in the western and central Pacific Ocean (WCPO), encompassed by the Convention Area of the Western and Central Pacific Fisheries Commission (WCP–CA), is a diverse fishery ranging from small-scale, artisanal operations in the coastal waters of Pacific states, to large-scale, industrial purse-seine, pole-and-line and longline operations both in the exclusive economic zones of Pacific states and in international waters (high seas). The main species targeted by these fisheries are skipjack tuna (*Katsuwonus pelamis*), yellowfin tuna (*Thunnus albacares*), bigeye tuna (*T. obesus*) and albacore tuna (*T. alalunga*).

During the early and mid-1990s, the total annual catch of the four main tuna species remained relatively stable, at about 1.5 million mt. In the subsequent years, annual catches increased and the total WCP–CA tuna catch for 2006 was estimated at 2,160,314 mt – only slightly less than the highest recorded catch taken in 2005. The purse-seine fishery accounted for an estimated 72% of the total catch, pole-and-line 10% and longline 10%. The remainder (8%) was taken by troll gear and a variety of artisanal gear types, mostly in eastern Indonesia and the Philippines. The 2006 WCP–CA tuna catch represented 78% of the total estimated Pacific Ocean catch of 2,771,070 mt and 50% of the provisional estimate of the global tuna catch.

The 2006 WCP–CA tuna catch was dominated by skipjack (71% of the total) and the annual catch of 1,539,021 mt represented the highest recorded catch for the species. The WCP–CA yellowfin catch for 2006 (401,773 mt; 19%) was about 10% lower than the 2005 catch, but comparable to the average catch from the previous decade. The WCP–CA bigeye catch (117,143 mt; 5% in 2006) has declined in recent years from the highest recorded level in 2004. The WCP–CA albacore catches (102,377 mt; 5% in 2006) have also tended to decline over the last four years, mainly due to lower catches in the north Pacific.

The 2006 WCP–CA **purse-seine** catch of 1,553,871 mt was the second highest recorded, only slightly less than the record catch taken in 2005 (1,592,214 mt), and the total purse-seine catch has exceeded 1,300,000 mt for the past five years. The 2006 purse-seine catch was dominated by a record catch of skipjack (1,306,707 mt; 84% of the total purse-seine catch), while the catch of yellowfin (221,546 mt; 15%) was lower than the relatively high level of catch in 2005. The 2006 estimate of bigeye catch by purse-seine (25,376 mt; 2%) was the second-lowest catch from the last decade. The FSM Arrangement purse-seine fleet was the highest catching sector, surpassing the Chinese Taipei fleet in recent years.

The 2006 **pole-and-line** catch estimates were not available for most pole-and-line fleets operating in the WCP–CA; however, the total catch estimate is expected to be similar to the level of recent years (200,000–220,000 mt). Skipjack accounts for most of the catch (typically more than 85% of the total catch in tropical areas), while the remainder of the catch is comprised of albacore, taken by the Japanese coastal and offshore fleets in the temperate waters of the north Pacific, yellowfin (5–7%) and a small component of bigeye (~1%). The Japanese distant-water and offshore fleets (144,012 mt in 2005) and the Indonesian fleets (44,295 mt in 2006) account for most of the WCP–CA pole-and-line catch. The Solomon Islands fleet (6,998 mt in 2006) has recovered from low catch levels experienced in the early 2000s.

The provisional 2006 **longline** catch of 226,226 mt was the lowest since 2000 and 14% lower than the highest recorded catch attained in 2004 (262,575 mt), although the 2006 WCP–CA albacore longline catch (81,437 mt – 36%) was a record for this fishery, mainly due to the increased catch in the south Pacific. The 2006 bigeye catch (70,919 mt – 31%) was the lowest for 5 years and the yellowfin catch (69,986 mt – 31%) was the lowest for 7 years. Most of the catch was taken by the large-vessel, distant-water fleets of Japan, Korea and Chinese Taipei. These fleets operate throughout the WCP–CA targeting bigeye and yellowfin tuna for the frozen sashimi market, and albacore tuna in the more temperate waters. However, the distant-water fleet has declined in recent years, resulting in a decline in the bigeye longline catch from the 2004 record level. The developing domestic longline

fisheries of Pacific Island countries have accounted for approximately 15% of the WCP–CA longline catch, including about 50% of the South Pacific albacore catch.

The WCP–CA **troll** fishery for South Pacific albacore operates in coastal waters around New Zealand, and in the south central Pacific in the vicinity of the Sub-Tropical Convergence Zone. Since the early 1990s, there has been a general decline in the total troll catch of South Pacific albacore, largely driven by a decline in catch by the USA fleet. The 2006 troll catch (2,886 mt) was the lowest for nearly 20 years.

Status of tuna stocks

Skipjack tuna

The most recent assessment of skipjack in the WCPO was conducted in 2005 and included data from 1972 to 2004. Current fishing mortality rates for skipjack tuna are estimated to be well below the F_{MSY} reference point and, therefore, overfishing is not occurring (i.e. $F_{CURRENT} < F_{MSY}$). The total biomass of skipjack has fluctuated above the biomass based reference point B_{MSY} and recent biomass levels are estimated to be well above the B_{MSY} level. Based on these results, the Scientific Committee of the WCPFC noted that the stock is not in an overfished state and that exploitation is modest relative to the stock's biological potential. However, it was further noted that any increases in purse-seine catches of skipjack may result in a corresponding increase in fishing mortality for yellowfin and bigeye tunas.

Yellowfin tuna

Since 1990, the biomass of yellowfin in the WCPO has steadily declined and fishing mortality rates have increased to the extent that current exploitation rates approximate the F_{MSY} reference point and there is a high probability (47%) that overfishing is occurring. The stock is not yet in an overfished state (i.e. $B_{CURRENT} > B_{MSY}$), although there is a relatively high probability that continued fishing at current levels of effort will move it to an overfished state. Further, the assessment indicates that the equatorial regions are likely to be overexploited, while exploitation rates in the subtropical regions are relatively low. Based on these results, the Scientific Committee of the WCPFC recommended that fishing mortality on the WCPO yellowfin stock be reduced from recent levels (2002–2005) to reduce the likelihood of overfishing. Higher reductions in fishing mortality would be required to maintain the biomass at higher levels relative to B_{MSY}. It was also noted that more urgent management actions may be required in the western equatorial region of the WCPO.

Bigeye tuna

The most recent WCPO bigeye assessment indicates the stock is not in an overfished state ($B_{CURRENT} > B_{MSY}$), although current fishing mortality rates are greater than the F_{MSY} level ($F_{CURRENT} > F_{MSY}$) and, therefore, overfishing is occurring. Recent catches have been sustained by higher-than-average levels of recruitment, which have also maintained biomass above the B_{MSY} level. Future levels of recruitment are highly uncertain, and a return to long-term average levels of recruitment is predicted to result in a rapid decline in biomass to below the B_{MSY} level. Based on the results of the assessment, the Scientific Committee of the WCPFC recommended that fishing mortality on the bigeye tuna in the WCPO be reduced by 25% of recent levels (2001–2004) in order to maintain the stock at a level that would produce the MSY. Higher reductions in fishing mortality would be required to maintain the biomass above the B_{MSY} level in the long-term. It was also noted that more urgent management actions may be required in the equatorial region of the WCPO.

South Pacific albacore tuna

The assessment indicates that the current level of exploitation of the total biomass is very low ($F_{CURRENT} << F_{MSY}$) and, consequently, the fishery impacts on the total biomass are low. Biomass levels have declined over the last decade due to a decline in recruitment; however, current biomass levels remain well above the MSY-based reference point ($B_{CURRENT} > B_{MSY}$). Nevertheless, the current level of longline catch is estimated to be having a considerably higher impact on the portion of the stock vulnerable to the longline fishery. The magnitude of this impact is uncertain, although the assessment indicates that the current level of impact is about 30%, having increased sharply in recent years. The impact on the adult component of the stock is considerably less due to the age-specific exploitation pattern of the longline fisheries. Based on the results of the assessment, the Scientific Committee of the WCPFC noted that current catch levels from the South Pacific albacore stock appear to be sustainable, and yield analyses suggest that increases in fishing mortality and yields are possible. However, given the age-specific mortality of the longline fleets, any significant increase in effort would reduce CPUE to low levels with only moderate increases in yields.

Ecosystem considerations

The document includes a summary of the information available from the WCPO tuna fishery concerning associated and dependent species, including information on the species composition of the catch from the tuna fisheries and an assessment of the impact of the fishery on these species.

Catch composition

The tuna fisheries of the WCPO principally target four main tuna species: skipjack, yellowfin, bigeye and albacore tuna. However, the method fisheries also catch a range of other species in association with these main species. Some of the associated species are of commercial value (by-product), while many others are of no value and are, consequently, discarded. There are also incidents of the capture of species of importance due to their ecological and/or social significance ('protected species'), including marine mammals, sea turtles and some species of shark (e.g. whale sharks).

The report summarises the available information concerning the catch composition of the main tuna fisheries in the WCPO, largely gained from the various observer programmes operating in the region. Overall, catches from unassociated and associated purse-seine sets are dominated by the tuna species (99.9% and 98.6%, respectively) and there has been limited interaction with protected species. Most of the observed interactions involved unidentified species of marine mammals and few mortalities have been recorded.

Species composition of the catch was also estimated for three main longline fisheries operating in the WCPO: the western tropical Pacific (WTP) shallow-setting longline fishery, the WTP deep-setting longline fishery, and the western south Pacific (WSP) albacore fishery. While estimates are uncertain due to the low level of observer coverage, some general conclusions are available. The main tuna species account for 46%, 72% and 72% of the total catch (by weight) of the three fisheries, respectively. Blue shark was the third-ranked species in the catch composition of all three fisheries. The WTP shallow fishery has a higher proportion of non-tuna species in the catch, principally shark and billfish species, while opah (moonfish) represents a significant component of the WSP albacore longline catch. There are also considerable differences in the species composition of the billfish catch between the three fisheries, while overall the WTP shallow and WSP albacore fisheries catch a higher proportion of surface-orientated species compared to the WTP deep-setting fishery.

Interactions with seabirds and marine mammals were very low in all three longline fisheries. Catches of the five species of marine turtles were observed in the equatorial longline fishery, although the observed encounter rate was very low and most of the turtles caught were alive at the time of release.

Impact of catches

In addition to the main tuna species, annual catch estimates for the WCPO are available for the main species of billfish (swordfish, blue marlin, striped marlin and black marlin). However, the catches of other associated species have not been accurately quantified. For the billfish species, preliminary stock assessments have been undertaken (Pacific-wide blue marlin, North Pacific swordfish, southwest Pacific swordfish, and southwest striped marlin), although they are hampered by limited information concerning species biology and stock structure. Nevertheless, the assessments generally indicate that these stocks are not overexploited at current levels of fishing effort.

For the other associated species, the lack of accurate catch data (and staff resources) has precluded an assessment of the level of impact on the abundance of the species by the tuna fisheries. However, as the level of information available for these species increases through established sampling programmes, there is likely to be increased emphasis on the assessment of some of these species in the future.

Ecosystem modelling

The report provides a summary of the physical oceanography of the WCPO, with particular emphasis on the interannual variability in the environmental conditions linked to the El Niño Southern Oscillation (ENSO). The impact of ENSO variation is evident in the operation of the main tuna fisheries and the population dynamics of the tuna species. During El Niño conditions the distribution of purse-seine catch in the western and central Pacific is generally displaced eastwards, indicating a spatial shift in the distribution of skipjack tuna. For longline fisheries, the vertical change in the thermal structure during El Niño (La Niña) events results in the rising (deepening) and vertical extension (contraction) of the temperature habitats of yellowfin and bigeye, thereby affecting the catchability of the species.

The assessment results indicate that recruitment in tuna populations is also influenced by ENSO variability, although the conditions favouring recruitment vary between species. El Niño events appear to result in higher recruitment for skipjack and yellowfin, while South Pacific albacore recruitment is higher under La Niña conditions.

To explore the underlying mechanisms by which the climate and environmental variability affect the pelagic ecosystem and tuna populations, a spatial ecosystem and population dynamics model (SEAPODYM) has been developed. The model has been applied to the skipjack in the WCPO and South Pacific albacore, and preliminary results are described. In future, the SEAPODYM model can be applied to investigate trends in abundance and spatial distribution of the species under different environmental conditions.

Ecosystem modelling is being supported through a research project to determine the trophic relationships between the main species groups in the WCPO pelagic ecosystem. This project has included an assessment of the diets of the main predator species and the results have been applied to develop a preliminary ecosystem model for the WCPO. The broader objectives of this collaborative project also include defining the biogeography of the pelagic tropical Pacific ecosystem and the characterisation of large-scale tuna movements related to upwelling regions along the equator.

Résumé

Tour d'horizon de la pêche thonière dans le Pacifique occidental et central

La pêche thonière est très diversifiée dans l'océan Pacifique central et occidental, zone d'application de la Convention portant création à la Commission des pêches du Pacifique central et occidental. On y trouve à la fois de petites entreprises artisanales dans les eaux côtières des États et Territoires océaniens, et de grandes entreprises industrielles de pêche à la senne, à la canne et à la palangre, tant dans les zones économiques exclusives des États et Territoires océaniens que dans les eaux internationales (la haute mer). Les principales espèces ciblées par ces flottilles sont la bonite (*Katsuwonus pelamis*), le thon jaune (*Thunnus albacares*), le thon obèse (*T. obesus*) et le germon (*T. alalunga*).

Au début et au milieu des années 90, le total des prises annuelles des quatre principales espèces de thonidés oscillait de façon relativement stable autour de 1,5 million de tonnes. Durant les années qui ont suivi, les prises annuelles ont augmenté jusqu'à ce qu'en 2006, les prises totales de thonidés dans la zone d'application de la Convention atteignent un chiffre estimatif de 2 160 314 tonnes, chiffre légèrement inférieur aux prises record de 2005. Environ 72 pour cent des prises totales sont capturées à la senne, 10 pour cent à la canne et 10 pour cent à la palangre. Le reste (8 pour cent) est réalisé à la traîne et par divers engins artisanaux, principalement en Indonésie orientale et aux Philippines. Les prises de thons réalisées en 2006 dans la zone du Pacifique occidental et central visée par la Convention représentaient 78 pour cent des prises totales estimées réalisées dans le Pacifique, soit 2 771 070 t, et 50 pour cent des prises estimées provisoires de thons à l'échelle mondiale.

En 2006, les prises de thonidés dans la zone d'application de la Convention étaient essentiellement constituées de bonite (71 % du total) et les 1 539 021 tonnes de bonite capturées sur

l'année ont ainsi formé un plafond jamais atteint auparavant par l'espèce. Celles de thon jaune réalisées en 2006 (401 773 t, soit 19 %) étaient d'environ 10 % moindres que celles de 2005, mais comparables aux prises moyennes des dix années précédentes. Les prises de thon obèse dans la zone d'application de la Convention (117 143 t ; soit 5 % en 2006) ont diminué au cours des dernières années, par rapport au record de 2004. Les prises de germon dans la zone d'application de la Convention (102 377 t ; soit 5 % en 2006) ont également accusé une baisse au cours des quatre dernières années, du fait de la diminution des prises dans le Pacifique Nord.

Les prises réalisées à la **senne** en 2006 dans la zone d'application de la Convention (1 553 871 t) arrivaient en seconde position, après le record de 2005 (1 592 214 t) et les prises totales à la senne ont dépassé 1 300 000 t au cours des cinq dernières années. En 2006 ont été enregistrées des prises record de bonite à la senne (1 306 707 t ; soit 84 % des prises totales à la senne), tandis que celles de thon jaune (221 546 t ; 15 %) étaient inférieures au niveau relativement élevé de 2005. Les prises estimées en 2006 de thon jaune à la senne (25 376 t ; 2 %) arrivaient en deuxième position sur les dix ans écoulés. La flottille de senneurs bénéficiant des conditions préférentielles de l'Accord des États fédérés de Micronésie a engrangé le volume le plus élevé de prises, surpassant ainsi ces dernières années la flottille taïwanaise.

Concernant les prises des canneurs dans la zone d'application de la Convention, les estimations de la plupart des flottilles n'étaient pas disponibles pour l'année 2006. Néanmoins, les estimations des prises totales devraient être similaires à celles des années précédentes (environ 200 000 à 220 000 tonnes). La bonite constitue la principale espèce capturée (généralement plus de 85 % du total dans les zones tropicales), tandis que le pourcentage restant est constitué de germon capturé par les flottilles japonaises pratiquant la pêche côtière et au large dans les eaux tempérées du Pacifique Nord, de thon jaune (5-7 %) et d'un léger volume de thon obèse (~1 %). Les flottilles japonaises pratiquant la pêche hauturière et la pêche au large (144 012 tonnes en 2005) et les flottilles indonésiennes (44 295 tonnes en 2006) réalisent la plupart des prises à la canne dans la zone d'application de la Convention. La flottille des Îles Salomon (6 998 tonnes en 2006) poursuit son redressement après les faibles prises enregistrées au début des années 2000.

Les estimations provisoires de prises à la **palangre** en 2006 s'élèvent à 226 226 t, le chiffre le plus bas depuis 2000, et de 14 % inférieur aux prises record enregistrées en 2004 (262 575 t), bien que les prises de germon à la palangre réalisées en 2006 dans la zone d'application de la Convention (81 437 t – 36 %) aient battu le record pour cette technique de pêche, du fait de l'augmentation des prises dans le Pacifique Sud, notamment. Les prises de thon obèse de 2006 (70 919 t – 31 %) étaient les plus faibles depuis 5 ans, et celles de thon jaune (69 986 t – 31 %) les plus basses depuis 7 ans. La majeure partie des prises a été réalisée par les gros navires du Japon, de la Corée et de Taiwan pratiquant la pêche hauturière. Ces flottilles opèrent dans l'ensemble de la zone d'application de la Convention et ciblent le thon obèse et le thon jaune destiné au marché du sashimi congelé, ainsi que le germon dans les eaux plus tempérées. Les flottilles pratiquant la pêche hauturière ont toutefois vu leurs effectifs décliner au cours des dernières années, d'où la diminution constatée dans les prises de thon obèse à la palangre par rapport au niveau record de 2004. Les flottilles nationales de palangriers, en plein essor dans le Pacifique, représentent environ 15 % des prises à la palangre dans la zone d'application de la Convention, dont la moitié est constituée des prises de germons du sud.

Les **ligneurs** ciblant le germon du sud dans cette même zone opèrent dans les eaux côtières entourant la Nouvelle-Zélande et dans le Pacifique central et méridional, aux abords de la zone de convergence subtropicale. Depuis le début des années 90, les prises totales de germon du sud à la traîne ont affiché une tendance à la baisse, motivée principalement par un fléchissement des prises de la flottille américaine. En 2006, les prises réalisées à la ligne (2 886 t) étaient les plus faibles depuis près de 20 ans.

État des stocks de thonidés

Bonite

La toute dernière évaluation des stocks de bonite dans le Pacifique central et occidental a été réalisée en 2005 et comprenait des données de la période 1972-2004. Les taux actuels de mortalité due à la pêche de la bonite sont estimés à un niveau bien inférieur au seuil de référence de mortalité due à la pêche correspondant à la production maximale équilibrée (PME). Il n'y a donc pas surpêche (mortalité due à la pêche actuelle < mortalité due à la pêche correspondant à la PME). La biomasse totale des stocks de bonite a fluctué dans une fourchette située au-dessus du seuil de référence de la biomasse associée à la PME et les niveaux de biomasse relevés récemment sont estimés à des niveaux bien supérieurs à ce seuil de référence de la biomasse. Sur la base de ces résultats, le Comité scientifique de la Commission a constaté que les stocks de bonite ne se trouvent pas dans un état de surexploitation et que le taux d'exploitation reste modeste par rapport au potentiel biologique de ce stock. Cependant, le Comité a indiqué que toute augmentation des prises de bonite à la senne pourrait se manifester par un accroissement de la mortalité due à la pêche du thon jaune et du thon obèse.

Thon jaune

Depuis 1990, la biomasse du thon jaune dans le Pacifique occidental et central a accusé un déclin constant et les taux de mortalité due à la pêche ont connu une augmentation telle que les taux d'exploitation actuels se rapprochent du seuil de mortalité due à la pêche correspondant à la PME. Il est très probable (à 47 %) qu'une surpêche ait lieu. Le stock n'est pas encore au stade de la surexploitation (biomasse actuelle > biomasse nécessaire à la PME), mais il est fort probable que, si l'effort de pêche se poursuit au niveau actuel, le thon jaune passera à l'état de stock surexploité, tandis que les taux d'exploitation dans les régions subtropicales sont relativement faibles. Sur la base de ces résultats, le Comité scientifique de la Commission des pêches du Pacifique occidental et central a préconisé de réduire la mortalité due à la pêche du thon jaune dans le Pacifique central et occidental par rapport aux niveaux récents (2002-2005), afin de maintenir la biomasse à des niveaux supérieurs par rapport à la PME. Il a également été noté que des mesures de gestion pourraient bien devoir s'imposer de toute urgence dans la région équatoriale occidentale du Pacifique central et occidental.

Thon obèse

La dernière évaluation en date des stocks de thon obèse dans le Pacifique central et occidental révèle que la ressource n'est pas en état de surpêche (biomasse actuelle > biomasse nécessaire à la PME). Malgré tout, les taux actuels de mortalité due à la pêche dépassent le taux de mortalité associée à la PME (mortalité due à la pêche actuelle > mortalité due à la pêche correspondant à la PME). Le thon obèse est donc victime de surpêche. Des niveaux de recrutement supérieurs à la moyenne ont permis d'absorber l'intense effort de pêche ainsi que de maintenir la biomasse au-dessus du seuil de biomasse associé à la PME. L'incertitude plane autour des futurs niveaux de recrutement et un retour aux niveaux de recrutement observés ces dernières années se traduirait par une chute rapide de la biomasse, qui passerait sous la barre de la biomasse nécessaire à la PME. S'inspirant des résultats de cette évaluation, le Comité scientifique de la Commission a recommandé une réduction de 25 % de la mortalité due à la pêche du thon obèse dans le Pacifique central et occidental par rapport aux taux de 2001–2004 en vue de maintenir les stocks à un niveau permettant d'atteindre une PME. Si, à long terme, on veut maintenir la biomasse du thon obèse à un niveau supérieur au seuil de biomasse nécessaire à la PME, il sera nécessaire de réduire davantage la mortalité due à la pêche. Il a été noté, par ailleurs, que des mesures de gestion seront peut-être requises de toute urgence dans la région équatoriale du Pacifique central et occidental.

Germon du sud

L'évaluation des stocks de germon du sud révèle que le niveau actuel d'exploitation de la biomasse totale est très bas (mortalité due à la pêche actuelle << mortalité correspondant à la PME). On peut donc en conclure que la pêche n'a qu'une faible incidence sur la biomasse totale du germon. Si les niveaux de biomasse accusent un déclin ces dix dernières années en raison d'une diminution du niveau de recrutement, les niveaux actuels de biomasse restent bien supérieurs au seuil de référence correspondant à la PME (biomasse actuelle > biomasse associée à la PME). Toutefois, on estime que le niveau actuel des prises à la palangre touche beaucoup plus la proportion des stocks plus exposée à la pêche à la palangre. Si l'ampleur de ce phénomène reste méconnue, l'évaluation montre que l'impact des palangriers est de l'ordre de 30 %, après une montée en flèche ces dernières années. Compte tenu du mode d'exploitation actuel ciblant des catégories d'âge, la composante adulte du stock a été relativement épargnée. Au vu de ces résultats, le Comité scientifique de la Commission a pris acte du fait que le volume actuel des prises de germon du sud semble correspondre à une exploitation durable de la ressource, et des analyses de rendement donnent à penser que la mortalité due à la pêche et les rendements peuvent être augmentés. Toutefois, puisque la mortalité engendrée par les palangriers touche des catégories d'âge particulières, toute intensification de l'effort de pêche ne permettrait qu'un accroissement modeste des rendements alors qu'elle entraînerait une forte réduction des prises par unité d'effort.

Aspects de l'écosystème

Le présent document établit une synthèse d'informations fournies par les pêcheries thonières de l'océan Pacifique occidental et central, concernant les espèces associées et dépendantes, en particulier sur la composition par espèce des prises réalisées par ces pêcheries et une évaluation de l'impact de ces prises sur les espèces concernées.

Composition des prises

Dans l'océan Pacifique occidental et central, la pêche thonière cible principalement quatre espèces de thonidés : la bonite, le thon jaune, le thon obèse et le germon du sud. Toutefois, selon les engins de pêche utilisés, les pêcheries capturent aussi, en même temps que ces principales espèces, diverses autres espèces. Parmi elles, certaines ont une valeur marchande (espèces secondaires), beaucoup d'autres n'ont aucune valeur et sont, par conséquent, rejetées à l'eau. Il y a aussi des cas de captures d'espèces importantes pour leur valeur écologique et/ou leur signification sociale (« espèces protégées »), notamment les mammifères marins, les tortues marines et certaines espèces de requins (comme les requins baleines).

On s'attache ici à rapporter les informations disponibles concernant la composition des prises des principales pêcheries thonières qui opèrent dans l'océan Pacifique occidental et central, et obtenues en grande partie grâce aux observateurs exerçant leurs fonctions dans la région. Dans l'ensemble, dans les prises faites par les senneurs sur des bancs non associés et associés, les thonidés prédominent (99,9% et 98,6%, respectivement), et il arrive rarement que ces navires capturent dans leurs filets des espèces protégées. Lorsque cela est arrivé, ce sont des espèces de mammifères marins non identifiées qui ont été remontées et rares ont été celles qui n'ont pas survécu.

On a également estimé la composition par espèce des prises des trois grands types de pêche à la palangre employés dans l'océan Pacifique occidental et central: la pêche à la palangre en eau peu profonde et la pêche à la palangre en eau profonde pratiquées dans l'océan Pacifique tropical occidental, et la pêche du germon pratiquée dans l'océan Pacifique sud-ouest. Bien que les estimations soient incertaines en raison de la zone limitée couverte par les observateurs, il est possible d'en tirer des conclusions générales. Les principales espèces de thonidés représentent 46%, 74%, et 62% du total des prises (mesurées en poids) des trois types de pêche, respectivement. Le peau bleue figure au troisième rang des prises des trois types de pêche. C'est la pêche en eau peu profonde dans l'océan Pacifique tropical occidental qui a capturé la plus forte proportion d'espèces autres que des thonidés, principalement des requins et des poissons à rostre. L'opa est la principale espèce secondaire capturée par les palangriers ciblant le germon dans le Pacifique sud. On remarque également d'importantes différences de composition des prises de poissons à rostre entre les trois pêcheries, celles ciblant le germon dans le Pacifique sud et jetant leur palangre à de faibles profondeurs dans le Pacifique ouest tropical capturant davantage de poissons évoluant à la surface que la palangre en eau profonde mouillée dans le Pacifique occidental tropical.

Les captures d'oiseaux de mer et de mammifères marins ont été très peu nombreuses, quelle que fût la technique de pêche à la palangre utilisée. Des prises par des palangriers opérant dans la zone équatoriale des cinq espèces de tortues marines ont été observées mais la proportion de cas cités par les observateurs a été très faible et les tortues capturées étaient pour la plupart bien vivantes lorsqu'elles ont été relâchées.

Incidences des prises

Outre des estimations concernant les prises des principales espèces de thonidés ciblées, on dispose d'estimations annuelles des prises des principales espèces de poissons à rostre dans l'océan Pacifique occidental et central (espadon, makaire bleu, marlin rayé, et makaire noir), mais on n'a pas quantifié de façon certaine les autres prises associées. S'agissant des espèces de poissons à rostre, des évaluations préliminaires ont été faites (pour le makaire bleu que l'on trouve dans tout le Pacifique et l'espadon qui évolue dans le Pacifique nord) ou sont prévues (espadon dans le Pacifique sud-ouest et marlin rayé), bien que ces évaluations soient difficiles à faire en raison du peu d'informations dont on dispose au sujet de la biologie et de la structure des stocks de ces espèces. Néanmoins, celles qui portent sur le makaire bleu que l'on trouve dans tout l'océan Pacifique et l'espadon du Pacifique nord indiquent toutes deux que les stocks ne sont pas surexploités par la pêche au niveau d'intensité où elle est pratiquée actuellement.

S'agissant des autres espèces associées, l'absence de chiffres exacts concernant les prises (et la pénurie de personnel) empêche la réalisation d'une évaluation des incidences de la pêche thonière sur l'abondance des espèces. Néanmoins, les programmes d'échantillonnage permettent à présent d'en savoir plus au sujet de ces espèces et on peut espérer que l'on s'attachera davantage à évaluer les stocks de ces espèces dans un proche avenir.

Modélisation de l'écosystème

Le rapport comprend un résumé de l'océanographie physique intéressant l'océan Pacifique occidental et central, et s'attarde en particulier sur la variabilité interannuelle des conditions environnementales liée au phénomène d'oscillation australe El Niño. Les conséquences de ce phénomène sont évidentes dans les rendements de la pêche des principales espèces de thonidés et la dynamique des populations de ces espèces. Lorsque El Niño agit, la répartition des prises des senneurs dans l'océan Pacifique occidental se déplace généralement vers l'est, ce qui induit un changement dans l'espace de la répartition des bonites. Pour les palangriers, la variation de la structure thermique de l'eau dans le sens de la verticalité pendant un épisode El Niño (La Niña) entraîne une élévation (une descente) et une extension verticale (une contraction) des habitats où se plaisent les thons jaunes et les thons obèses, et modifie donc les conditions de capture et la vulnérabilité de ces espèces.

Les résultats de l'évaluation indiquent que le recrutement des populations de thonidés est aussi influencé par la variabilité associée à El Niño, mais les conditions favorisant le recrutement varient selon les espèces. Lorsque El Niño se fait sentir, le recrutement de la bonite et du thon jaune est plus productif, tandis que c'est La Niña qui favorise le recrutement du germon du sud.

Afin d'étudier la manière dont le climat et la variabilité des facteurs environnementaux influent sur l'écosystème pélagique et les populations de thonidés, on a mis au point un modèle de simulation spatiale de l'écosystème et de la dynamique des populations (SEAPODYM). On a appliqué ce modèle à la bonite évoluant dans l'océan Pacifique occidental et central et au germon du sud, et établi les premiers résultats, rapportés ici. Dans l'avenir, on prévoit d'utiliser le modèle SEAPODYM pour étudier les conditions relatives à l'abondance et à la répartition dans l'espace des espèces, dans différents environnements.

La modélisation des écosystèmes s'inscrit dans un projet de recherche dont le but est de déterminer les relations trophiques entre les principaux groupes d'espèces au sein de l'écosystème pélagique de l'océan Pacifique occidental et central. Ce projet inclut la détermination de l'alimentation des principales espèces prédatrices et l'exploitation des résultats pour la conception d'un modèle préliminaire des écosystèmes de l'océan Pacifique occidental et central. Les objectifs généraux de ce projet mené en collaboration comprennent également l'établissement de la biogéographie de l'écosystème pélagique de l'océan Pacifique tropical et la caractérisation des déplacements des thonidés sur une grande échelle, liés aux zones de remontée des eaux le long de l'équateur.

Contents

List of figures

List of abbreviations and acronyms

ALB	albacore tuna
BET	bigeye tuna
CPUE	catch per unit of fishing effort
DWFN	distant-water fishing nation
ENSO	El Niño Southern Oscillation
EPO	eastern Pacific Ocean
ERA	ecological risk assessment
FAD	fish aggregation device
FL	fork length
FSM	Federated States of Micronesia
GLM	generalised linear modelling
GRT	gross registered tonnage
IATTC	Inter-American Tropical Tuna Commission
LL	longline
MSY	maximum sustainable yield
mt	metric tons
MULTIFAN-CL	length-based, age-structured computer model used for fish stock assessment
NPZD	nutrients-phytoplankton-zooplankton-detritus
OFP	Oceanic Fisheries Programme (SPC)
PDO	Pacific Decadal Oscillation
PH/ID	Philippines/Indonesia
PNG	Papua New Guinea
PS	purse-seine
RFMO	regional fisheries management organisation
SEAPODYM	spatial ecosystem and population dynamics model
SKJ	skipjack tuna
SLP	sea-level pressure
SOI	Southern Oscillation Index
SPC	Secretariat of the Pacific Community
SST	sea surface temperature
STCZ	Sub-Tropical Convergence Zone
TL	trophic level
WCP–CA	Western and Central Pacific Fisheries Commission Convention Area
WCPFC	Western and Central Pacific Fisheries Commission
WCPO	western and central Pacific Ocean
WSP	western south Pacific
WTP	western tropical Pacific
YFT	yellowfin tuna

Introduction

The western and central Pacific Ocean (WCPO) supports a diverse tuna fishery, ranging from small-scale, artisanal operations in the coastal waters of Pacific states, to large-scale, industrial purse-seine, pole-and-line and longline operations both in the exclusive economic zones of Pacific states and in international waters. The main species targeted by these fisheries are skipjack tuna (*Katsuwonus pelamis*), yellowfin tuna (*Thunnus albacares*), bigeye tuna (*T. obesus*) and albacore tuna (*T. alalunga*); a range of other species, including billfish, is taken incidentally in these fisheries.

In this report, we provide an overview of the tuna fisheries, with an emphasis on the year 2006, and current information on the status of the stocks of the target tuna species. We also provide an overview of the pelagic ecosystem in the WCPO, including information on the impacts of the fisheries and the physical environment. The report draws on data and research results obtained by SPC's Oceanic Fisheries Programme (OFP), particularly material presented at the 3rd regular session of the Scientific Committee (SC3) of the Western Central Pacific Fisheries Commission (WCPFC), held in Honolulu, Hawaii in August 2007 (see the WCPFC meetings homepage at http://www.wcpfc.int).

1 Total catch in the western and central Pacific Ocean

The four tuna species are distributed throughout the tropical and temperate waters of the Pacific Ocean, although the tropical surface fisheries, which target skipjack, yellowfin and bigeye tuna, dominate the total catch and tend to be concentrated in the western and eastern regions of the Pacific. For skipjack and yellowfin tuna, the mixing of stocks between the western and eastern Pacific is considered to be low. On this basis, the tuna fisheries of the Pacific Ocean can be separated into two broad areas: the western and central Pacific Ocean and the eastern Pacific Ocean (EPO), delineated by 150°W longitude (Figure 1). This boundary broadly approximates the eastern boundary of the Western and Central Pacific Fisheries Commission (WCPFC) Convention Area[1] (WCP–CA). Catch estimates presented in this report are for the WCP–CA.

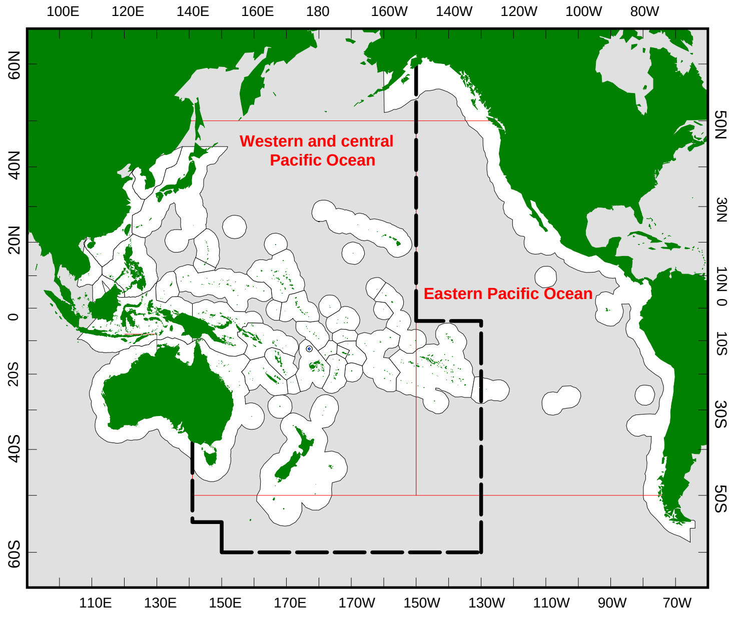


Figure 1. The western and central Pacific Ocean (WCPO), the eastern Pacific Ocean (EPO) and the WCPFC Convention Area (WCP–CA in dashed lines).

[1] The western boundary of the Convention Area north of the north coast of Australia has not been defined in the text of the Convention. Therefore, for statistical purposes, the western boundary of the WCPO Area, which was established at the 12th Meeting of the Standing Committee on Tuna and Billfish in June 1999, will be used in this regard and the entire area referred to as the 'WCPFC Statistical Area'. The coordinates of the western boundary are as follows: from the north coast of Australia due north along the 129° meridian of east longitude to its intersection with the 8° parallel of south latitude, thence due west along the 8° parallel of south latitude to the Indonesian peninsula, and from the Indonesian peninsula due east along the 2°30′ parallel of north latitude to the Malaysian peninsula.

The catch estimates presented herein represent the best available information at the time of writing. The catch estimates for the most recent years are routinely amended as more information becomes available (see http://www.spc.int/oceanfish/Docs/Statistics/TYB.htm for the latest statistics).

Annual total catches of the four main tuna species (skipjack, yellowfin, bigeye and albacore) in the WCP–CA increased steadily during the 1980s. Catches remained relatively stable during most of the 1990s until the sharp increase in catch during 1998. Over the past five years there has been an increasing trend in the total tuna catch, primarily due to increases in the catch of skipjack tuna by the purse-seine fishery (Figure 2 and Figure 3).

The total WCP–CA tuna catch for 2006 was estimated at 2,160,314 mt, the second highest annual catch recorded, and only slightly less than the record in 2005 (2,211,546 mt). During 2006, the purse-seine fishery accounted for an estimated 1,553,871 mt (72% of the total catch – 40,000 mt less than the record catch of 2005), with pole-and-line taking an estimated 209,805 mt (10%), the longline fishery an estimated 226,226 mt (10%), and the remainder (8%) taken by troll gear and a variety of artisanal gears, mostly in eastern Indonesia and the Philippines. The WCP–CA tuna catch (2,160,314 mt) for 2006 represented 78% of the total Pacific Ocean catch of 2,771,070 mt and 50% of the global tuna catch estimate, which was slightly less than 4.3 million mt.

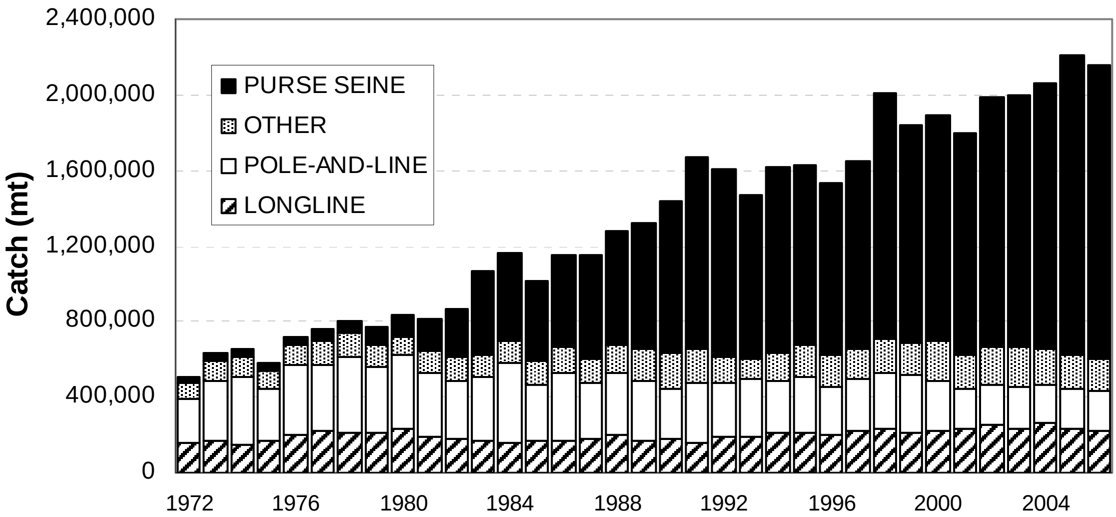


Figure 2. Annual total catch of skipjack, yellowfin, bigeye and albacore tuna, by fishing method, in the WCP–CA.

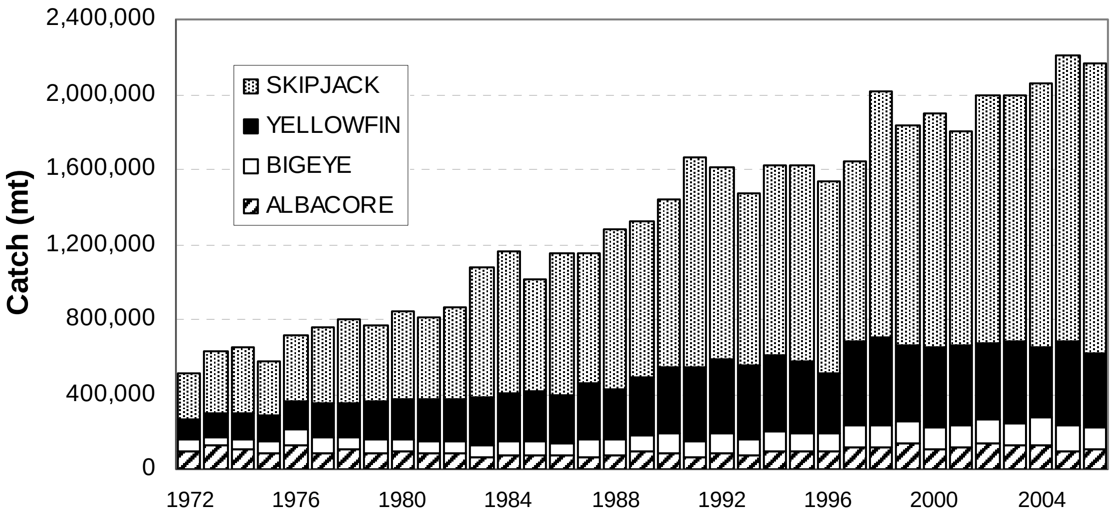


Figure 3. Annual total catch, by species, in the WCP–CA.

The 2006 WCP–CA catch of skipjack (1,539,021 mt – 71% of the total catch) was the highest ever, continuing the trend of consecutive record catches since 2002. The WCP–CA yellowfin catch for 2006 (401,773 mt – 19%) was about 10% lower than in 2005, and slightly lower than the average catch level for the period since 2000. The WCP–CA bigeye catch for 2006 (117,143 mt – 5%) was also lower than in 2005, and lower than the average catch level since 2000–2006. Recent WCP–CA albacore[2] catches (98,618 mt [4%] in 2005 and 102,377 mt in 2006 [5%]) have been the lowest for nearly ten years, mainly due to low catches in the North Pacific.

2 Tuna fishery by gear type

2.1 *Purse-seine*

2.1.1 Historical overview

During the mid-1980s, the purse-seine fishery (400,000-450,000 mt) accounted for only 40% of the total catch, but has grown in significance to a level now contributing around 72% of total tuna catch volume (~1,500,000 mt – Figure 2). The majority of the historic WCP–CA purse-seine catch has come from the four main DWFN fleets – Japan, Korea, Chinese-Taipei and USA, which numbered 147 vessels in 1995, but has gradually declined in numbers to 112 vessels in 2006. In contrast, there has been a steady increase in the number of vessels within Pacific Islands fleets, which totalled 63 vessels in 2006 (Figure 4). The remainder includes a large number of smaller vessels in the Indonesian and Philippines domestic fisheries, and a variety of other domestic and foreign fleets, including several relatively recent distant-water entrants into the tropical fishery (e.g. China, New Zealand and Spain).

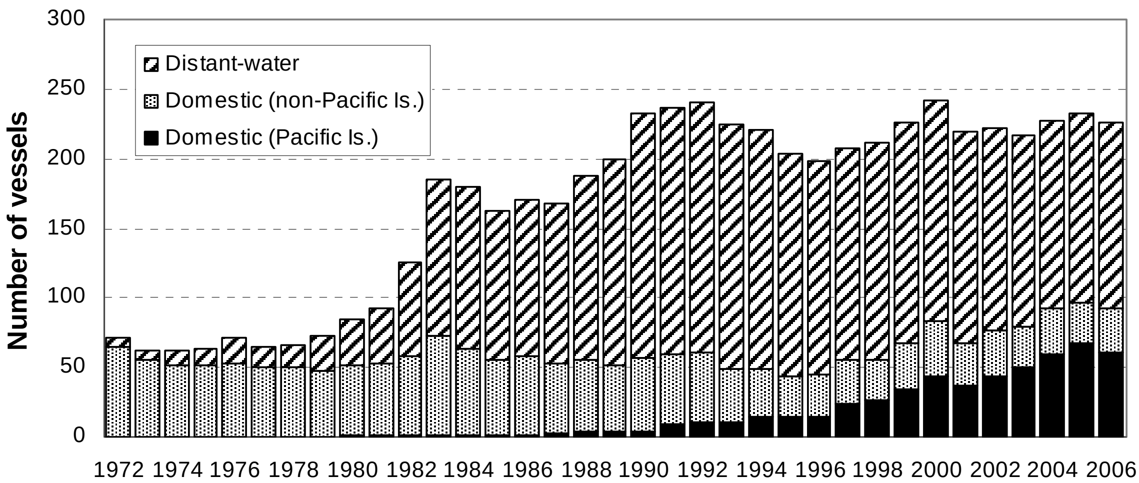


Figure 4. Number of purse-seine vessels operating in the WCP–CA. Domestic (non-Pacific Is.) includes vessels based in Australia, Japan and New Zealand, but not Philippine domestic vessels.

The WCP–CA purse-seine fishery is essentially a skipjack fishery, unlike those of other ocean areas. Skipjack generally account for 70–85% of the purse-seine catch, with yellowfin accounting for 15–30% and bigeye accounting for only a small proportion (Figure 5). Small amounts of albacore tuna are also taken in temperate water purse-seine fisheries in the North Pacific.

Features of the purse-seine catch by species during the past decade include:

- a general increase in the annual skipjack catchfrom about 800,000 mt in the mid 1990s to 1.3 million mt in the most recent years;

[2] includes catches of North and South Pacific albacore in the WCP–CA, which comprised 79% of the total Pacific Ocean albacore catch of 125,521 mt in 2006; the section 3.4 "South Pacific Albacore" is concerned only with catches of South Pacific albacore, which make up approximately 54% of the Pacific albacore catch.

- annual yellowfin catches fluctuating considerably between 115,000 and 270,000 mt. The proportion of yellowfin in the catch is generally higher during El Niño years and lower during La Niña years (for example, 1995/96 and to a lesser extent 1999/2000); and
- an increase in bigeye tuna purse-seine catches during the late 1990s coinciding with the introduction of drifting FADs. Since 2000, bigeye catches have been lower, in the range 24,000–35,000 mt, partially due to a reduction in the use of drifting FADs.

The temporal trend in total purse-seine fishing effort generally corresponded to the increase in the catch (Figure 5).

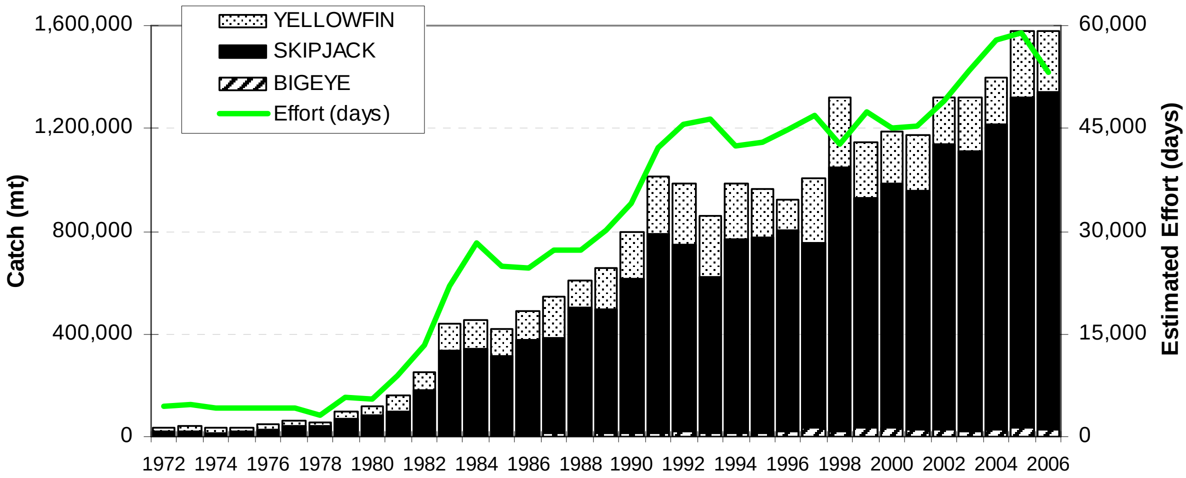


Figure 5. Annual purse-seine catches of skipjack, yellowfin and bigeye tuna and fishing effort (days fishing and searching) in the WCP–CA.

2.1.2 Recent trends

Catch estimates and fleet sizes

The provisional 2006 purse-seine catch of 1,553,871mt was the second highest on record but only 40,000 mt less than the record in 2005 1,592,214 mt). The 2006 purse-seine catch was dominated by a record catch of skipjack tuna (1,306,707 mt – 84% of the total catch), but experienced a drop in yellowfin tuna catch (221,546 mt – 15%) compared to the relatively high level taken during 2005 (252,753 mt). The estimated purse-seine bigeye catch for 2006 (25,376 mt – 2%) was the second-lowest catch over the past ten years. The total estimated purse-seine effort for 2006 was lower than the previous two years (Figure 5), even though the 2006 catch level is on par with 2005, which suggests good catch rates were experienced during 2006.

The total number of Pacific-island domestic vessels has now stabilised at 63 vessels after a period of sustained growth over more than a decade – at its highest level, there were 66 vessels (2005) in this category. The Pacific-islands purse-seine fleets comprise vessels fishing under the FSM Arrangement (30 vessels in 2006), the Vanuatu fleet operating under bilateral arrangements (8 vessels) and domestic vessels operating in PNG and Solomon Islands waters. The FSM Arrangement fleet comprises vessels managed by the Pacific Island "Home Parties" of PNG (18 vessels), the Marshall Islands (5 vessels), FSM (3 vessels), Kiribati (1 vessels) and the Solomon Islands (3 vessels) which fish over a broad area of the tropical WCP–CA.

The domestic Philippine purse-seine and ring-net fleets operate in Philippine and northern Indonesian waters, and have each taken about 150,000 mt in recent years (OFP, 2007). The domestic Indonesian purse-seine and ringnet fleets take a similar catch level which means that around 20% of the WCP-CA purse-seine catch comes from the waters of these countries.

Figure 6 shows the annual trends in the school types set on by the major purse-seine fleets. The proportion of sets on free-swimming (unassociated) schools of tuna declined for all fleets in 2006 (compared to 2005), with a corresponding increase on the number of sets on associated schools (logs and drifting FADs) – this trend was also experienced from 2003 to 2004. Overall, unassociated sets accounted for about 51% of all sets for these fleets during 2006 (compared to around 61% in 2005). The Korean purse-seine fleet predominantly fish on unassociated, free-swimming schools (71% of all sets during 2006), while the other fleets have concentrated on associated-set types in recent years. Of the associated set types, log sets have been favoured over drifting FAD sets by most purse-seine fleets in recent years, with the exception being the US fleet which continues to operate in more eastern (and southern) areas of the WCP–CA concentrating on drifting FAD sets (66%).

'Other' set types, principally comprised of sets associated with anchored FADs, represent an important component of the fishing activity by the FSM Arrangement vessels, particularly the vessels operating in PNG and Solomon Islands archipelagic waters (Figure 6).

Geographical distribution

The purse-seine catch distribution in tropical areas of the WCP–CA is strongly influenced by El Nino–Southern Oscillation Index (ENSO) events. Figure 7 illustrates the effect of ENSO events on the spatial distribution of the purse-seine activity, with fishing effort typically distributed further to the east during El Nino years and a contraction westwards during La Nina periods.

The WCP–CA experienced an ENSO-transitional (or neutral) period during 2001, an El Nino period during 2002 and into the first quarter of 2003, followed by a return to an ENSO-transitional (neutral) period for the remainder of 2003. The ENSO-neutral state continued into the first half of 2004 and then moved to a weak El Nino state in the second half of 2004. During 2005, the WCP–CA was generally in an ENSO-neutral state, moving from a weak El Niño in the early months of 2005 through to a weak La Nina-state by the end of 2005.

The weak La Nina established at the end of 2005 continued into the first part of 2006, but soon dissipated and a weak El Nino event then presided over the remainder of 2006. Fishing activity remained concentrated in the PNG, FSM and Solomon Islands area in the first six months of 2006 (as in previous years), but there was a clear movement eastwards by fleets into Nauru and Kiribati waters in the 3rd and 4th quarters of 2006, perhaps related to the prevailing ENSO conditions.

The distribution of effort by set type Figure 7 (right) for the past seven years shows that the establishment of the El Nino event during 2002 resulted in a higher proportion of log-associated sets east of 160°E than in the previous two years when drifting FADs were used to better aggregate schools of tuna in the absence of logs, and/or where unassociated schools were not as available in this area. The reduction in the use of drifting FAD sets in recent years is probably related to the displacement of effort further west to an area where free-swimming and log-asssociated tuna schools were more available to purse-seine fleets, and therefore less of a need to use drifting FADs. There was a significant increase in the number of log sets made during 2004 suggesting that more logs had moved into the main fishing area and had successfully aggregated tuna schools. The distribution of effort by set type has not changed significantly over the past three years (2004–2006) compared to the earlier periods shown in Figure 7 (right). The mode of fishing to the east of 170°E appears to depend on the availability of free-swimming schools (there were more available during 2005 than in 2004 and 2006, for example).

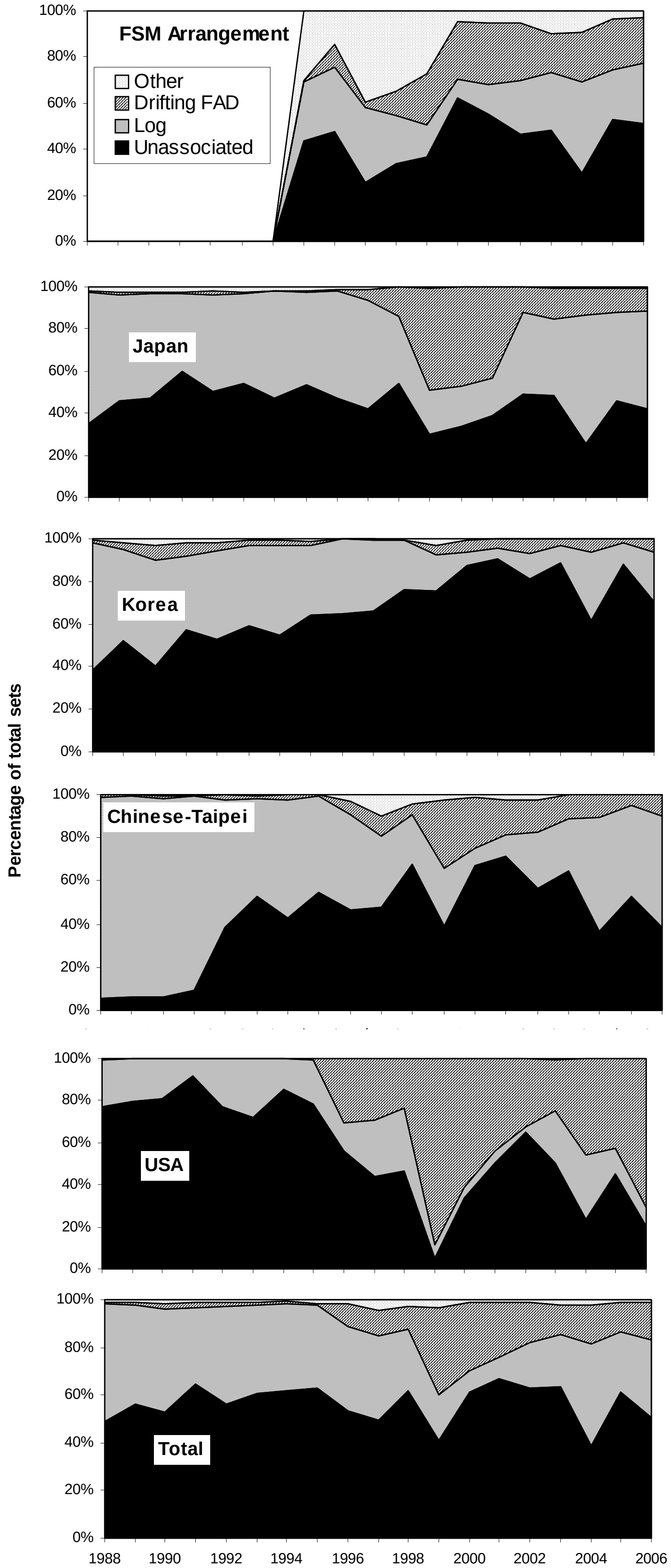


Figure 6. The percentage of total sets by set type for the major purse-seine fleets operating in the WCP–CA.

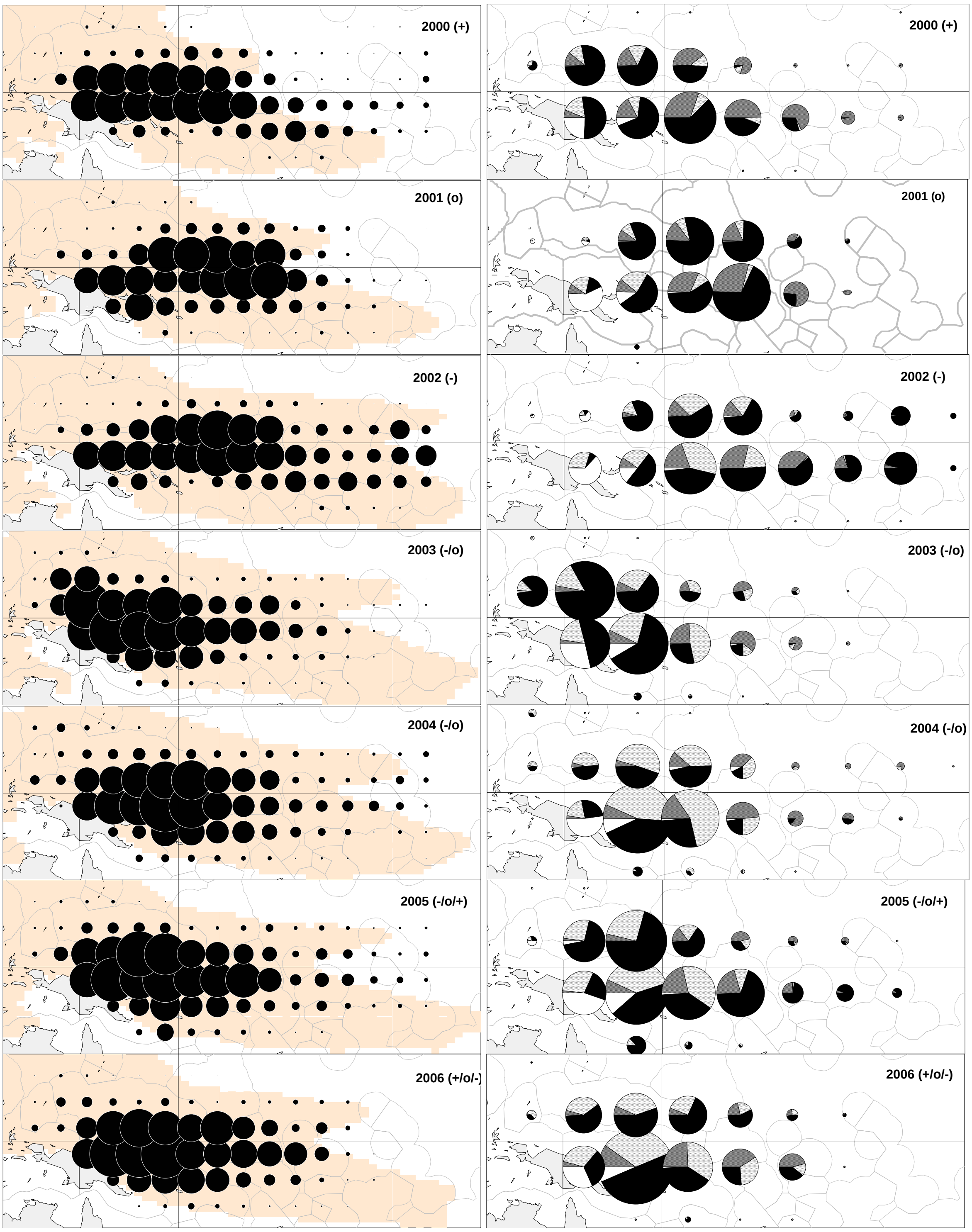


Figure 7. Distribution of purse-seine effort (days fishing – left; sets by set type – right), 2000–2006 (unassociated sets – black; log sets – light grey; drifting FAD sets – dark grey; anchored FAD sets – white). ENSO periods are denoted by: '+' = La Niña; '-' = El Niño; '--' = strong El Niño; 'o' = transition period. The vertical line is the 160°E longitude. Shading represents the extent of average sea surface temperature > 28.5°C

2.2 Pole-and-line

2.2.1 Historical overview

The WCP–CA pole-and-line fishery has several components:

- the year-round tropical skipjack fishery, mainly involving the domestic fleets of Indonesia, Solomon Islands and French Polynesia, and the distant-water fleet of Japan;
- the seasonal subtropical skipjack fisheries in the home waters of Japan, Australia, Hawai'i and Fiji; and
- a seasonal albacore/skipjack fishery east of Japan (largely an extension of the Japanese home-water fishery).

Economic factors and technological advances in the purse-seine fishery (also principally targeting skipjack) have resulted in a gradual decline in the number of vessels in the pole-and-line fishery (Figure 8) and a reduction in the annual pole-and-line fishing effort and catch during the last 15–20 years (Figure 9). These declines have occurred in all pole-and-line fleets over the last decade. Pacific Island domestic fleets have declined in recent years; fisheries formerly operating in Palau, Papua New Guinea and Kiribati are no longer active and only one or two vessels are now operating (seasonally) in Fiji. In the Solomon Islands fishery, fishing activity is starting to increase after problems in recent years. Several vessels continue to fish in Hawai'i and the French Polynesian bonitier fleet remains active, but more vessels have turned to longline fishing. Provisional statistics suggest that the Indonesian pole-and-line fishery has also declined over the past decade.

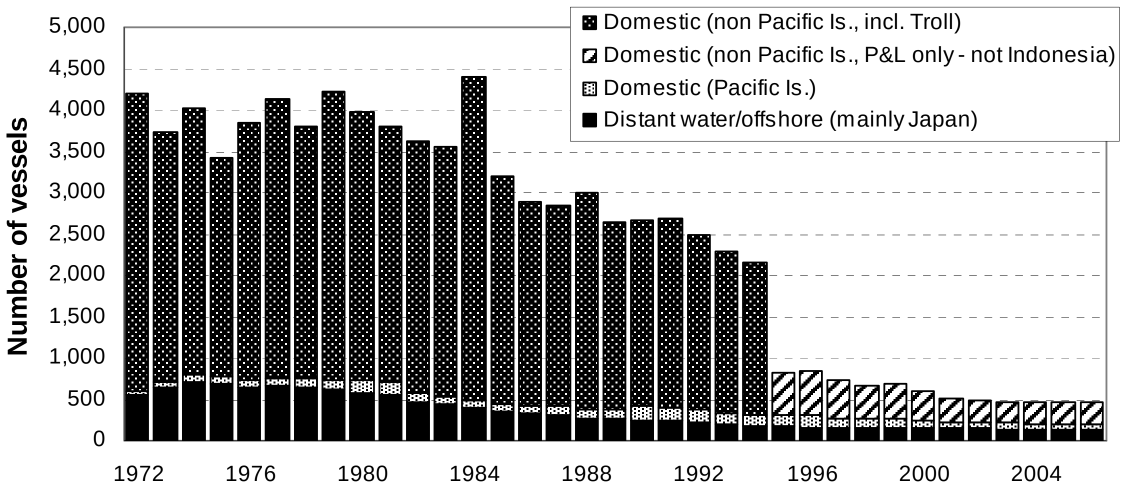


Figure 8. Pole-and-line vessels operating in the WCP–CA. Distinction between troll and pole-and-line gears in the Japanese coastal fleet was not possible for years prior to 1995. Indonesian baitboat fleet is not included.

2.2.2 Recent trends

Catch estimates

The 2006 catch estimates for key pole-and-line fleets operating in the WCP–CA have yet to be provided, although the total catch estimate is expected to be similar to the level of recent years (i.e. 200,000–220,000 mt). Skipjack tends to account for the vast majority of the catch (typically more than 85% of the total catch in tropical areas), while albacore, taken by the Japanese coastal and offshore fleets in the temperate waters of the north Pacific, yellowfin (5–7%) and a small component of bigeye (1–4%) make up the remainder of the catch. The Japanese distant-water and offshore (144,012 mt in 2005) and the Indonesian fleets (44,295 mt in 2006) account for most of the WCP–CA pole-and-line catch. The Solomon Islands fleet (6,988 mt in 2006) has recovered from low catch levels experienced in the early 2000s (only 2,778 mt in 2000 due to civil unrest), but is still far from the level (of over 20,000 mt annually) experienced during the 1990s.

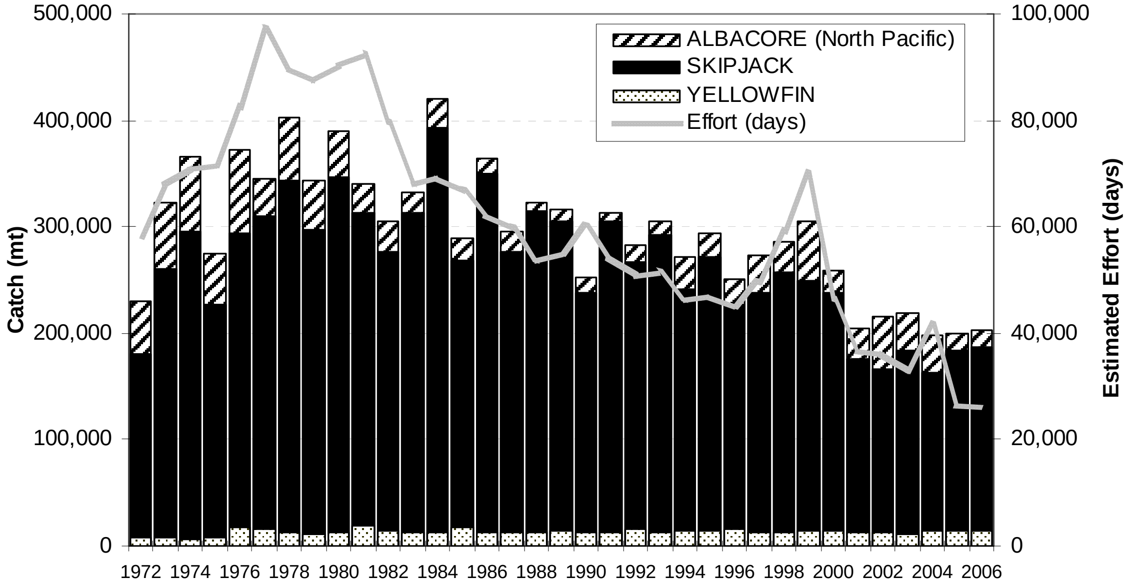


Figure 9. Pole-and-line fishing effort (estimated days) and catch, by species, in the WCP–CA. The 2006 catch figures for Japan were not available but the level of total catch for this fleet was assumed to be equivalent to 2005.

Geographical distribution

Figure 10 shows the average distribution of pole-and-line effort for 1995–2005 – 2006 data are incomplete, but the distribution of fishing effort is likely to be comparable to recent years. Effort in tropical areas is usually year-round and is dominated by the domestic fisheries in Indonesia and Solomon Islands and the Japanese distant-water fishery. Seasonal pole-and-line fisheries operate in the vicinity of Japan, conducted by both offshore and distant-water fleets, with highest effort and catch in the second and third quarters of the year. The effort in French Polynesian waters is essentially the bonitier fleet. Effort by the pole-and-line fleet based in Hawai'i is not included in Figure 10.

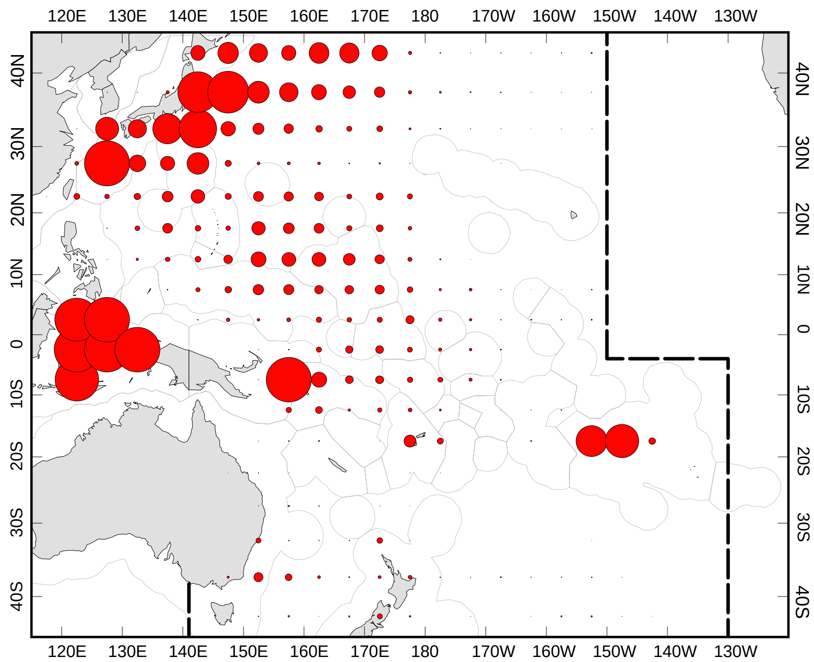


Figure 10. Average distribution of WCP–CA pole-and-line effort, 1995–2005.

2.3 Longline

2.3.1 Historical overview

The longline fishery continues to account for around 10–12% of the total WCP–CA catch (OFP, 2007), but rivals the much larger purse-seine catch in landed value. It provides the longest time series of catch estimates for the WCP–CA, with estimates available since the early 1950s (OFP, 2007). The total number of vessels involved in the fishery has generally fluctuated between 4,000 and 5,000 for the last 30 years (Figure 11).

The fishery involves two main types of operation –

- large (typically >250 GRT) **distant-water** freezer vessels which undertake long voyages (months) and operate over large areas of the region. These vessels may target either tropical (yellowfin, bigeye tuna) or subtropical (albacore tuna) species. Voluntary reduction in vessel numbers by at least one fleet has occurred in recent years;
- smaller (typically <100 GRT) **offshore** vessels which are usually **domestically-based**, undertaking trips of less than one month duration. Their catch is fresh-chilled and dispatched to air-freight sashimi markets or [albacore] canneries.

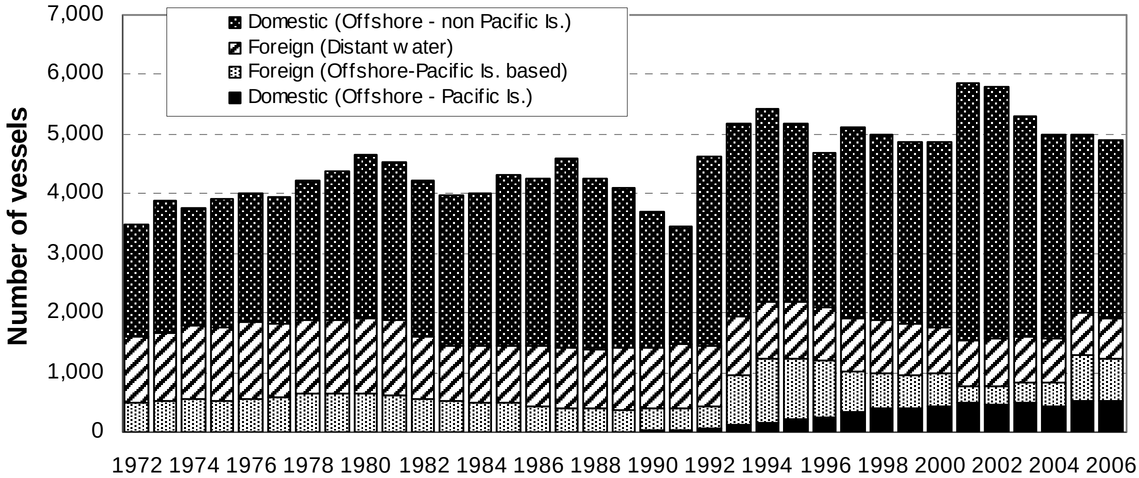


Figure 11. Longline vessels operating in the WCP–CA.

The following broad categories of longline fishery, based on type of operation, area fished and target species, are currently active in the WCP–CA:

- **South Pacific offshore albacore fishery** comprises Pacific-Islands domestic "offshore" vessels, such as those from American Samoa, Cook Islands, Fiji, French Polynesia, New Caledonia, Samoa, Solomon Islands, Tonga and Vanuatu; these fleets mainly operate in subtropical waters, with **albacore** tuna dominating the catch.
- **Tropical offshore bigeye/yellowfin-target fishery** includes "offshore" sashimi longliners from Chinese-Taipei, based in Micronesia, Guam, Philippines and Chinese-Taipei, mainland Chinese vessels based in Micronesia, and domestic fleets based in Indonesia, Micronesian countries, Philippines, PNG, the Solomon Islands and Vietnam.
- **Tropical distant-water bigeye/yellowfin-target fishery** comprises "distant-water" vessels from Japan, Korea, Chinese-Taipei, mainland China and Vanuatu. These vessels primarily operate in the eastern tropical waters of the WCP–CA (and into the EPO), targeting bigeye and yellowfin tuna for the frozen sashimi market.
- **South Pacific distant-water albacore fishery** comprises "distant-water" vessels from Chinese-Taipei, mainland China and Vanuatu operating in the south Pacific, generally below 20°S, targeting albacore tuna destined for canneries.

- **Domestic fisheries in the sub-tropical and temperate WCP–CA** comprise vessels targeting different species within the same fleet depending on market, season and/or area. These fleets include the domestic fisheries of Australia, Japan, New Zealand and Hawaii. For example, the Hawaiian longline fleet has a component that targets swordfish and another that targets bigeye tuna.
- **South Pacific distant-water swordfish fishery** is a relatively new fishery and comprises “distant-water” vessels from Spain.
- **North Pacific distant-water albacore and swordfish fisheries** mainly comprise “distant-water” vessels from Japan (swordfish and albacore), Chinese-Taipei (albacore only) and Vanuatu (albacore only).

Additionally, small vessels in Indonesia, Philippines and more recently in Papua New Guinea target yellowfin by handlining and small vertical longlines, usually around the numerous arrays of anchored FADs in home waters (although, not included in Figure 11). The commercial handline fleets target yellowfin tuna which comprise the majority of the overall catch (> 85%).

The WCP–CA longline tuna catch steadily increased from the early years of the fishery (i.e. the early 1950s) to 1980 (227,707 mt), but declined in the five years after this to 157,072 mt in 1984 (Figure 12). Since 1984, catches steadily increased over the next 15 years until the late 1990s, when catch levels were again similar to 1980. However, the composition of the catch in the late 1970s and early 1980s, a period when yellowfin tuna were targeted (e.g. ALB–19%;BET–27%;YFT–54% in 1980), has become more balanced over the past decade (e.g. ALB–36%;BET–31%;YFT–31%; SKJ–2% in 2006).

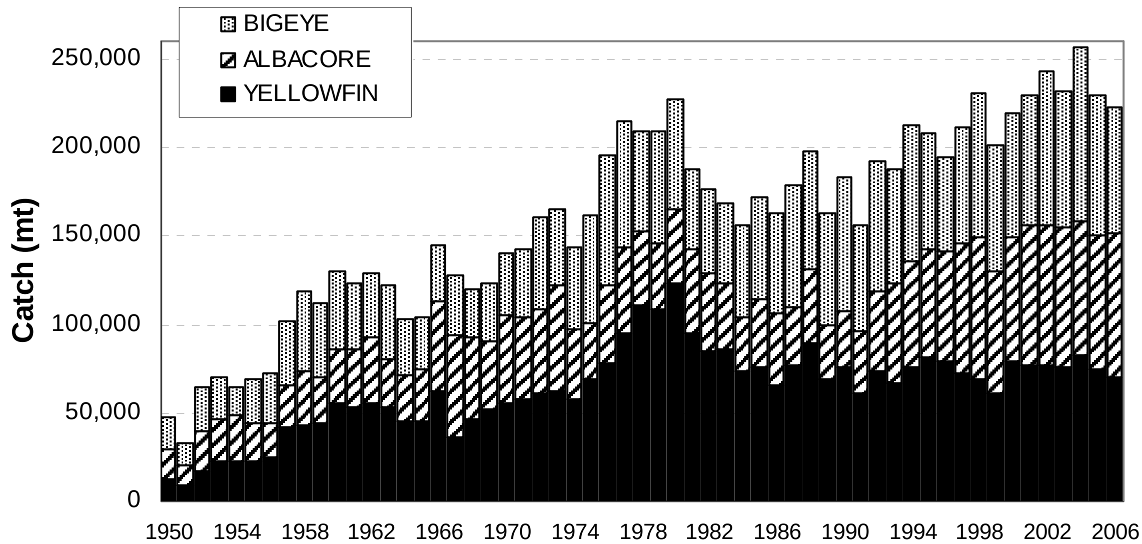


Figure 12. Longline catch in the WCP–CA.

Total longline fishing effort steadily increased following the development of the fishery in the 1950s (**Error! Reference source not found.**). Since the mid-1980s, most of the increase in fishing effort has occurred in the equatorial region of the WCP–CA and effort in this area increased sharply in the late 1990s. The increase in fishing effort directed towards South Pacific albacore, largely by Pacific Island fleets, is evident from the sharp increase in fishing effort south of 10°S during the same period (**Error! Reference source not found.**).

2.3.2 Recent trends

Catch estimates and fleet sizes

The provisional WCP–CA longline catch (226,226 mt) for 2006 was the lowest since 2000 and 14% lower than the highest on record which was attained in 2004 (262,575 mt). The WCP–CA albacore longline catch (81,437 mt – 36%) for 2006 was a record for this fishery. The bigeye catch

(70,919 mt – 31%) for 2006 was the lowest for 5 years, and the yellowfin catch (69,986 mt – 31%), the lowest for 7 years.

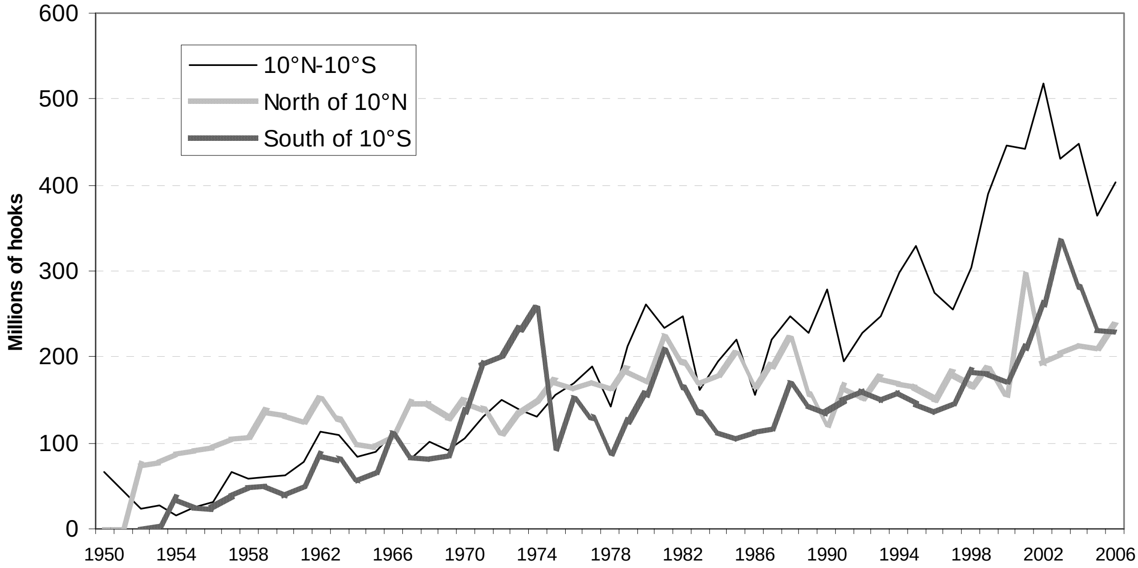


Figure 13. Estimated longline effort (millions of hooks set) by area in the WCP–CA, 1950–2006.

A significant change in the WCP–CA longline fishery over the past 10 years has been the growth of Pacific Islands domestic albacore fishery, which has gone from taking 33% of the total south Pacific albacore longline catch in 1998, to accounting for over 59% of the catch in 2006. The combined national fleets making up the Pacific Islands domestic albacore fishery have numbered around 300 (mainly small "offshore") vessels in recent years.

The clear shift in effort by some vessels in the Chinese-Taipei distant-water longline fleet to targeting bigeye in the eastern equatorial waters of the WCP–CA resulted in a reduced contribution to the albacore catch in recent years (which was compensated by the increase in Pacific-Islands fleet albacore catches), and a significant increase in bigeye catches. During the 1990s, this fleet consistently took less than 2,000 mt of bigeye tuna each year, but in 2002, the bigeye catch went up to 8,741 mt, and by 2004 it was up to 16,888 mt. The 2006 bigeye catch by the Chinese-Taipei distant-water longline fleet declined to 7,841 mt which is thought to be related to a 12% drop in vessel numbers (133 vessels in 2005 to 117 vessels in 2006). The Korean distant-water longline fleet has also experienced a large decline in bigeye and yellowfin catches in recent years, with a corresponding drop in vessel numbers – from 184 vessels active in 2002 down to 130 vessels in 2006 (30% decline).

With domestic fleet sizes continuing to increase at the expense of foreign-offshore and distant-water fleets (Figure 11), the evolution in fleet dynamics no doubt has some effect on the species composition of the catch. For example, the increase in effort by the Pacific-Islands domestic fleets has primarily been in albacore fisheries, although this has been balanced to some extent by the switch to targeting bigeye tuna (from albacore) by certain vessels in the distant-water Chinese-Taipei fleet.

Geographical distribution

Figure 14 shows the distribution of effort by category of fleet for the period 2000–2005 (representing the most recently available data for all fleets, but reflecting the likely distributions for 2006). The large-vessel, distant-water fleets of Japan, Korea and Chinese Taipei account for most of the effort, but there has been a reduction in vessel numbers in some fleets over the past decade. Effort is widespread as sectors of these fleets target bigeye and yellowfin for the frozen sashimi market in central and eastern tropical waters, and albacore in the more temperate waters for canning.

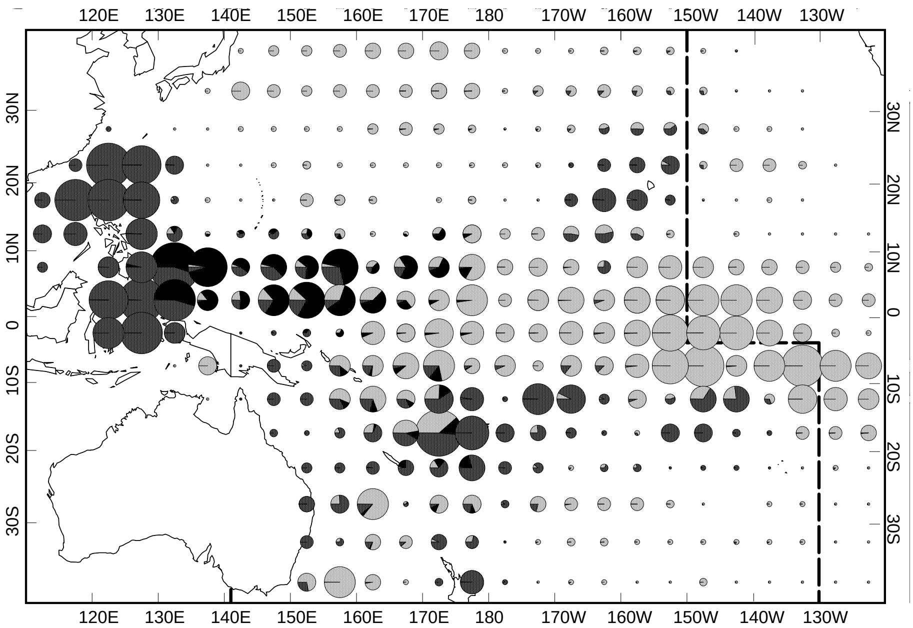


Figure 14. Distribution of longline effort for distant-water fleets (light grey), foreign-offshore fleets (black) and domestic fleets (dark grey) for the period 2000–2005.

Activity by the foreign-offshore fleets from Japan, mainland China and Chinese-Taipei is restricted to the tropical waters, targeting bigeye and yellowfin for the fresh sashimi market; these fleets have limited overlap with the distant-water fleets. The substantial "offshore" effort in the west of the region is primarily by the Indonesian and Chinese-Taipei domestic fleets targeting yellowfin and bigeye. The growth in domestic fleets in the South Pacific over recent years has been noted; the most significant examples are the increases in the American Samoan, Fijian and French Polynesian fleets and the recent establishment of the Niue fleet.

Figure 15 shows species composition of the catch by area for 2003 and 2004 (2005 and 2006 data are incomplete). Most of the yellowfin catch is taken in tropical areas, especially in the western parts of the region, with smaller catches in seasonal subtropical fisheries. The majority of the bigeye catch is also taken from tropical areas, but in contrast to yellowfin this catch is mainly taken in the eastern parts of the WCP–CA, adjacent to the traditional EPO bigeye fishing grounds. The albacore catch is mainly taken in subtropical and temperate waters in both hemispheres. Species composition is likely to vary from year to year in waters where there is some overlap in species targeting, for example in the latitudinal band 10°–20°S.

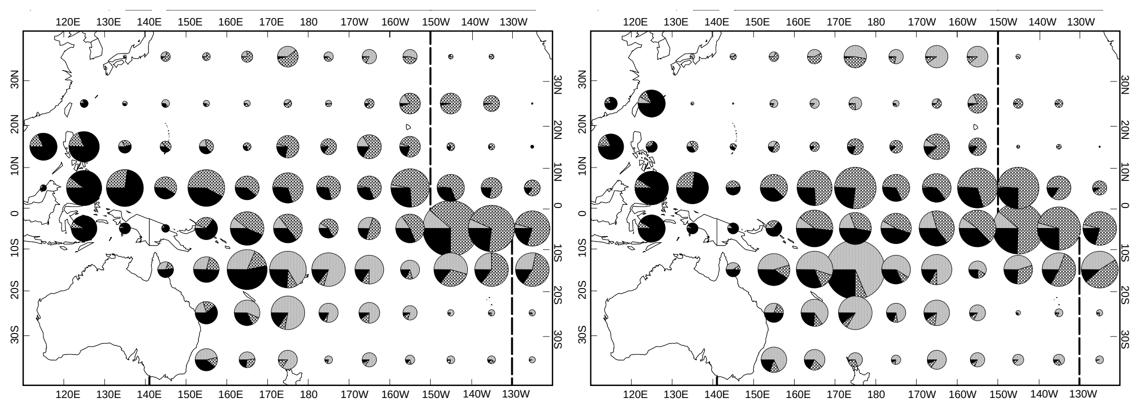


Figure 15. Distribution of longline catch, by species, during 2003 (left) and 2004 (right)
(black = yellowfin tuna; hatching = bigeye tuna; grey = albacore tuna).

(Note that the domestic fleet effort excludes the Japanese coastal fishery and the Vietnam fishery; catches from some distant-water fleets targeting albacore in the North Pacific are not covered.)

2.4 *Troll*

2.4.1 Historical overview

The South Pacific troll fishery is based in the coastal waters of New Zealand, and along the Sub-Tropical Convergence Zone (STCZ; east of New Zealand at about 40°S). The fleets of New Zealand and the United States have historically accounted for most of the catch, which is almost exclusively comprised of albacore tuna (Figure 16).

The fishery expanded following the development of the STCZ fishery after 1986, with the highest catch attained in 1989 (8370 mt). Since then, annual catches have declined to 4000–6000 mt in recent years. The level of effort expended by the troll fleets each year varies relative to the market price (albacore for canning) and expectations of fishing success. There has been a substantial decline in total fishing effort over the last five years (Figure 16).

2.4.2 Recent trends

The 2006 troll albacore catch (2,886 mt) was the lowest for nearly 20 years, and mainly due to a reduction in active vessel numbers and hence overall effort. The fleets of New Zealand (182 vessels caught 2,109 mt in the 2005/2006 season) and USA (8 vessels caught 600 mt in the 2005/2006 season) account for most of the albacore troll catch, with minor catches from the Canadian (2 vessels caught 135 mt in the 2005/2006 season) and the Cook Islands (2 vessels caught 254 mt in the 2005/2006 season) fleets.

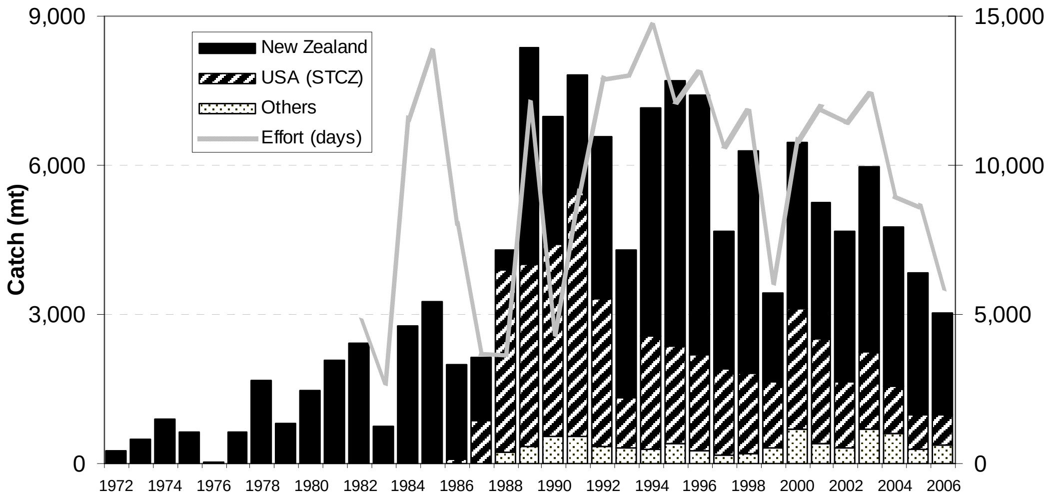


Figure 16. Annual troll fishing effort (days) and catch of albacore tuna in the South Pacific Ocean.

Figure 17 shows the distribution of effort for troll fleets for 2005 and 2006, with effort primarily off the coast of New Zealand and in the Sub-tropical convergence zone (STCZ).

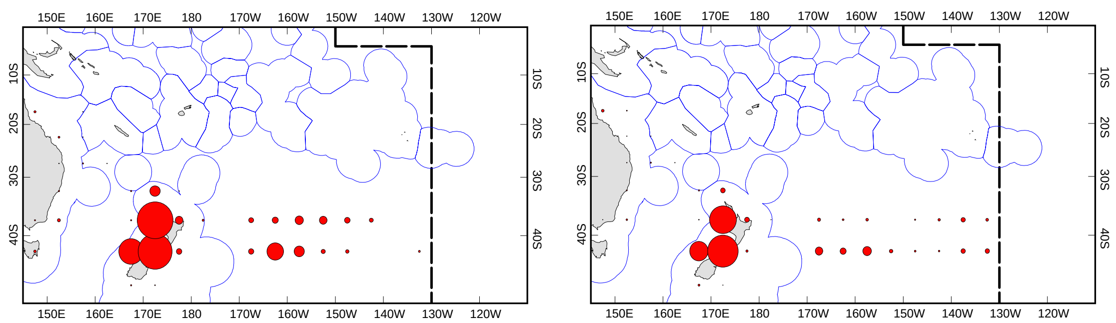


Figure 17. Distribution of South Pacific albacore tuna troll fishery effort during 2005 (left) and 2006 (right).

3 Status of tuna stocks

In this section, we review the status of skipjack, yellowfin, bigeye and South Pacific albacore tuna stocks. The reference area used for skipjack, yellowfin and bigeye tuna is the WCPO as earlier defined. For albacore tuna, we consider the stock within the southern Pacific Ocean, including the area east of the WCPFC boundary.

In each section, the catch history for that species is briefly summarised. Two types of fishery indicators of stock status are then reviewed: trends in catch per unit of effort, and the size composition of catches. In some circumstances, measures based on these variables can provide useful, albeit approximate, indications of the impact of fishing on the stocks. Finally, the results of stock assessment analyses, focusing on the most recent MULTIFAN-CL analyses, are reviewed.

It is important to note that the assessments are still evolving and may change over the next few years as additional data become available and new insights into the statistical properties of the models are obtained. Nevertheless, the results presented represent the best available information on the current status of WCPO tuna stocks.

3.1 Skipjack tuna

3.1.1 Catch

Skipjack tuna is the dominant species in the WCP–CA tuna catch, accounting for nearly two-thirds of the target tuna species catch over the past decade (OFP 2007). This species is taken primarily by purse-seine and pole-and-line gear, with smaller catches by other artisanal gear in eastern Indonesia and the Philippines.

Total skipjack catches in the WCP–CA have increased steadily since 1970, more than doubling during the 1980s, and continuing to increase in subsequent years to exceed 1.4 million mt in each of the last three years (Figure 18). Pole-and-line fleets, primarily Japanese, initially dominated the fishery, and the pole-and-line catch peaked at 380,000 mt in 1984. The relative importance of this fishery has declined over the subsequent years. The increase in skipjack catch during the 1980s was principally due to growth in the international purse-seine fleet and increased catches by domestic purse-seine fleets from the Philippines and Indonesia (accounting for 20–25% of the total WCP–CA skipjack catch in recent years).

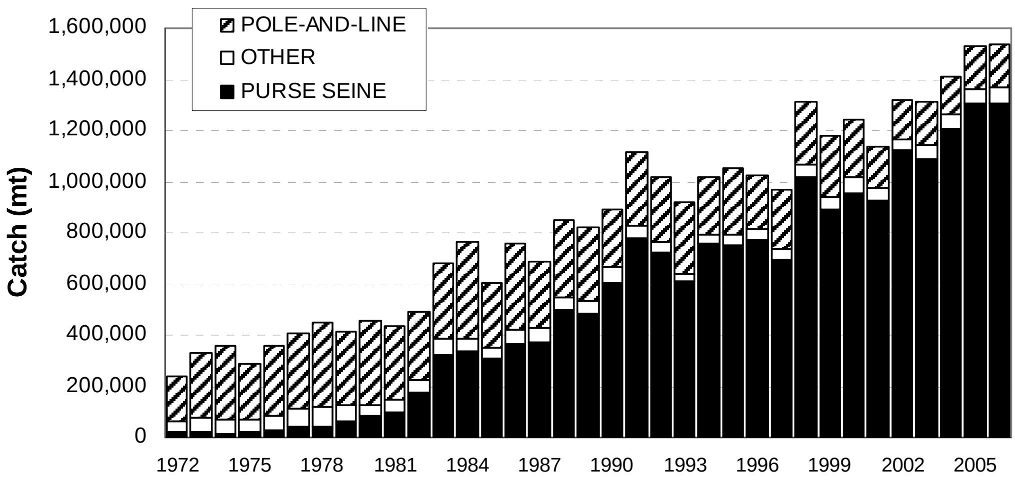


Figure 18. WCP–CA skipjack tuna catch, by gear.

The 2006 WCP–CA skipjack catch of 1,539,021 mt was the third consecutive record catch and 400,000 mt more than the 2001 catch. This new level was attained due to another record catch taken in the purse-seine fishery (1,306,707 mt – 85%). The balance of the catch was taken by the **pole-and-line** gear (172,893 mt – 11%) and **unclassified** gears in Indonesia, Philippines and Japan (~55,000 mt – 4%), while the **longline** fishery accounted for less than 1% of the total catch.

Most of the skipjack catch is taken in equatorial areas, and most of the remainder is taken in the seasonal home-water fishery of Japan (Figure 19). The domestic fisheries in Indonesia (purse-seine, pole-and-line and unclassified gears) and the Philippines (e.g. ring-net and purse-seine) account for the majority of the skipjack catch in the western equatorial portion of the WCP–CA. The central tropical waters are dominated by the purse-seine catches from several foreign and domestic fleets. The spatial distribution of skipjack catch by purse-seine vessels in the central and eastern equatorial areas is influenced by the prevailing ENSO conditions.

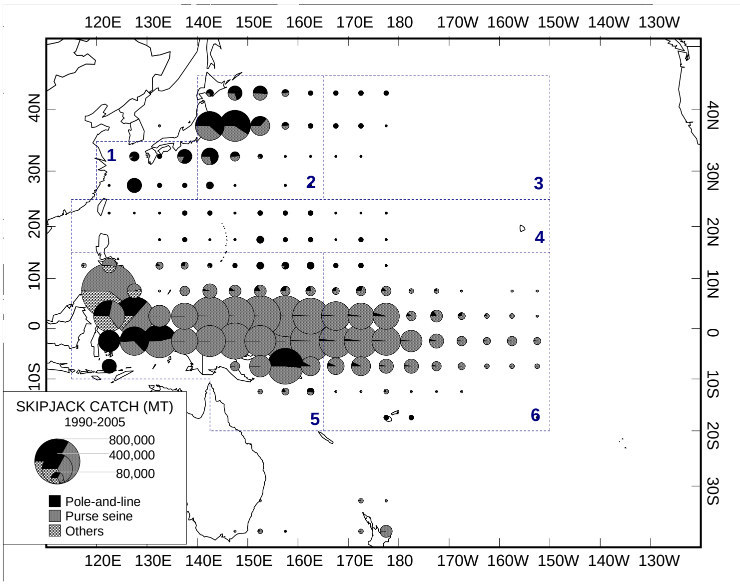


Figure 19. Distribution of skipjack tuna catch, 1990–2005. **The six-region spatial stratification used in stock assessment is shown.**

3.1.2 Catch per unit of effort

Various skipjack tuna CPUE time series can be examined as possible indicators of stock abundance and/or fishery performance. Nominal CPUE series (i.e. simply catch divided by reported effort) for Japanese, USA, Korean and Chinese Taipei purse-seiners by major set types are shown in Figure 20. These fleets are the major purse-seine fleets fishing in the WCP–CA.

The 2006 purse-seine skipjack CPUE for all set types was generally higher than in 2005, with the exception of the US and Korean fleets catches on unassociated (free-swimming) schools. During 2006, high catch rates of skipjack were experienced for log- and drifting FAD-associated sets by all fleets, perhaps suggesting an increase in the efficiency for this style of fishing. The higher (overall) skipjack CPUE during 2006 resulted in a record catch, despite some decline in overall effort expended. Contrary to the period 2000–2004, the skipjack CPUE for the US fleet returned to the level of the other major fleets in recent years. One of the main reasons for this situation is probably the greater overlap in areas fished by the US and other fleets during 2005 and 2006 (compared to previous years) and a higher proportion of associated sets conducted by the US fleet.

Since 1980, there has been a steady increase in total purse-seine skipjack CPUE (Figure 20), related to increased abundance and/or increases in effective effort due to changes in fishing strategy and technological advances in equipment used to locate schools of tuna.

Conversely, since the late 1980s until recently, there was a decline in the nominal catch rate of skipjack tuna from the Japanese distant-water pole-and-line fleet for the entire WCP–CA fishery (Figure 21). However, the declining trend in CPUE appears to be largely due to the spatial shift in the pole-and-line fishery (due to the interaction with the purse-seine fishery), and a standardised analysis of catch and effort data (following Ogura & Shono 1999) that accounts for such factors moderates the trend in nominal CPUE. There is no strong trend in skipjack tuna CPUE from Solomon Islands and Japanese offshore pole-and-line fleets.

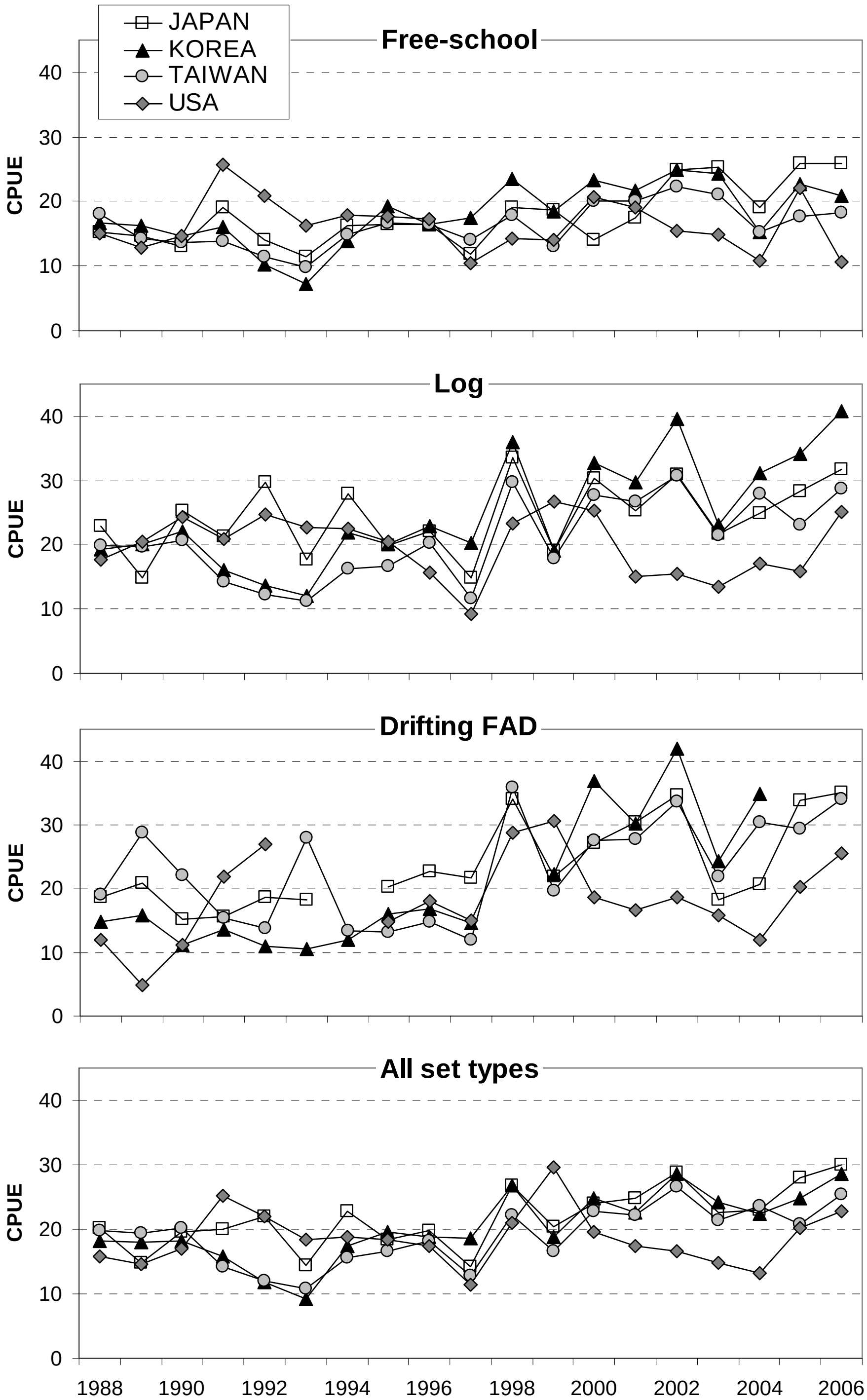


Figure 20. Skipjack tuna CPUE (mt per day) by major set type categories (free-school, log and drifting FAD sets) and all set types for Japanese, Korean, Chinese Taipei and USA purse-seiners fishing in the WCP–CA. **Effort and CPUE were partitioned by set type according to the proportions of total sets attributed to each set type.**

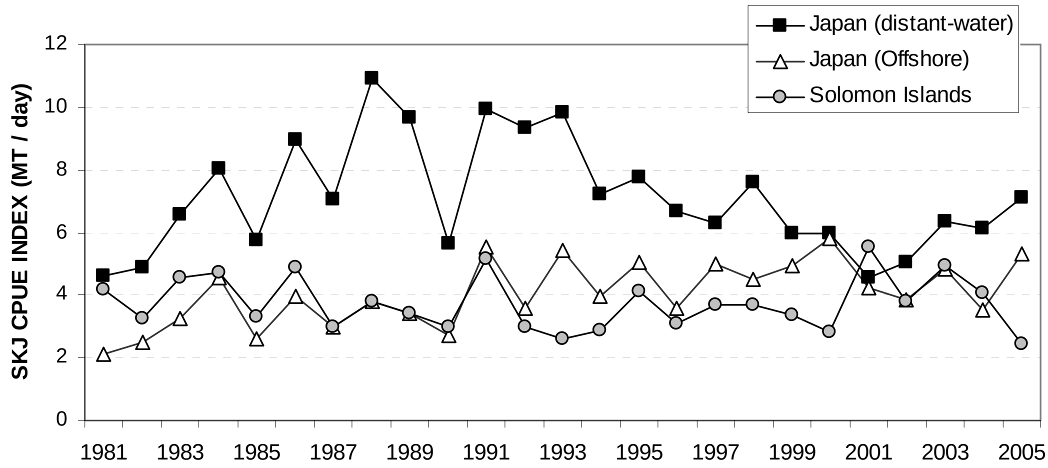


Figure 21. Annual skipjack tuna catch rates (mt per day) for the main WCP–CA pole-and-line fleets.

3.1.3 Size of fish caught

As fisheries become heavily exploited, the size distribution of fish caught often changes (usually with a decline in the proportion of large fish). Therefore, it is useful to monitor the size composition of the catch as another potential indicator of the impact of fishing. Other factors, however, such as variable recruitment and changes in fishing methods, may also impact the catch size composition. Decadal trends in catch-at-size for the Indonesian/Philippine domestic fisheries and the pole-and-line and purse-seine fleets are shown in Figure 22.

The pole-and-line fishery accounted for nearly all of the catch up to the 1980s, but since that time the purse-seine gear and the Indonesian and Philippines fisheries have been dominant. Purse-seine unassociated sets usually take slightly larger skipjack than the pole-and-line and purse-seine associated sets (i.e. log and FAD). In contrast, the Philippine and Indonesian domestic fisheries take much smaller fish and account for most of the WCP–CA skipjack catch in the 20–40 cm size range. The dominant mode in the overall skipjack catch is generally within the 50–60 cm range, corresponding to 1–2-year-old fish.

3.1.4 Stock assessment

An integrated, length-based, age- and spatially structured model known as MULTIFAN-CL (www.multifan-cl.org; Fournier et al. 1998; Hampton and Fournier 2001) is now routinely applied to tuna stock assessment in the WCPO. For skipjack tuna, a six-region stratification of the WCPO (see Figure 2019) similar to that employed by Ogura and Shono (1999) is used.

The most recent assessment of skipjack in the WCPO was conducted in 2005 and included data from 1972 to 2004. Catch, effort and length frequency data, stratified by quarter, for 24 fisheries were used in the analysis: seven purse-seine fisheries, three longline fisheries, Philippine and Indonesian domestic fisheries, and 12 pole-and-line fisheries classified by distant-water, offshore and domestic fleet types. For the distant-water pole-and-line fisheries, estimates of effective (or standardised) effort were derived from a generalised linear modelling (GLM) approach. Tagging data from a number of regional and sub-regional tagging programmes were also incorporated into the analysis.

The model structure included quarterly recruitment, 16 quarterly age classes, independent mean lengths for the first six age classes with von Bertalanffy growth constraining the mean lengths for the remaining age classes, age-specific natural mortality and quarterly movement among the model regions. The model estimated structural time-series variation in catchability for all fisheries, except for the Japanese offshore fisheries and the distant-water pole-and-line fisheries. A more detailed description of the data, the model structure employed for the analysis and the complete set of results is given in Langley et al. 2005 (http://www.wcpfc.int/sc1/pdf/SC1_SA_WP_4.pdf).

The stock assessment included a number of alternative model options, investigating the impact of different assumptions regarding temporal trends in catchability and the spawning stock-recruitment relationship. The summary of the results presented in this report is from the 'base-case' analysis. The results of the other alternative model runs may differ from the base-case analyses; however, the overall conclusions regarding stock status are comparable for the range of models investigated.

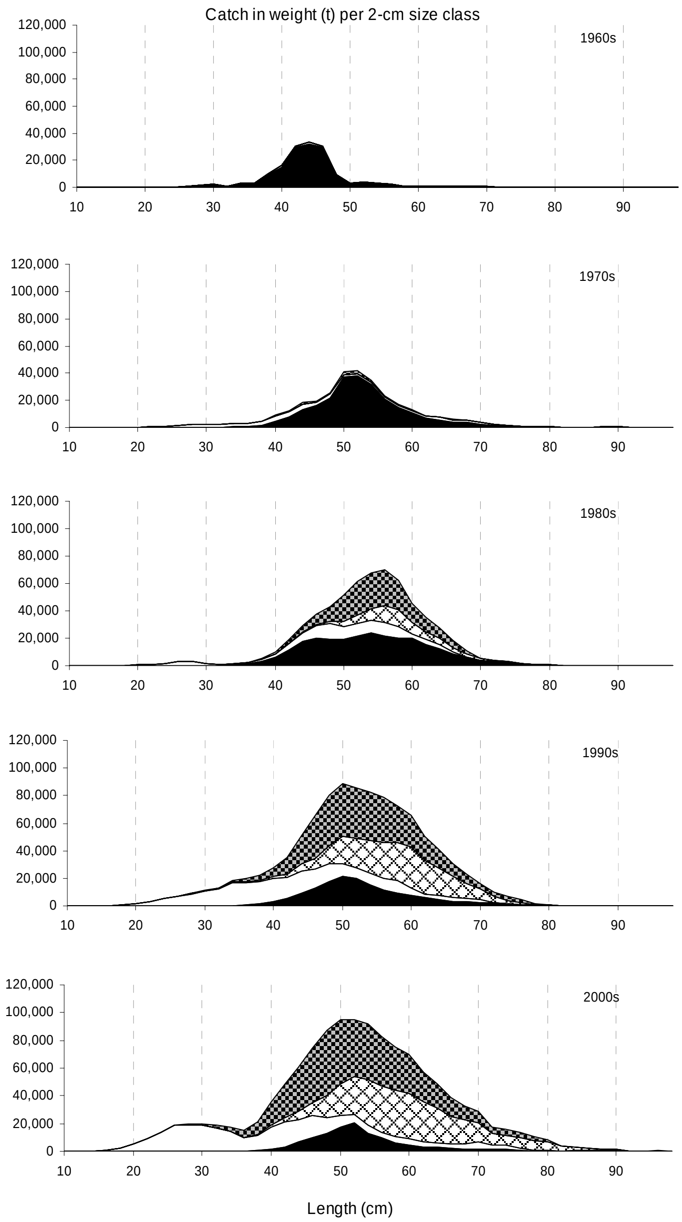


Figure 22. Average annual catches of skipjack tuna in the WCP–CA by size and gear type during decadal periods (black – pole-and-line; white – Phil-Indo fisheries; grey – purse-seine associated; hatching – purse-seine unassociated).

Annual average **fishing mortality rates** for juvenile and adult skipjack tuna for the entire WCPO are presented in Figure 23. Fishing mortality rates for juvenile skipjack remained low throughout the model period, while there has been a general increase in the fishing mortality rates for adult skipjack consistent with the steady increase in total catch from the fishery (see Figure 18).

Recruitment has fluctuated throughout the model period (Figure 24), with low/high recruitment generally associated with La Niña/El Niño events (see Section 4.7). There is also estimated to have been an overall increase in the level of recruitment throughout the model period.

Recruitment in the most recent year that included the model (2004) is estimated to have been extremely high, although the recruitment estimate is highly uncertain.

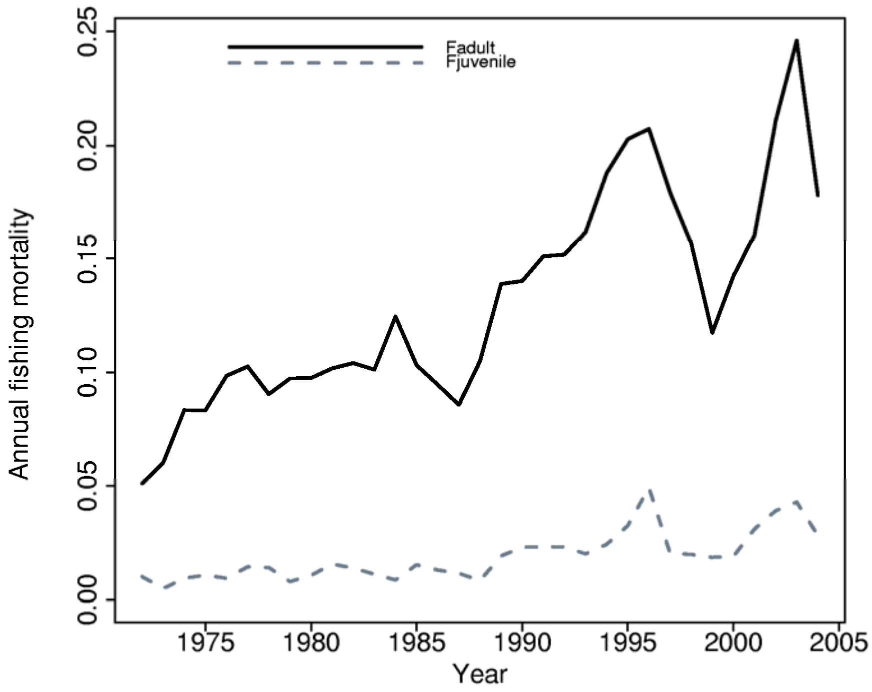


Figure 23. Estimated average annual fishing mortality rates for juvenile and adult skipjack tuna.

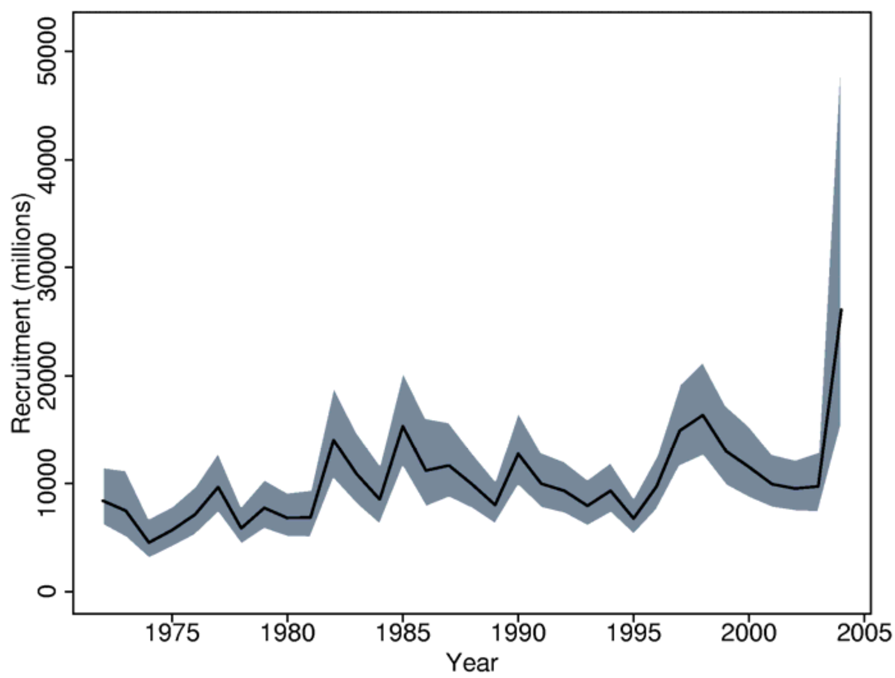


Figure 24. Estimated annual skipjack tuna recruitment (millions) for the WCPO. The shaded area indicates the approximate 95% confidence intervals.

Trends in **total biomass** of skipjack tuna generally follow the temporal trend in recruitment. Total biomass fluctuated through the model period with stock biomass peaking during the mid-1980s and in the late 1990s (Figure 25). Biomass trends are dominated by the trend in biomass from the two equatorial regions of the WCPO, in particular the eastern equatorial region, which is estimated to be lightly exploited.

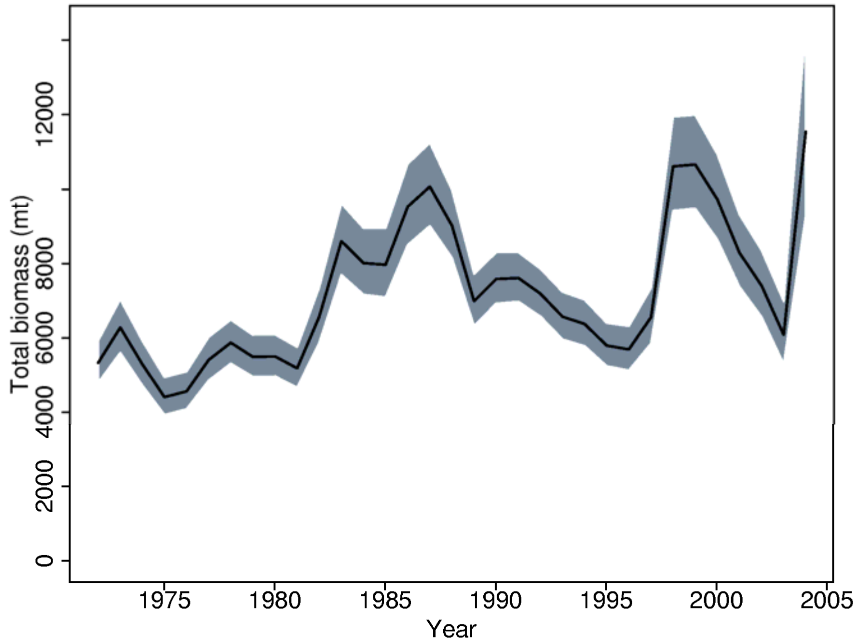


Figure 25. Estimated annual average total skipjack tuna biomass (thousand mt). The shaded area indicates the approximate 95% confidence intervals.

Overall, the **impact of the fishery** on the total level of skipjack biomass in the WCPO is estimated to be low throughout the model period (Figure 26). While the fishery impact has increased over the last two decades, it is estimated to be about 15% in recent years; i.e. the fishery has reduced the level of total biomass by approximately 15%. However, fishery impacts are higher (about 25%) in the western equatorial region – the region that accounts for most of the skipjack tuna catch in the WCPO. Most of the impact is attributable to the catch taken by the purse-seine fishery.

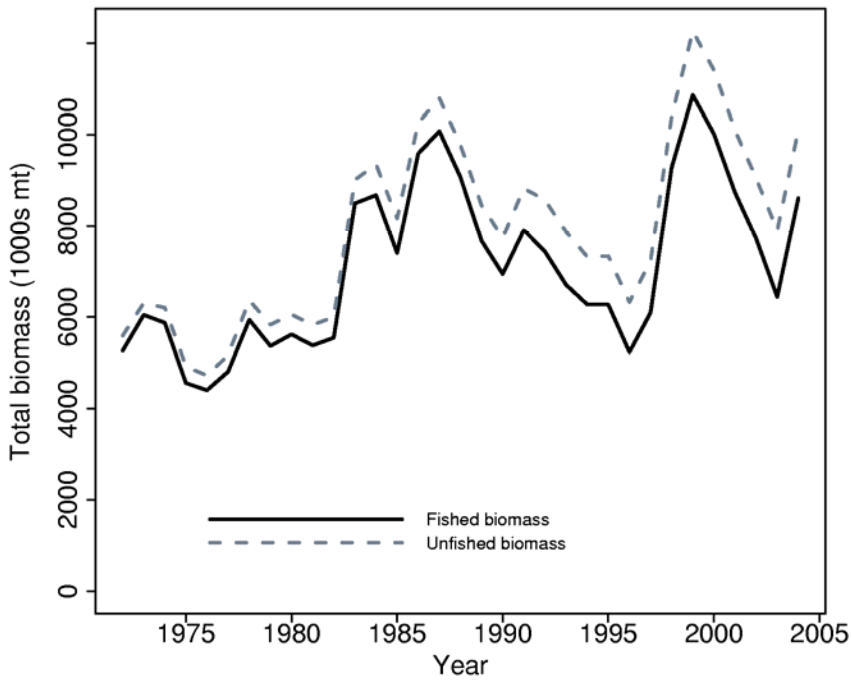
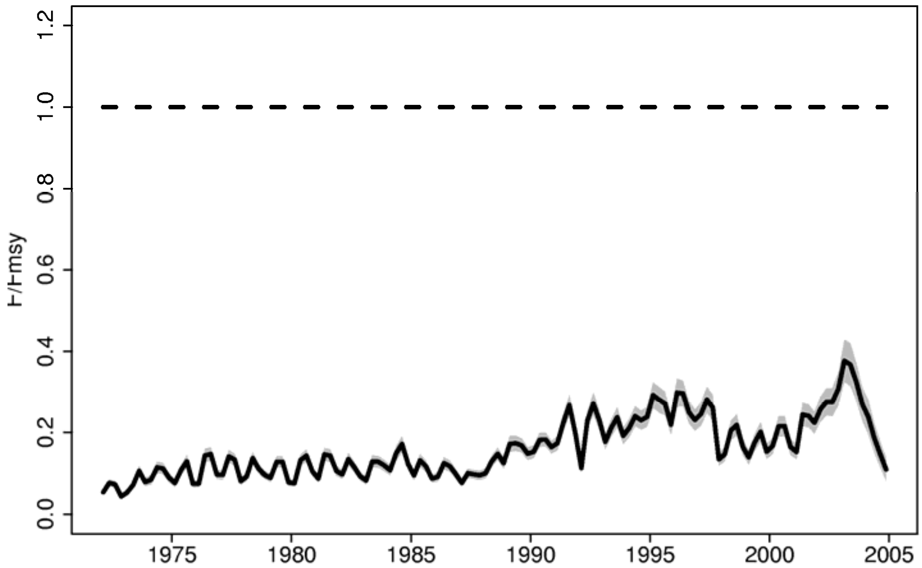


Figure 26. The estimated impact of fishing on WCPO skipjack tuna biomass. The lower biomass trajectory (darker line) represents the model estimates of total biomass. The upper trajectory is the estimated biomass that would have occurred in the absence of fishing, assuming that recruitment was unaffected by fishing.

Conclusion

Current fishing mortality rates are estimated to be well below the F_{MSY} reference point and, therefore, overfishing is not occurring (i.e. $F_{CURRENT} < F_{MSY}$) (Figure 27). The total biomass of skipjack has fluctuated above the biomass-based reference point B_{MSY} and recent biomass levels are estimated to be well above the B_{MSY} level.

Based on these results, the Scientific Committee of the WCPFC noted that the stock is not in an overfished state and that exploitation is modest relative to the stock's biological potential. However, it was further noted that any increase in purse-seine catches of skipjack may result in a corresponding increase in fishing mortality for yellowfin and bigeye tunas.



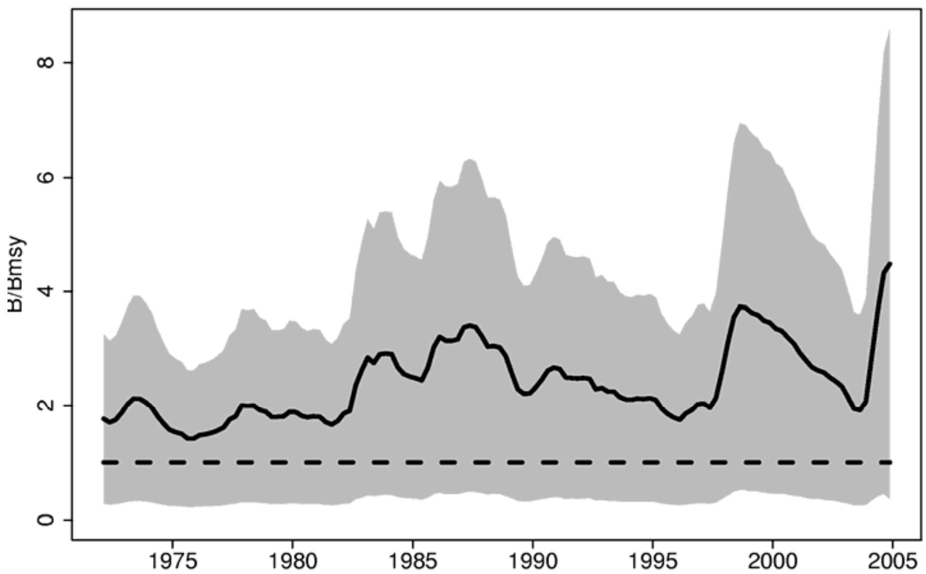


Figure 27. Trends in the biological reference points for the WCPO skipjack tuna stock: fishing mortality relative to the fishing mortality at MSY (top) and total biomass relative to the total biomass at MSY (bottom). The dashed line represents the reference level (MSY).

3.2 *Yellowfin tuna*

3.2.1 Catch

Yellowfin tuna, an important component of tuna fisheries throughout the WCP–CA, are harvested with a diverse variety of gear types, from small-scale, artisanal fisheries in Pacific Island and southeast Asian waters to large, distant-water longliners and purse-seiners that operate widely in equatorial and tropical waters. Purse-seiners catch a wide size range of yellowfin tuna, whereas the longline fishery catches mostly adult fish. Yellowfin tuna usually represent 20–25% of the overall purse-seine catch, but may contribute higher percentages of the catch in individual sets as unassociated schools of large yellowfin tuna are often directly targeted by purse-seiners.

Since 1997, the total yellowfin catch in the WCP–CA has been relatively stable at between 380,000 and 470,000 mt (Figure 28). The 1998 catch was the largest on record (462,882 mt) and followed two years after an unusually low catch in 1996, largely due to poor catches in the purse-seine fishery. Catches in recent years have been relatively stable, although the 2004 catch (366,866 mt) was the lowest since 1996. The 2006 catch (401,773 mt) is slightly below the average level for the last 10 years, with no significant deviation from recent catch levels in any of the fisheries. The purse-seine catch for 2006 (221,546 mt – 55% of the total WCP–CA yellowfin catch) was lower than the 2005 level, but still one of the highest catches over the past ten years. In recent years, the yellowfin longline catch has ranged 75,000–82,000 mt, which is well below catches taken in the late 1970s to early 1980s (90,000–120,000 mt), presumably related to changes in targeting practices by some of the large fleets and the gradual reduction in the number of distant-water vessels. The WCP–CA **longline** catch for 2006 was 69,986 mt (17% of the total WCP–CA yellowfin catch), the lowest catch since 1999. The reduction in vessels numbers from Asian fleets fishing in the tropical central Pacific is thought to be one of the main reasons for the decline in catches.

The high catches of yellowfin experienced recently in the EPO (annual catches of over 400,000 mt for 2001–2003) were not sustained in 2004 and 2005, and dropped significantly in 2006 (181,246 mt) to a level not experienced since the mid-1980s.

The **pole-and-line** fisheries took 14,286 mt (4% of the total yellowfin catch) during 2006, and **'other'** category accounted for close to 100,000 mt (which was 24% of the total catch for all gears). Catches in the '**other**' category are largely composed of yellowfin taken by various assorted gears (e.g. ring net, bagnet, gillnet, handline and seine net) in the domestic fisheries of the Philippines and eastern Indonesia[3]. Figure 29 shows the distribution of yellowfin catch by gear type for 1990–2005 (data for 2006 are incomplete). As with skipjack, most of the catch is taken in equatorial areas by large purse-seine vessels, and a variety of gears in the Indonesian and Philippine fisheries.

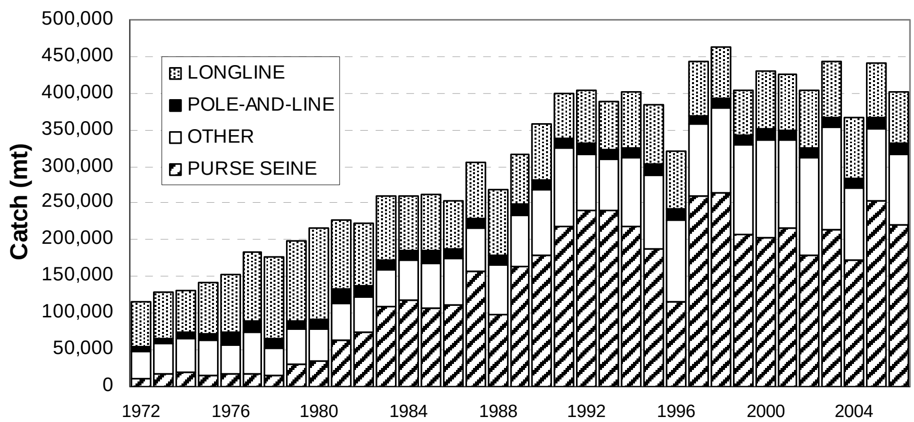


Figure 28. WCP–CA yellowfin tuna catch, by gear.

[3] Indonesia has recently revised the proportion of catch by species for their domestic fisheries which has resulted in differences in species composition by gear type since 2004 compared to what has been reported in previous years.

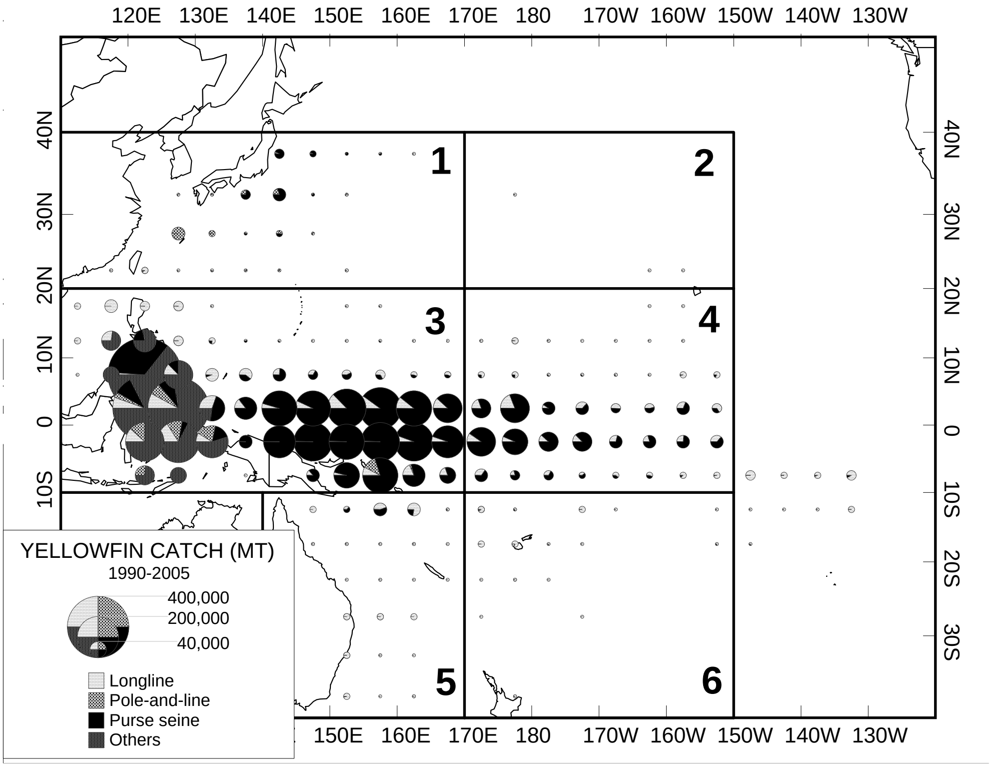


Figure 29. Distribution of yellowfin tuna catch, 1990–2005. **The six-region spatial stratification used in stock assessment is shown.**

The east–west distribution of the purse-seine yellowfin catch is strongly influenced by ENSO events, with larger catches taken east of 160°E during El Niño episodes. In recent years, there has been considerable interannual variation in the distribution of purse-seine yellowfin catch by set type (Figure 30). Higher proportions of yellowfin in the overall catch (by weight) usually occur during El Niño years as fleets have access to 'pure' schools of large yellowfin that are more available in the eastern tropical areas of the WCP–CA. There was evidence of this phenomena during 2001 (Figure 30) and for the most recent El Niño year (2002). In contrast, during recent La Niña years, drifting FADs and log sets east of 160°E accounted for a significant proportion of the total purse-seine catch of yellowfin. Yellowfin comprised a higher proportion of the total purse-seine catch in 2005 and 2006 than in 2004, with most of the yellowfin catch taken from unassociated sets (Figure 30).

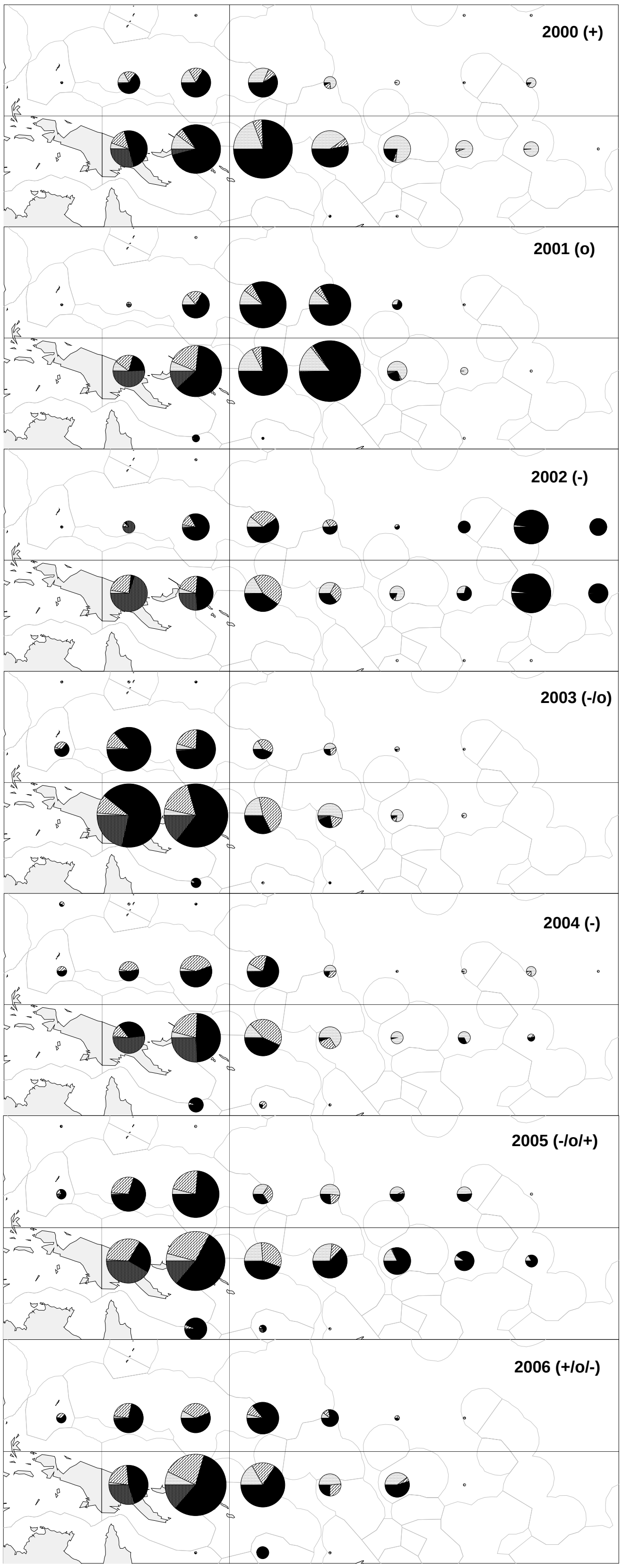


Figure 30. Distribution of purse-seine yellowfin catch by set type, 2000–2006 **(solid – unassociated; striped – log; light grey – drifting FAD; dark grey – anchored FADs). ENSO periods are denoted by '+': La Niña; '-': El Niño; '--': strong El Niño; '0': transitional period. The horizontal and vertical lines represent the equator and 160°E respectively.**

3.2.2 Catch per unit of effort

Yellowfin purse-seine CPUE is characterised by strong interannual variability and differences among the fleets (Figure 31). School-set CPUE is strongly related to ENSO variation in the WCPO, with CPUE generally higher during El Niño episodes. This is believed to be related to increased catchability of yellowfin tuna due to a shallower surface-mixed layer during these periods. ENSO variability is also believed to impact the size of yellowfin and other tuna stocks through impacts on recruitment. In line with this hypothesis, the purse-seine fishery generally experienced a decline in yellowfin CPUE during La Niña periods (1995–96 and 1999–2000), while higher CPUE was experienced during previous strong El Niño years (1994–1995 and 1997–98).

Yellowfin CPUE for 2006 was generally lower than in 2005, but not as low as in 2004, acknowledged to be a year with poor yellowfin catches (Figure 31). Associated (log and drifting FAD) sets generally produce higher catch rates (mt/day) for skipjack than unassociated sets, yet unassociated sets produce a higher catch rate for yellowfin than associated sets. This is mainly due to unassociated sets in the eastern areas of the tropical WCP–CA taking large, adult yellowfin, which account for a larger catch (by weight) than the (mostly) juvenile yellowfin encountered in associated sets. Yellowfin catch rates for the first half of 2006 were at a similar level for each of the set types (Williams and Reid, 2007), but the yellowfin CPUE for unassociated sets had improved by the end of 2006, suggesting that unassociated schools with large yellowfin were perhaps available in the second half of 2006. Since 1998, there has been a general decreasing trend in yellowfin tuna CPUE for the purse-seine fishery (Figure 31).

The distant-water longline fishery, which has operated since the early 1950s, provides another means of monitoring changes in yellowfin tuna abundance. As longliners target larger fish, the CPUE time series should be more indicative of adult yellowfin tuna abundance. However, as with purse-seine CPUE, the interpretation of longline CPUE is confounded by various factors, such as the changes in fishing depth that occurred as longliners shifted from primarily yellowfin tuna targeting in the 1960s and early 1970s to target bigeye tuna from the late 1970s onwards. Such changes in fishing practices will have changed the effectiveness of longline effort with respect to yellowfin tuna, and need to be accounted for if the CPUE time series are to be interpreted as indices of relative abundance.

For the 2007 stock assessment, a GLM approach was applied to standardise the Japanese longline CPUE time series to account for the temporal changes in fishing operation. The details of the analysis are described in Langley et al. (2005b) and the resulting indices derived for each of the main fishery regions (see Figure 29) are presented in Figure 32. These indices were used in the 2007 stock assessment as the principal indices of relative abundance for the portion of the yellowfin stock vulnerable to the longline fishery (see Section 3.2.4).

The western equatorial region (region 3) accounts for most of the catch from the yellowfin fishery. The CPUE indices for this region decline steadily from the development of the fishery in the 1950s to approximately a third of the initial CPUE level in the most recent years (Figure 32). There is considerable variation in the CPUE trends among the other regions, although a number of the regions reveal strong declines in CPUE following the initial development of the fishery. These declines are considered too great to represent the biomass trend in the entire region; rather, they may be due to hyperdepletion in localised areas within the region.

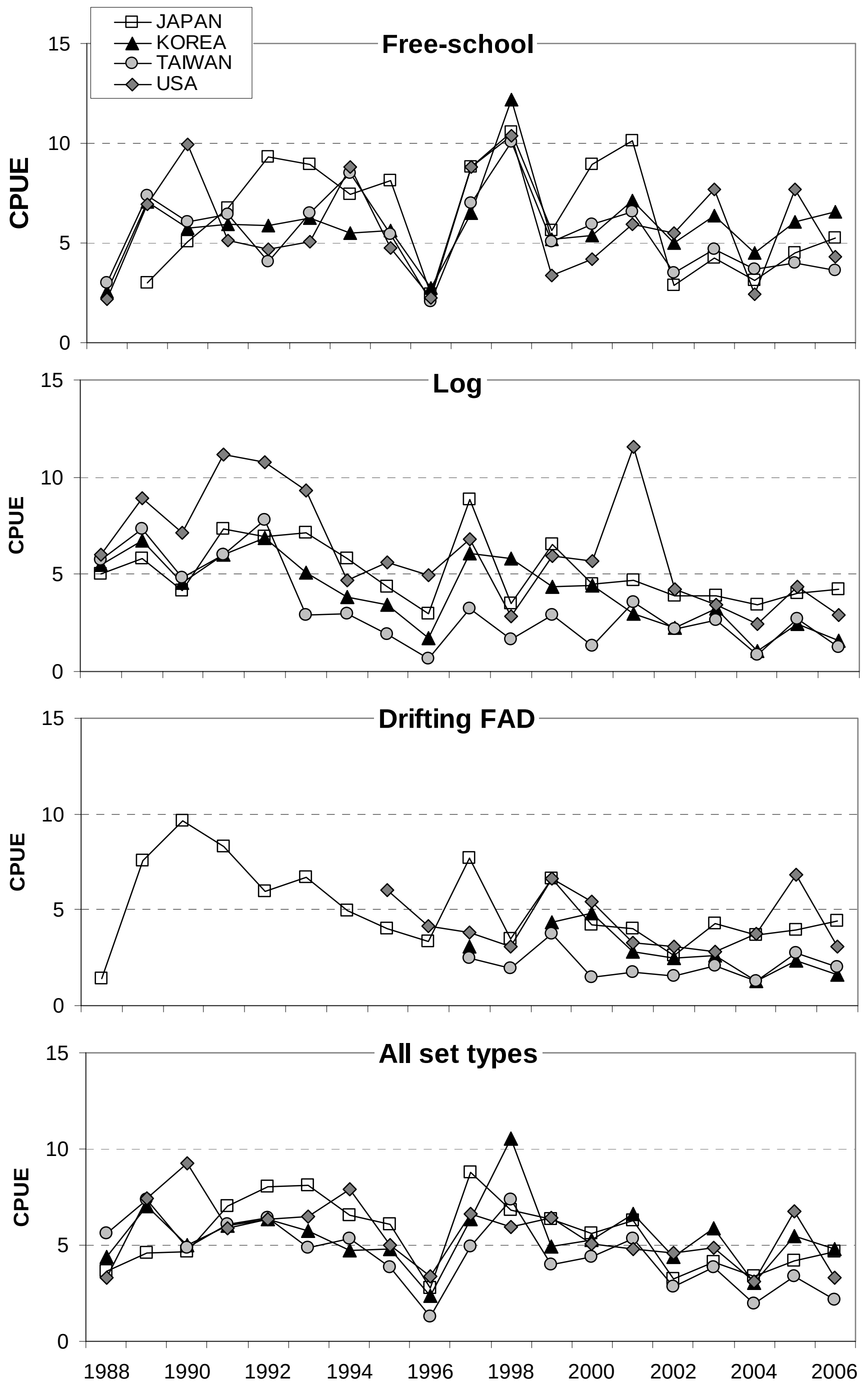


Figure 31. Yellowfin tuna CPUE (mt per day) by major set type categories (free-school, log and drifting FAD sets) and for all sets combined for Japanese, Korean, Chinese Taipei and USA purse-seiners fishing in the WCP–CA. **Effort and CPUE were partitioned by set type according to the proportions of total sets attributed to each set type.**

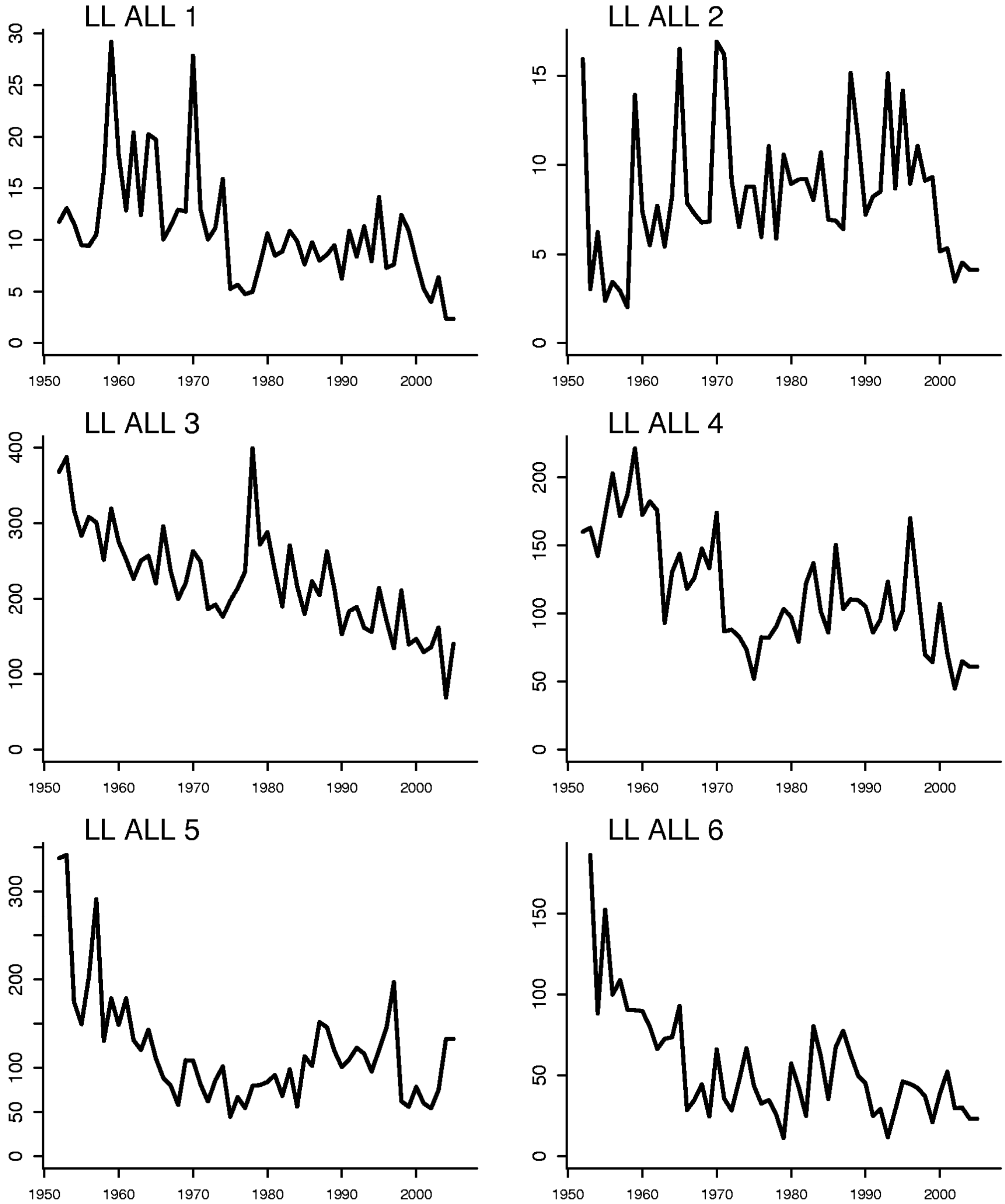


Figure 32. Annual trends in yellowfin GLM standardised CPUE indices for the Japanese longline fleet by MFCL region. The region (X) is denoted by the number in the fishery code (LL ALL X).

3.2.3 Size of fish caught

Average annual yellowfin tuna catch-at-size for the Indonesian/Philippine domestic fisheries and the longline and purse-seine fisheries is shown in Figure 33. The domestic surface fisheries of the Philippines and Indonesia take large quantities of small yellowfin (20–50 cm). Purse-seine sets on floating objects (i.e. associated schools) generally take smaller fish than sets on unassociated or free-swimming schools, which are often ‘pure’ schools of large, adult yellowfin. Yellowfin taken in unassociated purse-seine sets are of a similar size to fish taken in the longline fishery and the handline fishery in the Philippines (both gears target adults in the range 80–160 cm). The purse-seine catch of adult yellowfin tuna, on average, has been higher than the longline catch over the past 10–15 years.

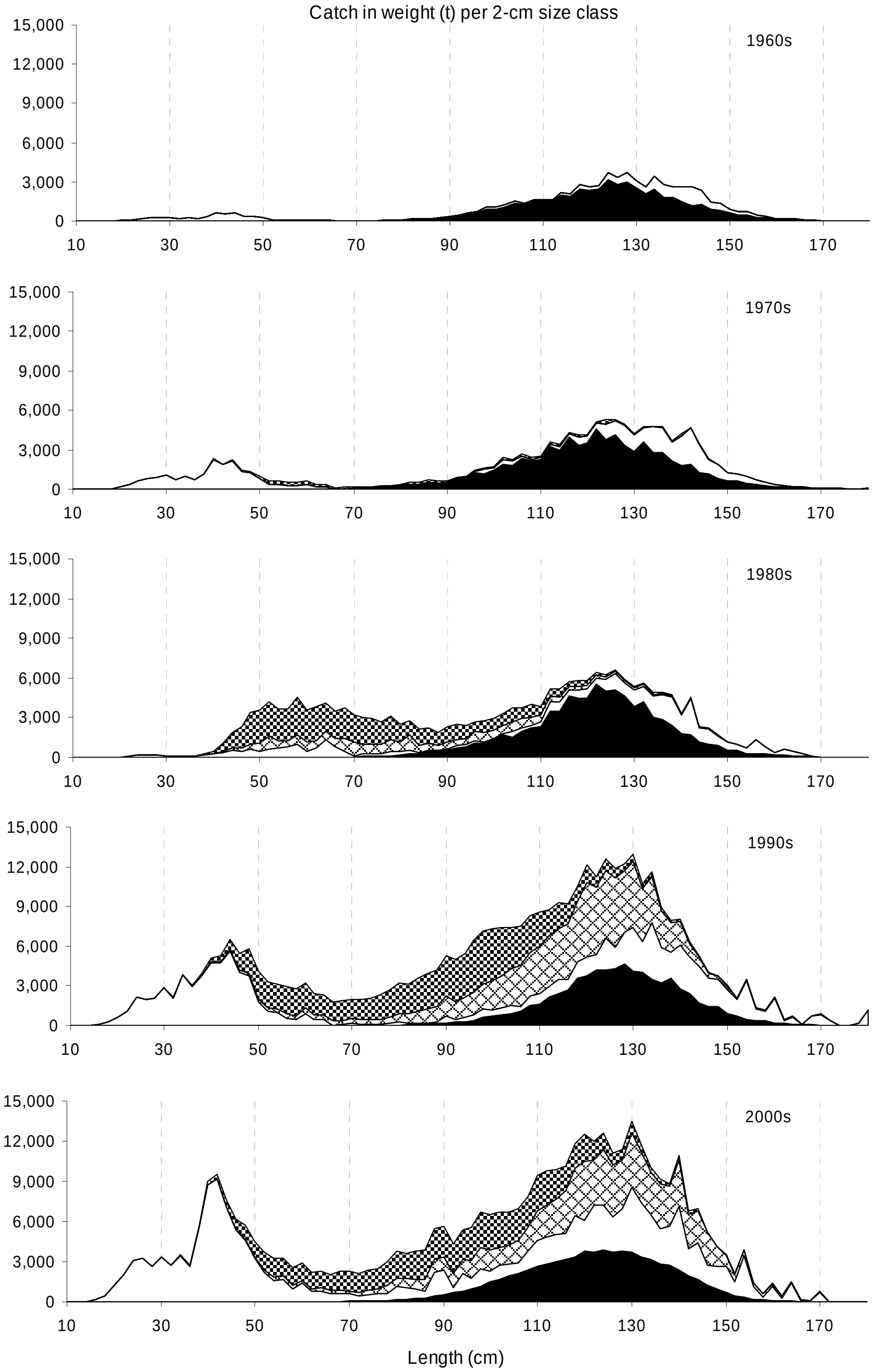


Figure 33. Average annual catches of yellowfin tuna in the WCP–CA by size and gear type during decadal periods (black – longline; white – Phil-Indo fisheries; small hatching – purse-seine associated; large hatching – purse-seine unassociated).

3.2.4 Stock assessment

The most recent application of the MULTIFAN-CL model to yellowfin tuna in the WCPO included a six-region spatial stratification (see Figure 29). The model encompasses 1952–2006, with the time period stratified by quarter. The model structure includes quarterly recruitment, 28 quarterly age classes, independent mean lengths for the first eight age classes with von Bertalanffy growth constraining the mean lengths for the remaining age classes, structural time-series variation in catchability for all non-longline fisheries, age-specific natural mortality, and quarterly movement among the model regions.

Catch, effort and size data (both length and weight frequency), stratified by quarter, for 24 fisheries (14 longline, an Indonesian domestic fishery, Philippine handline and domestic fisheries, two Japanese coastal fisheries, an equatorial pole-and-line fishery, and four equatorial purse-seine fisheries classified by associated and unassociated sets) were used in the analysis. For the longline fisheries, estimates of effective (or standardised) effort were derived from a GLM approach (Langley et al. 2005). Tagging data from a number of regional and sub-regional tagging programmes were also incorporated into the analysis. A more detailed description of the data, the model structure employed for the analysis and the complete set of results is given in Langley et al. 2007 (http://www.wcpfc.int/sc3/pdf/WCPFC-SC3%20SA-SWG%20WP-01.pdf).

The 2007 stock assessment included a number of alternative model options, investigating the influence of a number of different data sets and structural assumptions. The summary of the results presented in this report are from the 'base-case' analysis, using a six-region spatial structure and a relatively low weighting of the size frequency data. The details of this assessment may differ from the other analyses; however, the overall conclusions are similar to the other assessment models.

Annual average **fishing mortality rates** for juvenile (less than 100 cm) and adult yellowfin tuna for the WCPO as a whole are shown in Figure 34. Fishing mortality rates for both juvenile and adult yellowfin tuna increased continuously from 1970 until recent years, with juvenile fishing mortality rates increasing sharply from 1990 to a level higher than adult yellowfin in the late 1990s. The model suggests that fishing mortality rates declined slightly in the last few years, although fishing mortality rates for this period are poorly estimated.

Recruitment estimates for the entire WCPO region indicate considerable variation about the level of average recruitment. Initial recruitment was relatively high but declined to a lower level during the early 1970s. Recruitment increased during the late 1970s and remained relatively high during the 1980s (Figure 35). There was a general decline in recruitment during the 1990s, while recent recruitment approached the long-term average level.

The **biomass** trajectory is comparable to the temporal trend in recruitment. Biomass declined during the 1960s and early -1970s, before increasing in the mid-1970s (Figure 36). Biomass levels remained relatively stable during the 1980s then declined steadily from 1990 onwards, largely due to the decline in the biomass in the western equatorial region – the area accounting for most of the total yellowfin catch.

The **impact of fishing** on the total biomass was insignificant prior to 1980, but has steadily increased in the subsequent period as catches and fishing mortality have increased (Figure 37). Fishing is estimated to have reduced the overall stock biomass by about 40% in recent years. The impact is considerably higher in the tropical regions (about 60%) compared to the subtropical regions. Furthermore, the attribution of depletion to various fisheries or groups of fisheries indicates that the Philippine/Indonesian domestic fishery has the greatest impact, particularly in its home region. The purse-seine fishery also has high impact, particularly in the equatorial regions (Figure 38).

Conclusion

Since 1990, the biomass of yellowfin in the WCPO has steadily declined and fishing mortality rates have increased to the extent that current exploitation rates approximate the F_{MSY} reference point and there is a high probability (47%) that overfishing is occurring (Figure 39). The stock is not yet in an overfished state (i.e. $B_{CURRENT} > B_{MSY}$), although there is a relatively high probability that continued fishing at current levels of effort will move it to an overfished state. Further, the assessment indicates that the equatorial regions are likely to be overexploited, while exploitation rates in the subtropical regions are relatively low.

Based on these results, the Scientific Committee of the WCPFC recommended that fishing mortality on the WCPO yellowfin stock be reduced from recent levels (2002–2005) to reduce the likelihood of overfishing. Higher reductions in fishing mortality would be required to maintain the biomass at higher levels relative to B_{MSY}. It was also noted that more urgent management actions may be required in the western equatorial region of the WCPO.

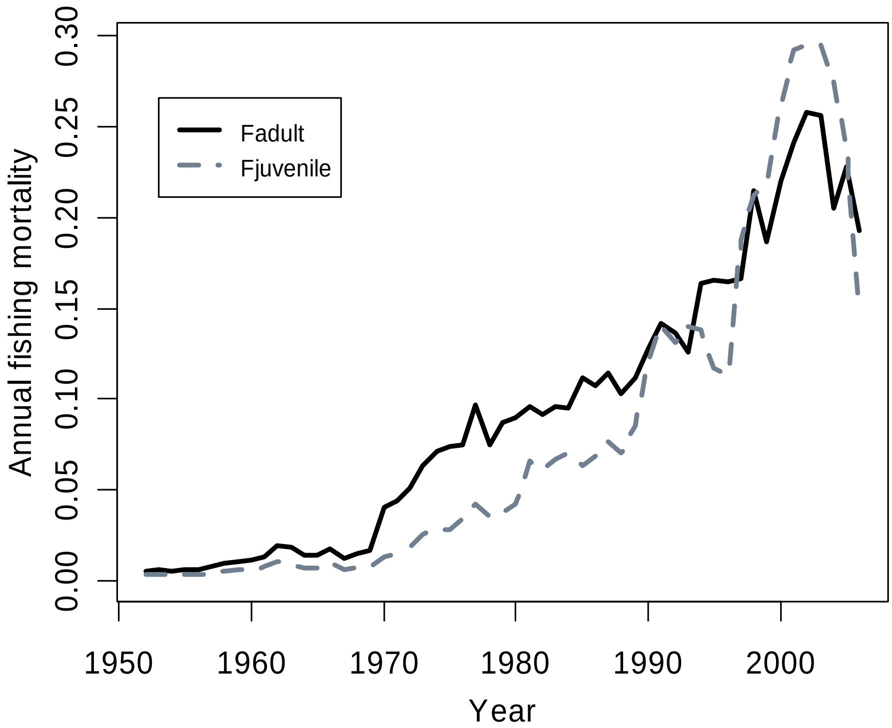


Figure 34. Estimated average annual fishing mortality rates for juvenile (less than 100 cm) and adult yellowfin tuna.

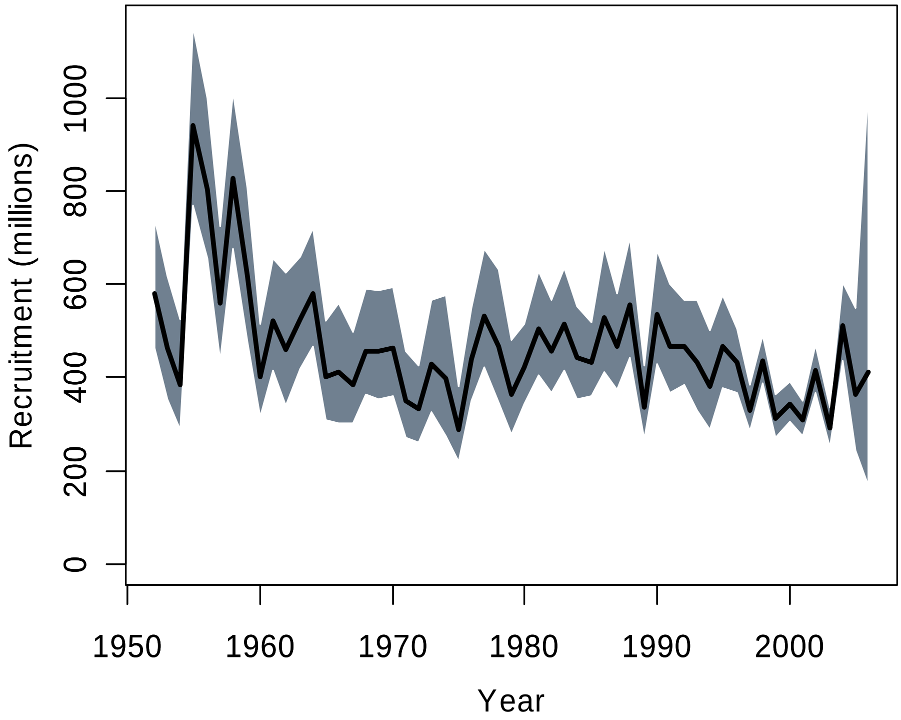


Figure 35. Estimated annual yellowfin tuna recruitment (millions) for the WCPO. The shaded area indicates the approximate 95% confidence intervals.

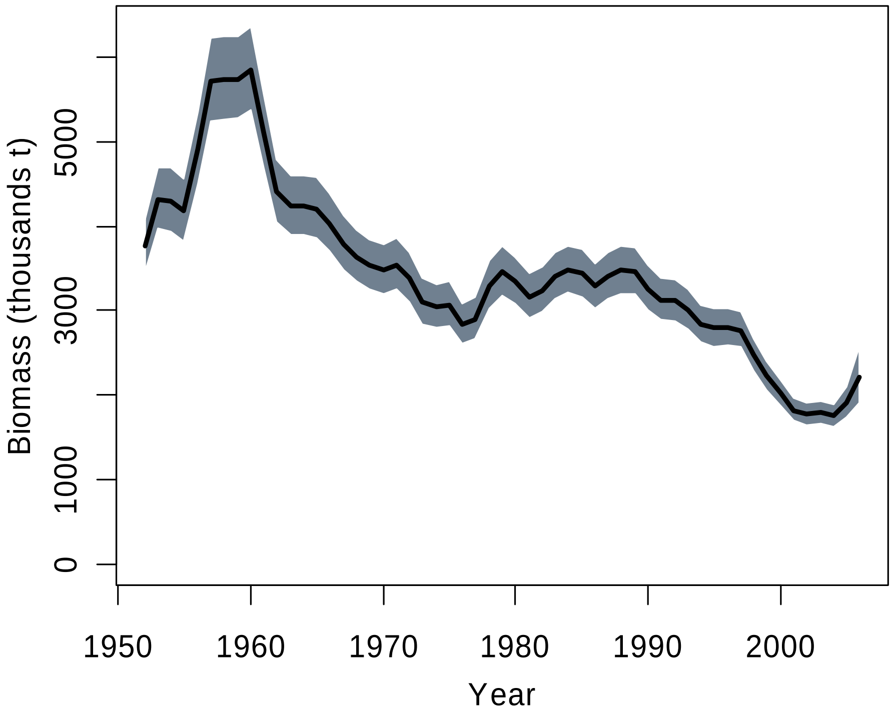


Figure 36. Estimated annual total yellowfin biomass (thousand mt) for the base-case analysis. The shaded area indicates the approximate 95% confidence intervals.

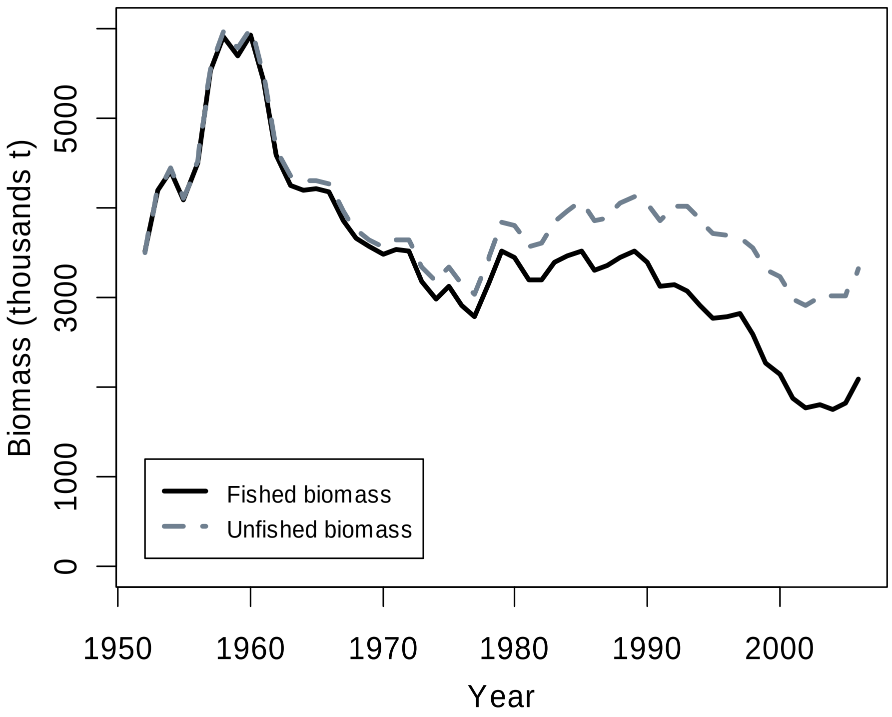


Figure 37. The estimated impact of fishing on yellowfin tuna biomass. The lower biomass trajectory (darker line) represents the model estimates of total biomass. The upper trajectory is the estimated biomass that would have occurred in the absence of fishing, assuming that recruitment was unaffected by fishing.

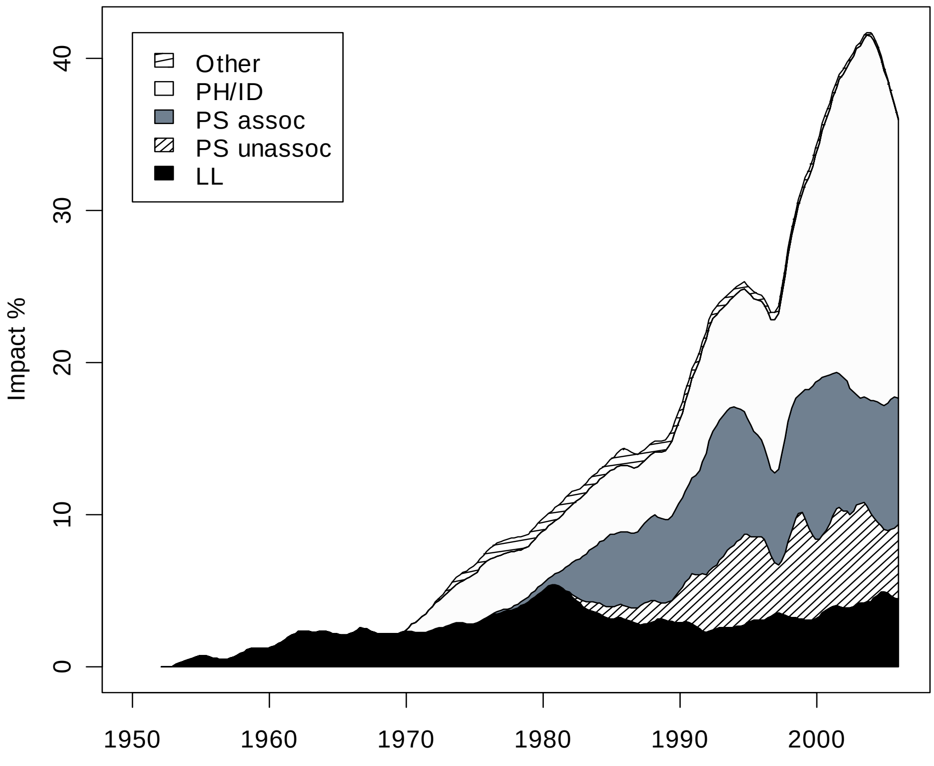


Figure 38. The estimated impact of each fishery on the yellowfin tuna total biomass in the WCPO. Impact is expressed as the proportional reduction in biomass attributed to fishing.

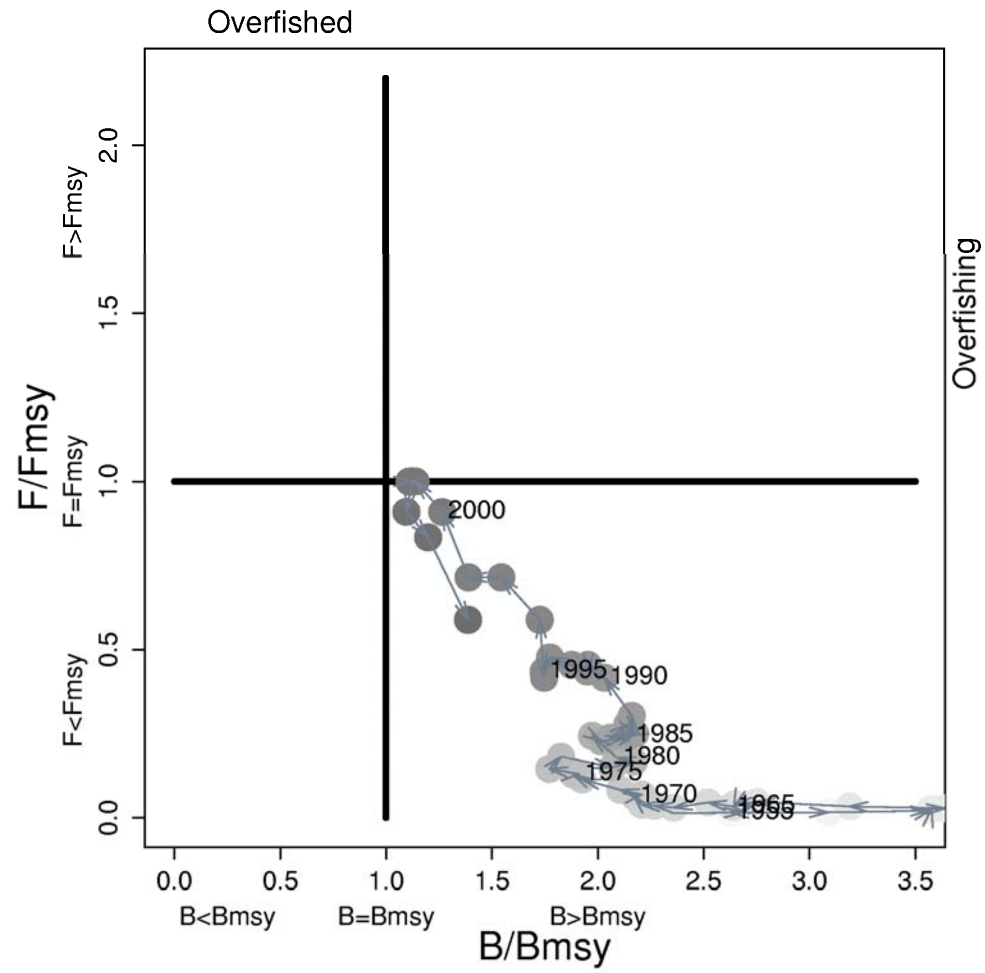


Figure 39. Temporal trend in annual stock status for the WCPO yellowfin stock, relative to B_{MSY} (x-axis) and F_{MSY} (y-axis) reference points, for the model period (1952–2006). The colour of the points is graduated from light grey (1952) to dark grey (2006) and the points are labelled at five-year intervals.

3.3 Bigeye tuna

3.3.1 Catch

Bigeye tuna are an important component of tuna fisheries throughout the Pacific Ocean. Juvenile bigeye are taken by purse-seine and pole-and-line (surface) gears, while longline vessels principally catch adult fish. Bigeye is a principal target species of both the large distant-water longliners from Japan, Korea and, more recently, Chinese Taipei, and the smaller fresh sashimi longliners based in several Pacific Island countries. Prices paid for both frozen and fresh product on the Japanese sashimi market are the highest of all the tropical tunas. Bigeye tuna are the economic cornerstone of the tropical longline fishery in the western and central Pacific Ocean, the catch of which in the WCP–CA has an estimated landed value of approximately US$600 million annually.

Since 1980, the Pacific-wide total catch of bigeye (all gears) has varied between 120,000 and 260,000 mt (Figure 40), with Japanese longline vessels generally contributing over 80% of the catch until the early 1990s. The 2006 bigeye catch for the Pacific Ocean (117,143 mt) is about 10,000 mt below the average level for the past ten years.

The **purse-seine** catch in the **EPO** (73,043 mt in 2006) continues to account for a significant proportion (71%) of the total EPO bigeye catch, although the provisional 2006 EPO longline bigeye catch (30,271 mt) is the lowest since 1971 – the decline in the EPO longline catch in recent years is probably related to the reduction of vessels in distant-water fleets targeting this species. The **WCP–CA longline** bigeye catches have fluctuated between 70,000–96,000 mt since 1999, with the 2006 catch (70,919 mt) around 6,000 mt lower than average over the past ten years. The **WCP–CA purse-seine** bigeye catch for 2006 was estimated to be 25,376 mt which is one of the lowest catches for more than 10 years (Figure 40). Over the past decade, the **WCP–CA pole-and-line** fishery has generally accounted for between 2,000–4,000 mt of bigeye catch annually, although recent revisions to the estimates for the Indonesian fishery have resulted in an increase (to 6,000–9,000 mt) since 2004. The "**other**" category, representing various gears in the Philippine, Indonesian[4] and Japanese domestic fisheries, has accounted for an estimated 11,000–20,000 mt (10–15% of the total WCP–CA bigeye catch) in recent years.

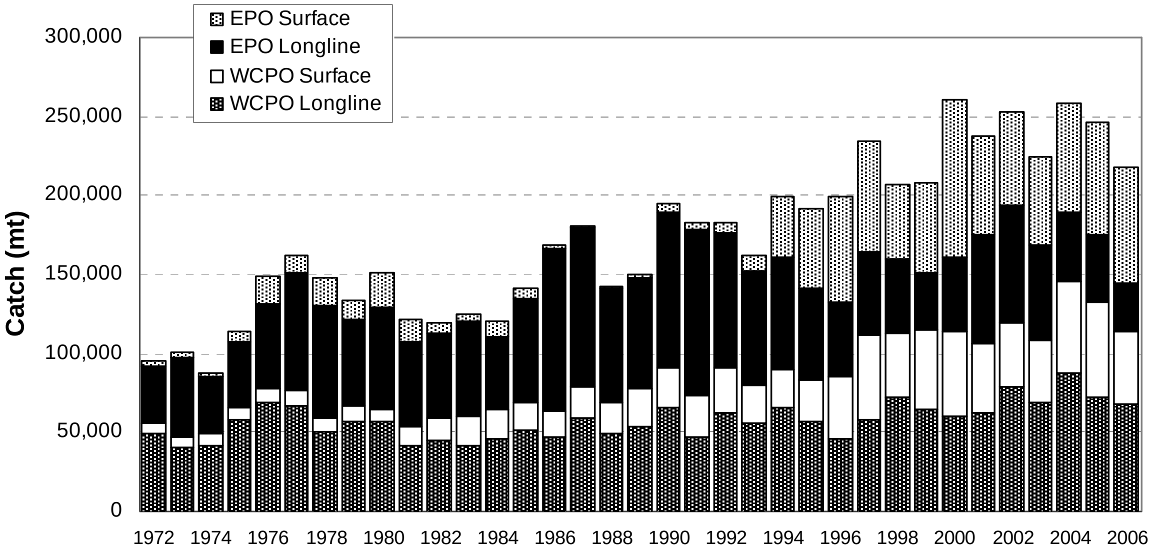


Figure 40. Bigeye tuna catch in the Pacific Ocean.

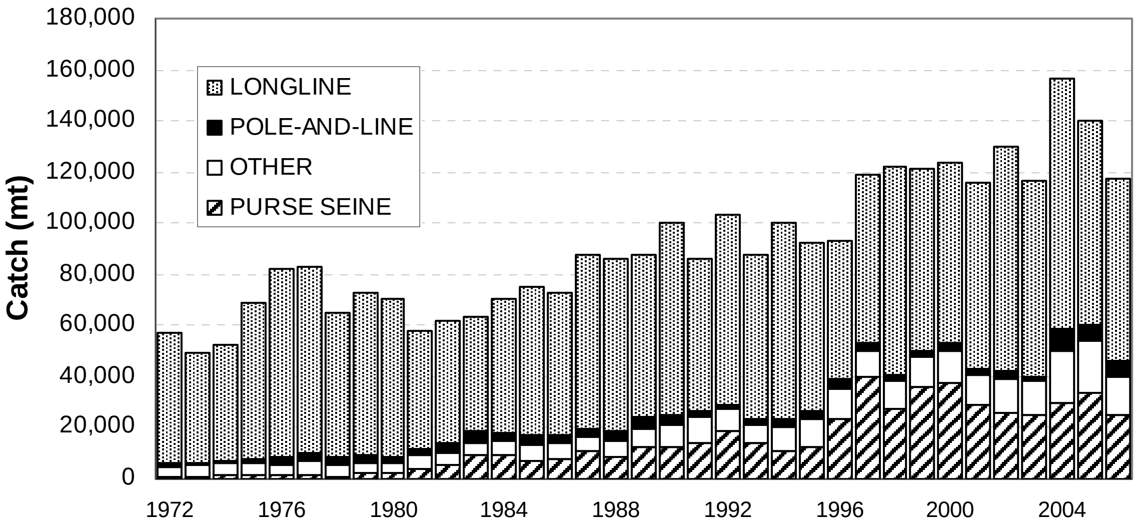


Figure 41. WCP–CA bigeye tuna catch, by gear.

[4] Indonesia has recently revised the proportion of catch by species for their domestic fisheries which has resulted in differences in species composition by gear type since 2004 compared to what has been reported in previous years.

Figure 42 shows the spatial distribution of bigeye catch in the Pacific for the period 1990–2005 (2006 data are incomplete). Most of the WCP–CA catch is taken in equatorial areas, both by purse-seine and longline, although longline catches are also taken in subtropical areas (e.g. east of Japan and off the east coast of Australia). In the equatorial areas, much of the longline catch is taken in the central Pacific, contiguous with the important traditional bigeye longline area in the eastern Pacific.

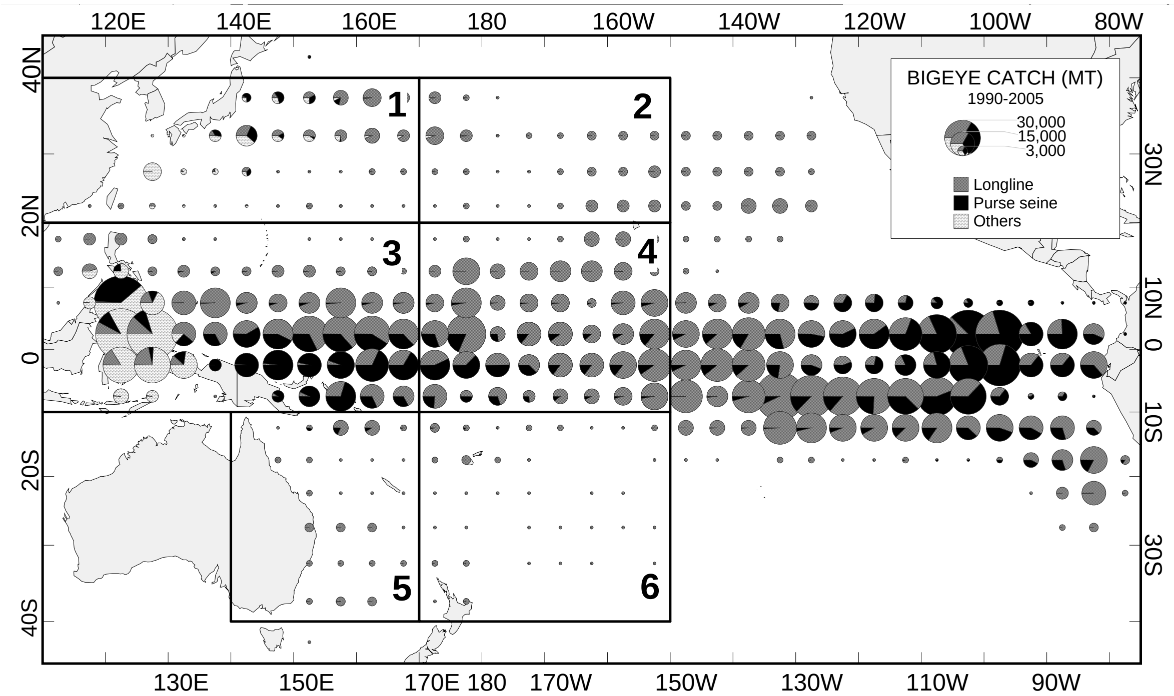


Figure 42. Distribution of bigeye tuna catch, 1990–2005. **The six-region spatial stratification used in stock assessment for the WCPO is shown.**

3.3.2 Catch per unit of effort

The longline fishery provides the most potentially useful information on bigeye tuna's relative abundance in the Pacific. Prior to 1980, yellowfin was the preferred target species in the WCP–CA longline fishery. Since 1980, bigeye tuna have been increasingly targeted by the longline fishery and these temporal trends need to be taken into account in the interpretation of CPUE data from the fishery.

A GLM approach was applied to account for changes in the operation of the fishery and derive standardised indices of bigeye CPUE from the Japanese longline fishery (see Langley et al. 2005 for details). These indices were derived for the six regions used to define the bigeye fishery operating in the WCPO (see Figure 43) and incorporated in the 2006 stock assessment for bigeye (see Section 3.3.4) as an index of relative abundance of the portion of the stock vulnerable to the longline fishery.

Considerable differences in the CPUE trends are evident among regions (Figure 43). The equatorial areas of the fishery (regions 3 and 4) account for most of the bigeye catch and, for both areas, the standardised CPUE indices declined between the early 1950s and early 1970s. However, the CPUE trends deviated over the subsequent period. For the western equatorial region (region 3), the CPUE indices for 1970–2000 fluctuated about the average level, while CPUE in the eastern equatorial region (region 4) remained relatively constant until the late 1990s and subsequently declined (Figure 43).

Trends in the CPUE indices differed for the other regions of the WCPO fishery. For regions 1, 2 and 5, CPUE declined sharply during the first 20 years of the fishery, and have continued to decline at a lower rate from 1970 to the present (Figure 43). For region 6, the CPUE indices fluctuated over the history of the fishery, with higher CPUE during the early period of the fishery and during the 1980s (Figure 43).

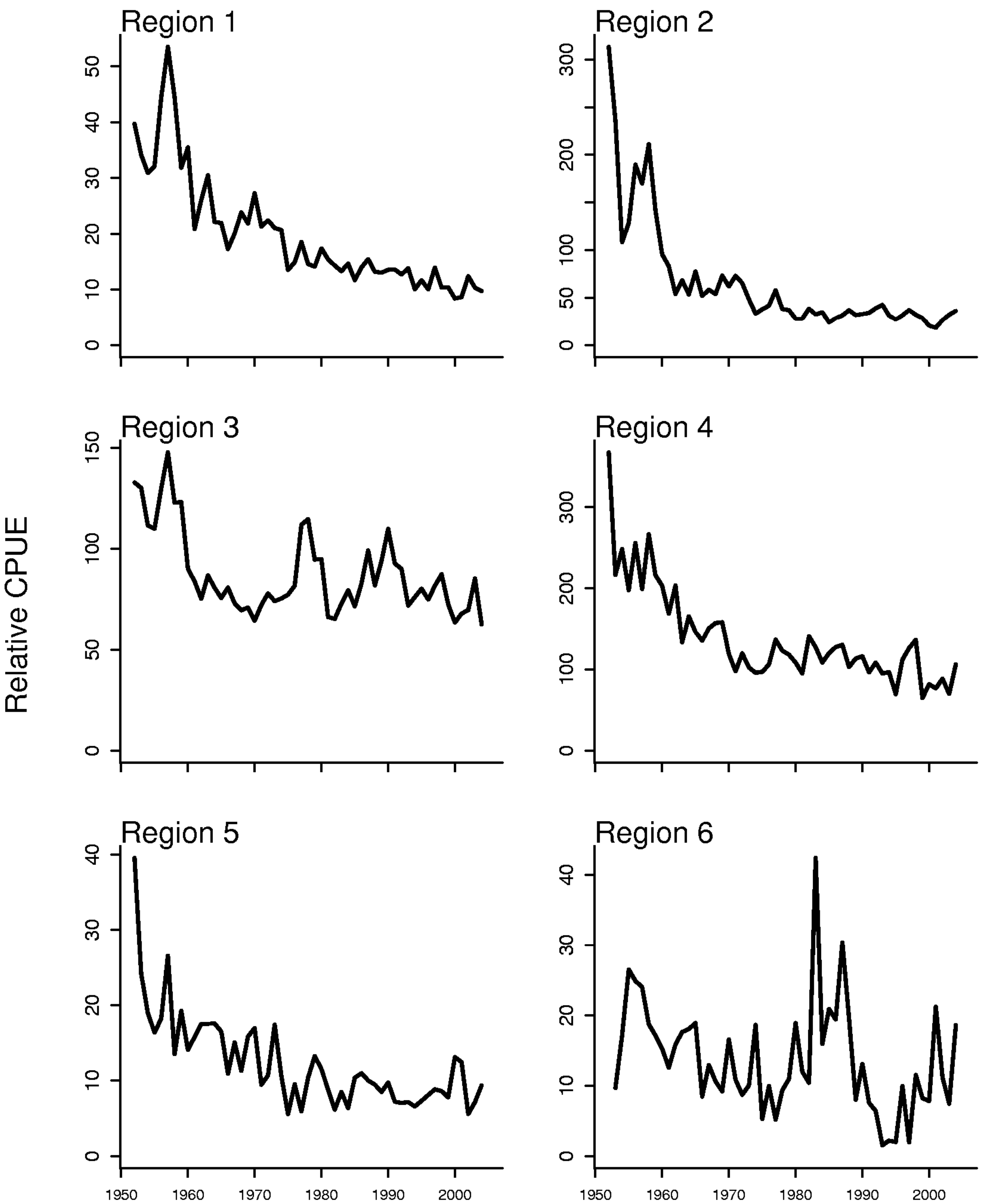


Figure 43. Annual trends in bigeye GLM standardised CPUE indices for the Japanese longline fleet by MFCL region.

3.3.3 Size of fish caught

Average annual catch-at-size of bigeye tuna in the WCP–CA is shown in Figure 44. The longline fishery has accounted for most of the catch of large bigeye in the WCP–CA. This is in contrast to large yellowfin tuna, which (in addition to the longline gear) are also taken in significant amounts from unassociated (free-swimming) schools in the purse-seine fishery and in the Philippine handline fishery. Large bigeye tuna are rarely caught in the WCP–CA purse-seine fishery and only a small catch is taken by the handline fishery in the Philippines. Bigeye tuna sampled from the longline fishery are predominantly adult fish with a mean size of about 130 cm FL (80–160 cm FL).

The domestic surface fisheries of the Philippines and Indonesia catch small bigeye (20–60 cm FL). Associated sets account for nearly all the bigeye catch in the WCP–CA purse-seine fishery, with considerable variation in the sizes from year to year. As with yellowfin (see Figure 33), catches of medium-sized (60–100 cm FL) bigeye from all fisheries are relatively low, indicating a period in their life history when the species is less vulnerable to the main fishing gear.

Since the 1980s, there has been a reduction in the proportion of very large (greater than 170 cm FL) bigeye in the longline catch. This is consistent with an increase in the exploitation rate of the adult component of the population (see Section 3.3.4).

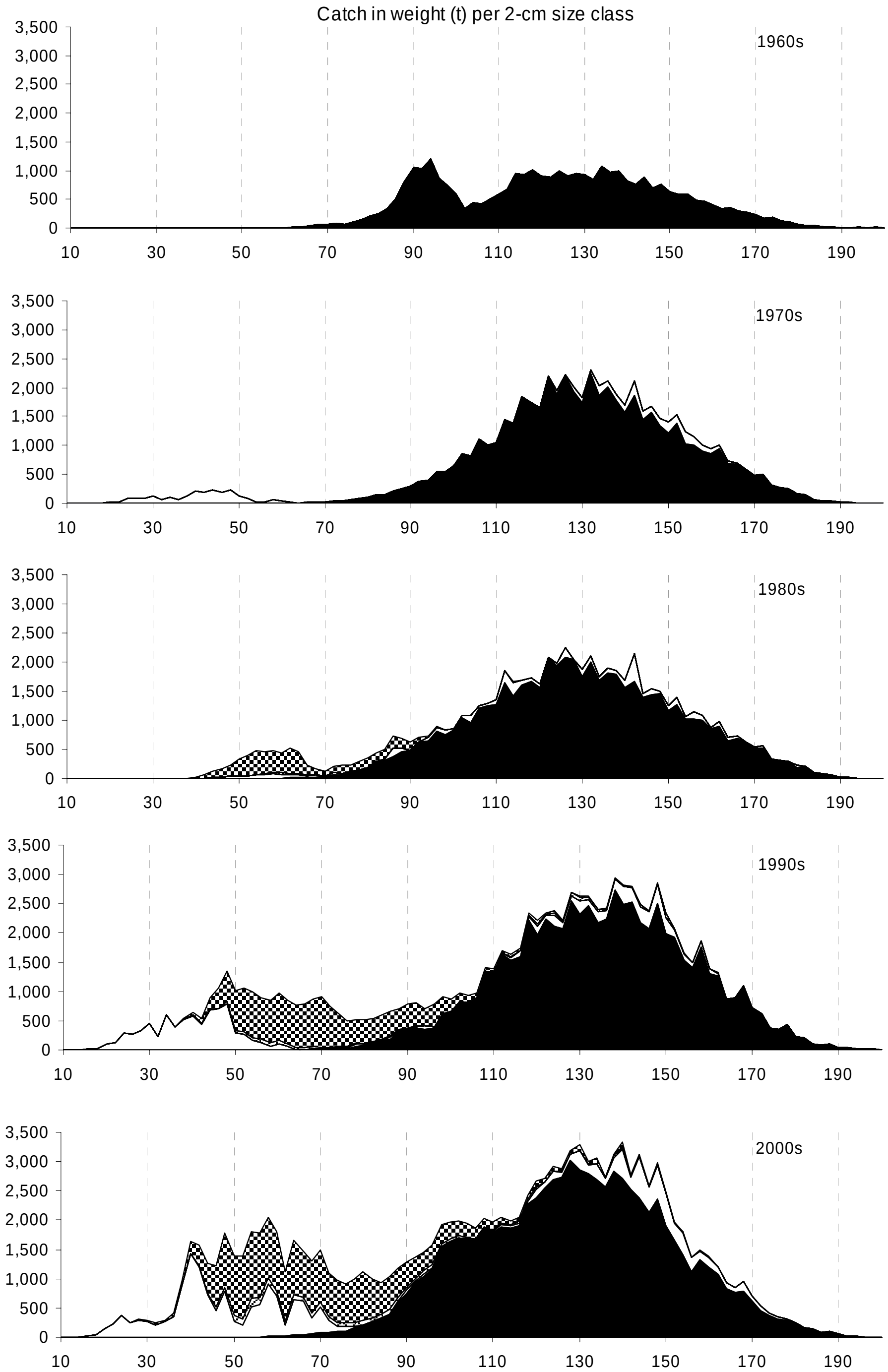


Figure 44. Average annual catches of bigeye tuna in the WCP–CA by length and gear type during decadal periods **(black – longline; white – Phil-Indo fisheries; grey – purse-seine associated; hatching – purse-seine unassociated, catches negligible).**

3.3.4 Stock assessment

In recent years, separate stock assessments have been undertaken for bigeye tuna in the WCPO (i.e. west of 150°W) and EPO. The division of the analysis in the central Pacific is based on the jurisdictional boundary of the two RFMOs responsible for management of the tuna resource in the Pacific. The separation of the bigeye stock in the central Pacific assumes that movement of fish between the WCPO and the EPO is minimal. The sensitivity of the assessment results to this assumption has been investigated by comparing the results of the two separate assessments with a MULTIFAN-CL analysis of bigeye tuna for the entire Pacific (Hampton & Maunder 2006).

This report summarises the results of the assessment for the component of the bigeye stock in the WCPO. The most recent assessment was conducted in 2006 using MULTIFAN-CL and adopted a spatial structure that apportions the WCPO into six regions (see Figure 42). The model encompasses 1952–2005, with the time period stratified by quarter. The model structure includes quarterly recruitment, 40 quarterly age classes, independent mean lengths for the first eight age classes with von Bertalanffy growth constraining the mean lengths for the remaining age classes, structural time-series variation in catchability for all non-longline fisheries, age-specific natural mortality, and quarterly movement among the model regions.

Catch, effort and size data (both length and weight frequency), stratified by quarter, for 20 fisheries (13 longline, a combined Philippine/Indonesian domestic fishery, a Philippine hand-line fishery, a Hawaiian handline fishery, and four purse-seine fisheries classified by associated and unassociated sets) were used in the analysis. For the longline fisheries, estimates of effective (or standardised) effort were derived from a GLM approach (Langley et al. 2005). Tagging data from a number of regional and sub-regional tagging programmes were also incorporated into the analysis. A more detailed description of the data, the model structure employed for the analysis and the complete set of results is given in Hampton et al. 2006 (http://www.wcpfc.int/sc2/pdf/SC2_SA_WP2.pdf).

The 2006 stock assessment included a number of alternative model options, investigating the impact of different assumptions regarding the spatial stratification and the relative weighting of the size frequency data in the model. The summary of the results presented in this report is from the 'base-case' analysis, using the six-region spatial structure and a relatively low weighting of the size frequency data. The details of this assessment may differ from the other analyses; however, the overall conclusions are similar to the other assessment models.

Annual average **fishing mortality rates** for juvenile (less than 100 cm) and adult bigeye tuna for the WCPO are shown in Figure 45. Fishing mortality for juvenile and adult bigeye increased gradually from 1950 to 1990 and then increased rapidly during the subsequent period, particularly for juvenile bigeye. These recent trends are attributable to the maintenance of longline catches despite a decline in adult biomass and a large increase in the catch of juvenile bigeye from purse-seine associated (log and FAD) sets. Catches of juvenile bigeye from the Indonesia and Philippines surface fisheries are also assumed to have increased.

Annual **recruitment** estimates are presented in Figure 46. Recruitment was relatively high in the early model period and generally declined in the 1950s and 1960s. Since 1990, bigeye recruitment is estimated to have been well above the long-term average recruitment level. The overall trend in recruitment is largely driven by the trends in recruitment from the two equatorial regions of the WCPO. Recent recruitment is estimated to have been high in both of these regions. The model estimates of recruitment are consistent with trends in the size composition of the catch, particularly from the main longline fisheries. However, model estimates of recruitment are also likely to be sensitive to estimated and assumed levels of catch of juvenile bigeye from the purse-seine and Indonesia/Philippines surface fisheries. Further investigation is required to ascertain the robustness of recent recruitment estimates.

The estimated **biomass** trajectory for bigeye in the WCPO is shown in Figure 47. The total biomass of bigeye tuna is estimated to have declined by about 60% during the 1950s and 1960s, mainly due to a large decline in recruitment during the early years of the fishery. In the subsequent period, total biomass is estimated to have remained relatively stable, with the increased fishing mortality rates being countered by increasing annual recruitment. However, the biomass trajectories vary between regions, with the region supporting the highest longline catch (region 4) revealing a decline in biomass since 1990.

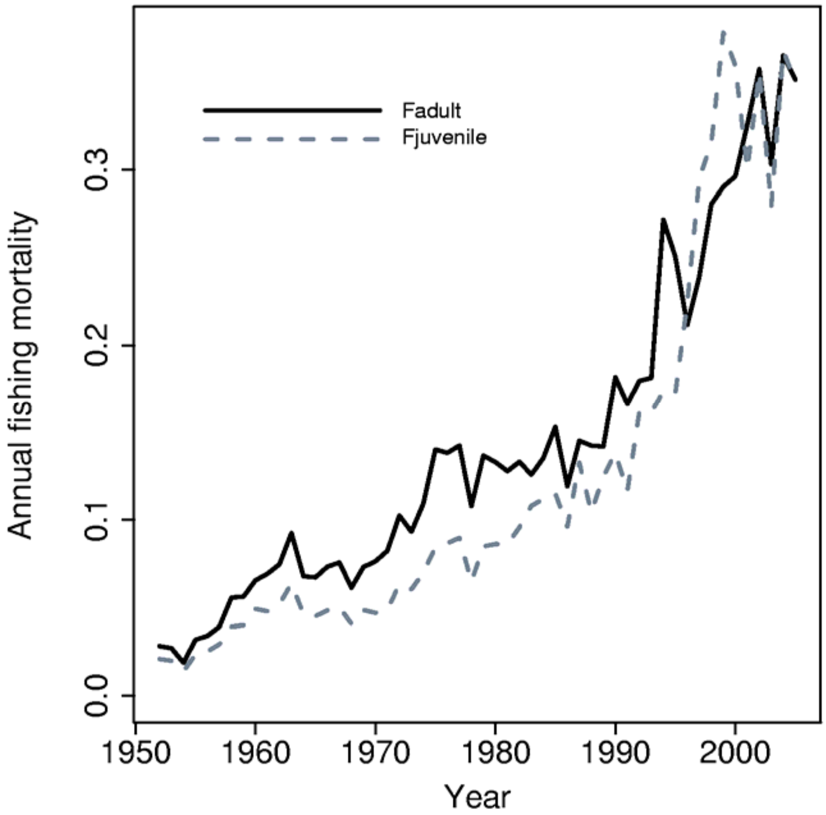


Figure 45. Estimated average annual fishing mortality rates for juvenile (less than 100 cm) and adult bigeye tuna.

The ***impact of fishing*** on the total biomass has increased over time as catches and fishing mortality have increased (Figure 48). The level of impact increased from the mid-1970s and then increased again sharply from the mid-1990s. The current level of catch, in particular from the longline fishery and, more recently, the purse-seine fishery, is having a large impact on the biomass level (Figure 49). The impact of fishing is highest in the equatorial area (regions 3 and 4), reducing the biomass in these regions by 70–80%. However, despite the high fishery impact (increasing fishing mortality), the model predicts total biomass has remained relatively stable due to the recent high level of recruitment.

Conclusion

The most recent bigeye assessment indicates the stock is not in an overfished state ($B_{CURRENT} > B_{MSY}$) although current fishing mortality rates are greater than the F_{MSY} level ($F_{CURRENT} > F_{MSY}$) and, therefore, overfishing is occurring (Figure 50). Recent catches have been sustained by higher-than-average levels of recruitment, which have also maintained biomass above the B_{MSY} level. Future levels of recruitment are highly uncertain and a return to long-term average levels of recruitment is predicted to result in a rapid decline in biomass to below the B_{MSY} level.

Based on the results of the assessment, the Scientific Committee of the WCPFC recommended that fishing mortality on the bigeye tuna in the WCPO be reduced by 25% of recent levels (2001–2004) in order to maintain the stock at a level that would produce the MSY. Higher reductions in fishing mortality would be required to maintain the biomass above the B_{MSY} level in the long term. It was also noted that more urgent management actions may be required in the equatorial region of the WCPO.

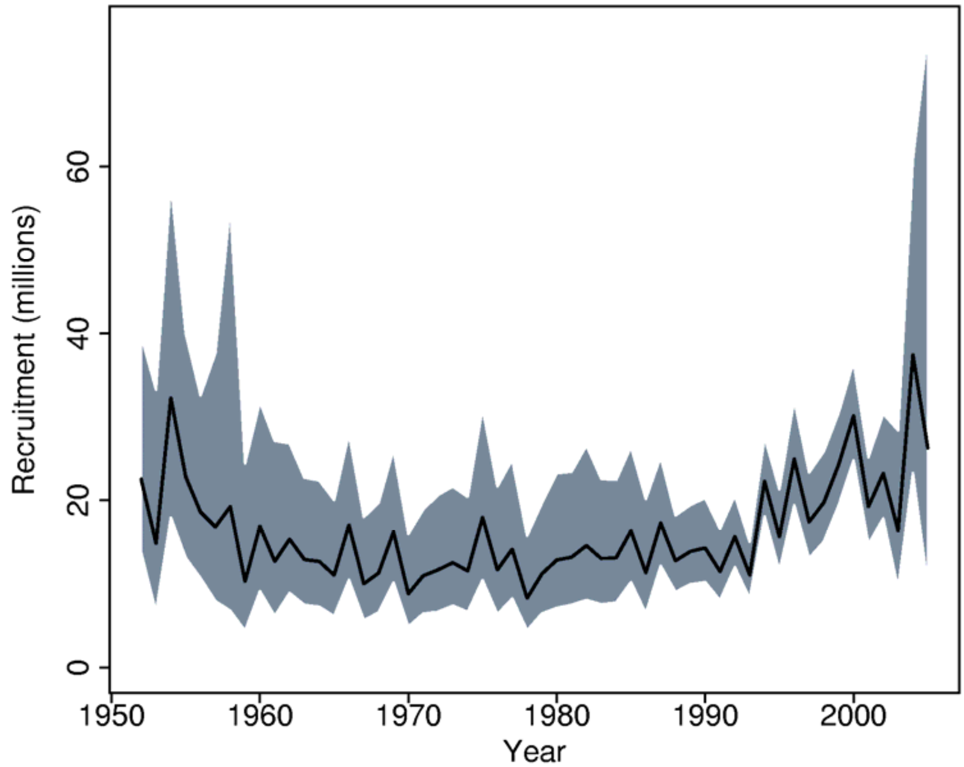


Figure 46. Estimated annual bigeye tuna recruitment (millions) for the WCPO. **The shaded area indicates the approximate 95% confidence intervals.**

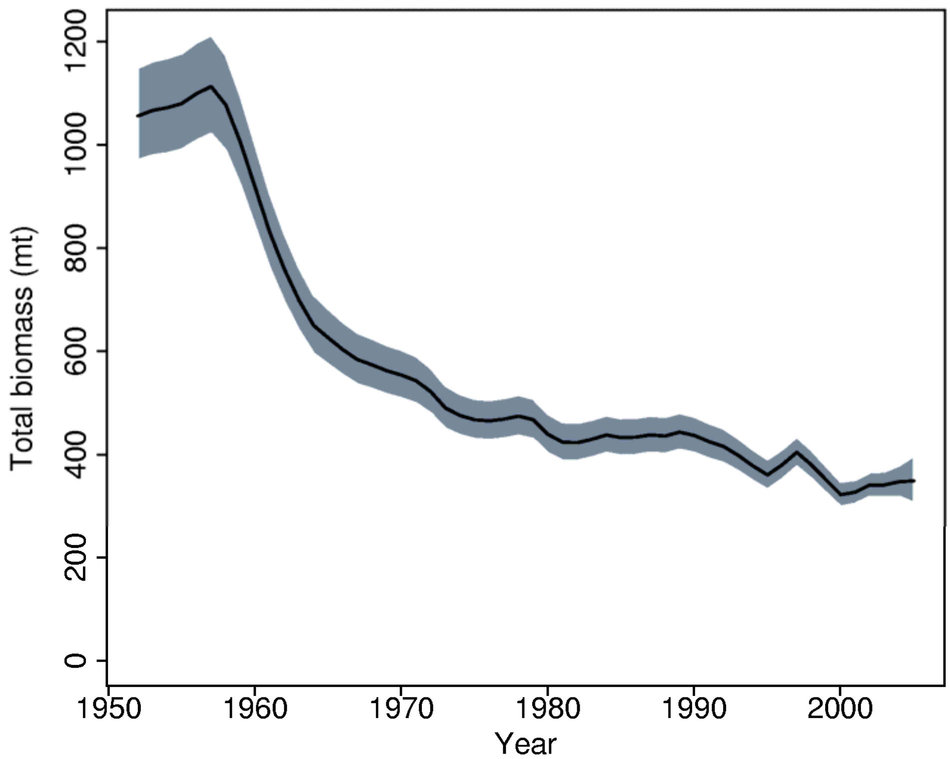


Figure 47. Estimated annual total biomass (thousand mt) of bigeye tuna for the WCPO for the base-case analysis. **The shaded area indicates the approximate 95% confidence intervals.**

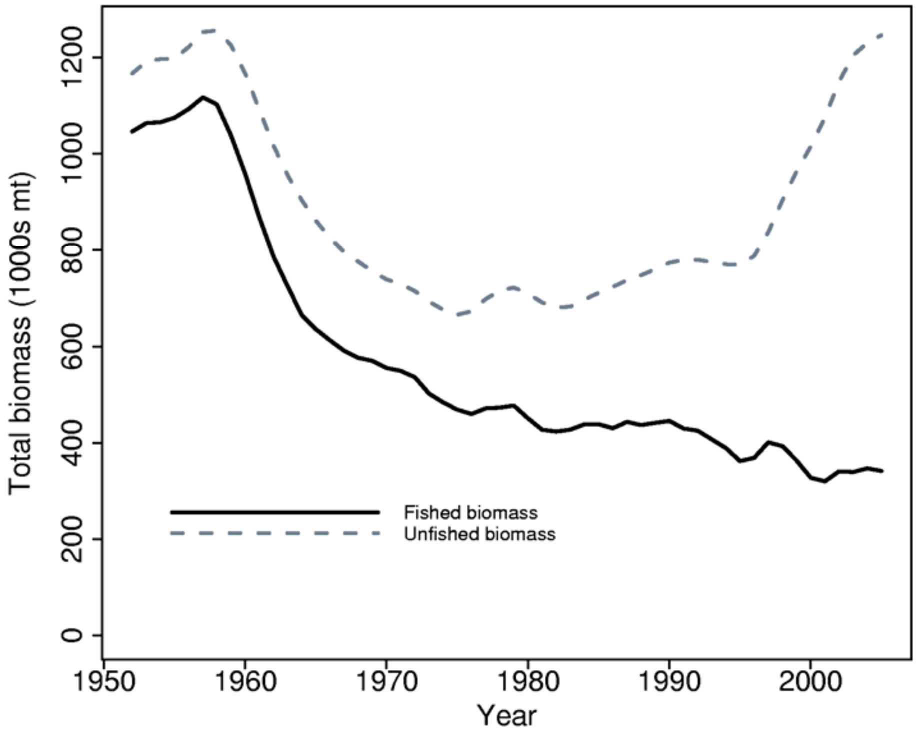


Figure 48. The estimated impact of fishing on bigeye tuna biomass in the WCPO. **The lower biomass trajectory (darker line) represents the model estimates of total biomass in each area. The upper trajectory is the estimated biomass that would have occurred in the absence of fishing, assuming that recruitment was unaffected by fishing.**

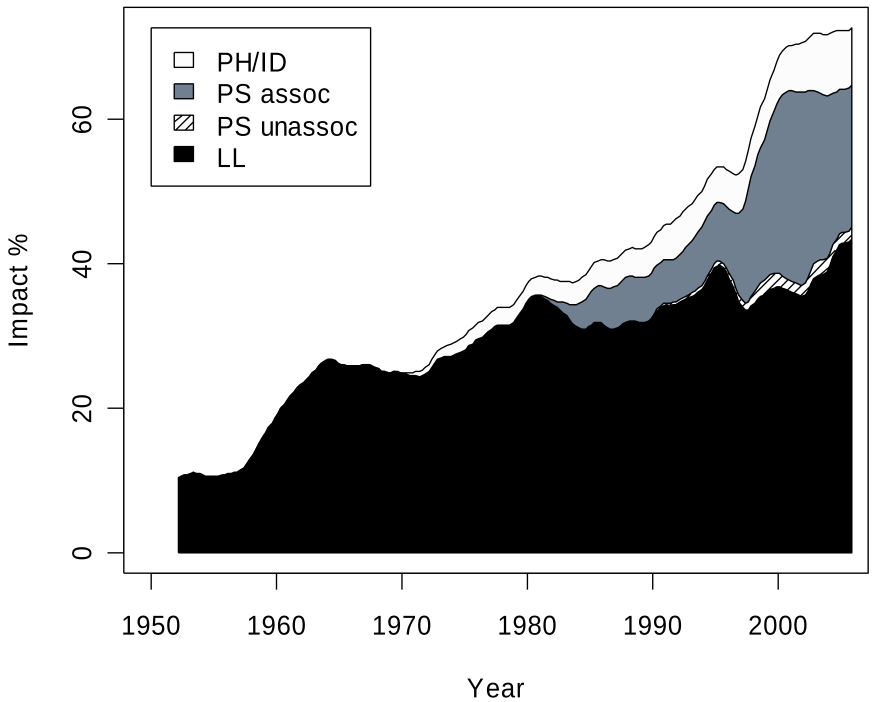


Figure 49. The estimated impact of each fishery on the bigeye tuna biomass in the WCPO. Impact is expressed as the proportional reduction in biomass attributed to fishing.

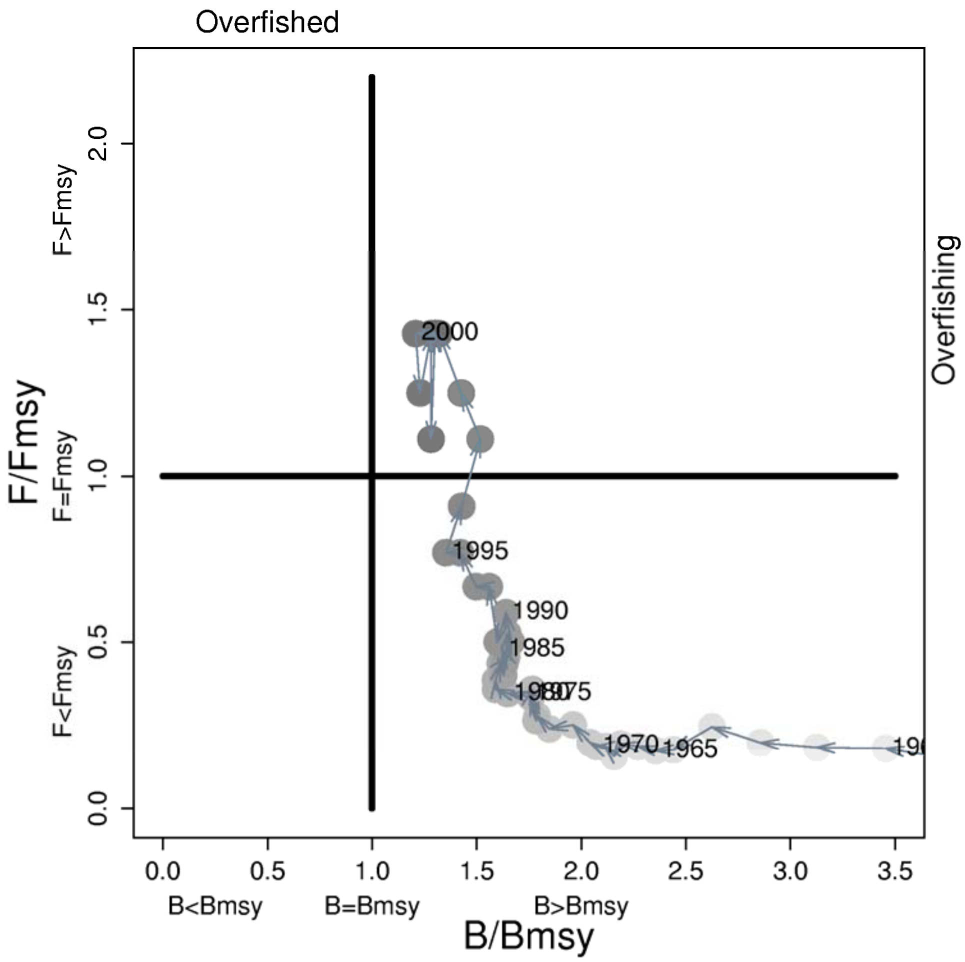


Figure 50. Temporal trend in annual stock status for the WCPO bigeye tuna stock, relative to B_{MSY} (x-axis) and F_{MSY} (y-axis) reference points, for the model period (1952–2005). The colour of the points is graduated from light grey (1952) to dark grey (2005) and the points are labelled at five-year intervals.

3.4 South Pacific albacore tuna

3.4.1 Catch

South Pacific albacore are exploited by a variety of longline fleets, by a domestic troll fleet in New Zealand coastal waters, and by a small international troll fleet operating seasonally in the region of the STCZ.

Prior to 2001, south Pacific albacore catches were in the range 25,000–40,000 mt, although a significant peak was attained in 1989 (48,562 mt), when driftnet fishing was in existence. Since 2001, catches have easily exceeded this range, primarily as a result of the growth in several Pacific Islands domestic longline fisheries. The south Pacific albacore catch in 2006 (68,324 mt) was the highest on record, primarily due to a record catch in the longline fishery.

During the post-driftnet era, **longline** has accounted for most (> 75%) of the south Pacific albacore catch, while the **troll** fishery has caught 3,000–8,000 mt during the November – April fishing season (Figure 51). The WCP–CA albacore catch (102,377 mt in 2006) includes north Pacific catches (from the longline, pole-and-line and troll fisheries) and typically contributes around 80–90% of the total Pacific catch of albacore.

The longline catch is widely distributed in the south Pacific (Figure 53), but with catches concentrated in the western part of the Pacific. The Chinese-Taipei distant-water longline fleet catch is taken throughout the region, while the Pacific Island domestic longline fleet catch is restricted to the latitudes 10°–25°S. Troll catches are distributed in New Zealand's coastal waters, mainly off the South Island, and along the SCTZ**.** Less than 20% of the overall south Pacific albacore catch is usually taken east of 150°W.

The Chinese Taipei distant-water longline fleet has been the dominant fleet in the south Pacific albacore fishery for more than two decades. However, in recent years an increasing number of vessels in this fleet have shifted to target bigeye in the eastern equatorial waters of the WCP–CA, which has resulted in a reduced contribution to the overall albacore catch (Figure 52). In contrast, annual longline albacore catches by Pacific Island countries have increased significantly since the 1990s (Figure 52), with increased fleet sizes in all countries participating in the fishery. In 2006, the catch by Pacific Island fleets has represented around 60% of the total south Pacific albacore longline catch.

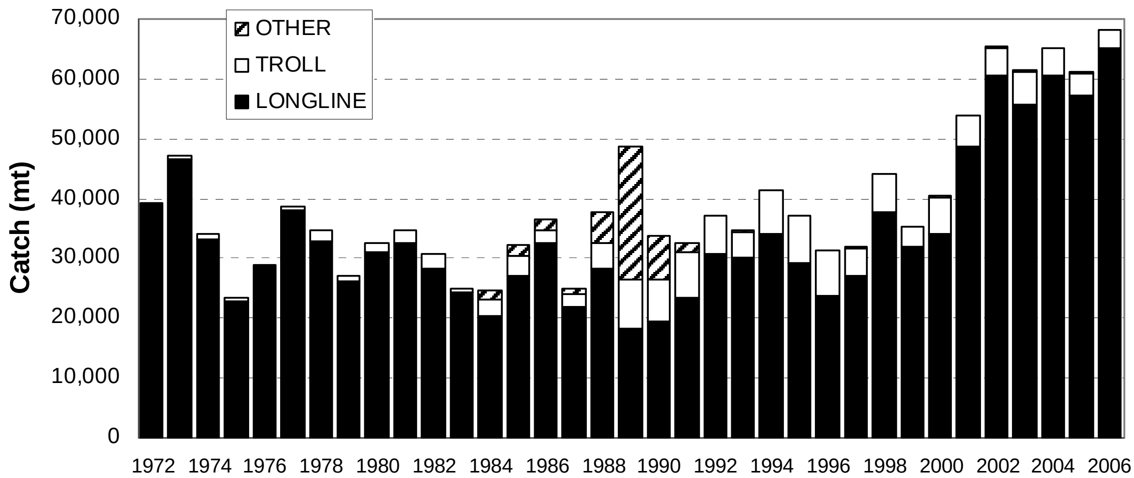


Figure 51. South Pacific albacore tuna catch, by gear **('Other' is primarily catch by the driftnet fishery).**

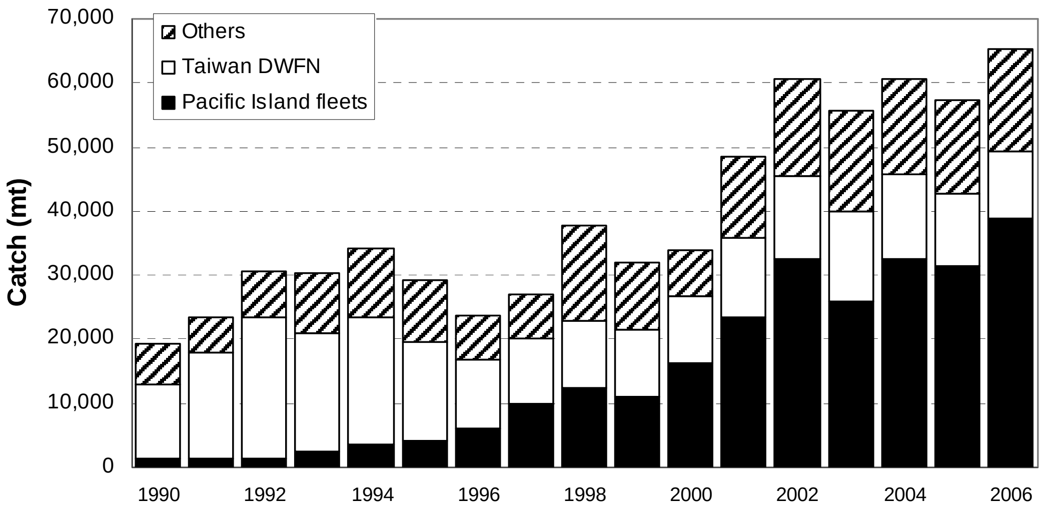


Figure 52. South Pacific albacore longline catch (mt) by fleet category.

The longline catch is widely distributed in the south Pacific (Figure 53), but with catches concentrated in the western part of the region. The Chinese Taipei distant-water longline fleet catch is taken throughout the south Pacific, while the Pacific Island domestic longline fleet catch is restricted to the latitudes 10°–25°S. Troll catches are distributed in New Zealand's coastal waters, mainly off the South Island, and along the SCTZ. Less than 20% of the total south Pacific albacore catch is usually taken east of 150°W.

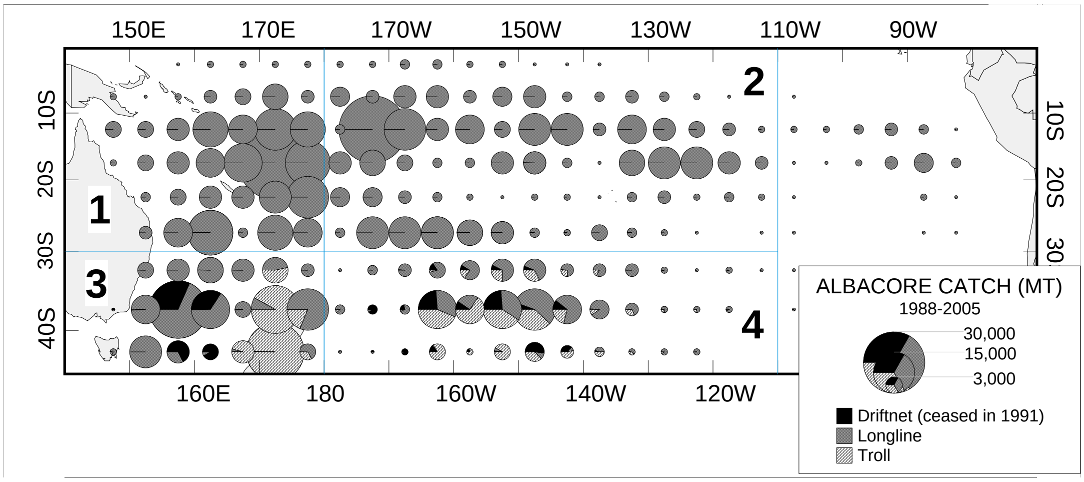


Figure 53. Distribution of South Pacific albacore tuna catch, 1988–2005. **The four sub-areas used in the analysis of CPUE data are also presented.**

3.4.2 Catch per unit of effort

The key fishery indicators for South Pacific albacore tuna are longline and troll fishery CPUE. For the longline fishery, data from the Chinese Taipei distant-water fleet are generally used as this fleet has consistently targeted albacore tuna over a long period of time. Trends in longline for the four sub-areas included in the South Pacific albacore stock assessment (see Figure 53) are presented in Figure 54. While there is considerable interannual variation in CPUE, all sub-areas reveal a general decline in CPUE, by about 50% between the late 1960s–early 1970s and recent years. The recent sharp decline in CPUE in the northeastern area is attributable to the significant increase in effort targeting bigeye (and yellowfin) in the waters north and east of French Polynesia. Standardised CPUE indices were calculated for the Chinese Taipei longline fleet (Langley 2003). For each of the main fishery areas, the standardised indices were very similar to the nominal CPUE.

Recent trends in the catch rate of albacore from the Pacific Island domestic longline fisheries were summarised in Langley 2006. In 2003–2004, low catch rates of albacore were experienced in a number of these domestic fisheries, in particular Vanuatu, Fiji, Tonga, Samoa, the Cook Islands and French Polynesia (Figure 55). These changes in catch rate were linked to changes in the prevailing oceanographic conditions in the southwestern Pacific. The unfavourable oceanographic conditions observed in 2003–2004 persisted in 2005 in the more eastern areas of the region and, consequently, catch rates in Tonga and French Polynesia remained at a low level (Langley 2006).

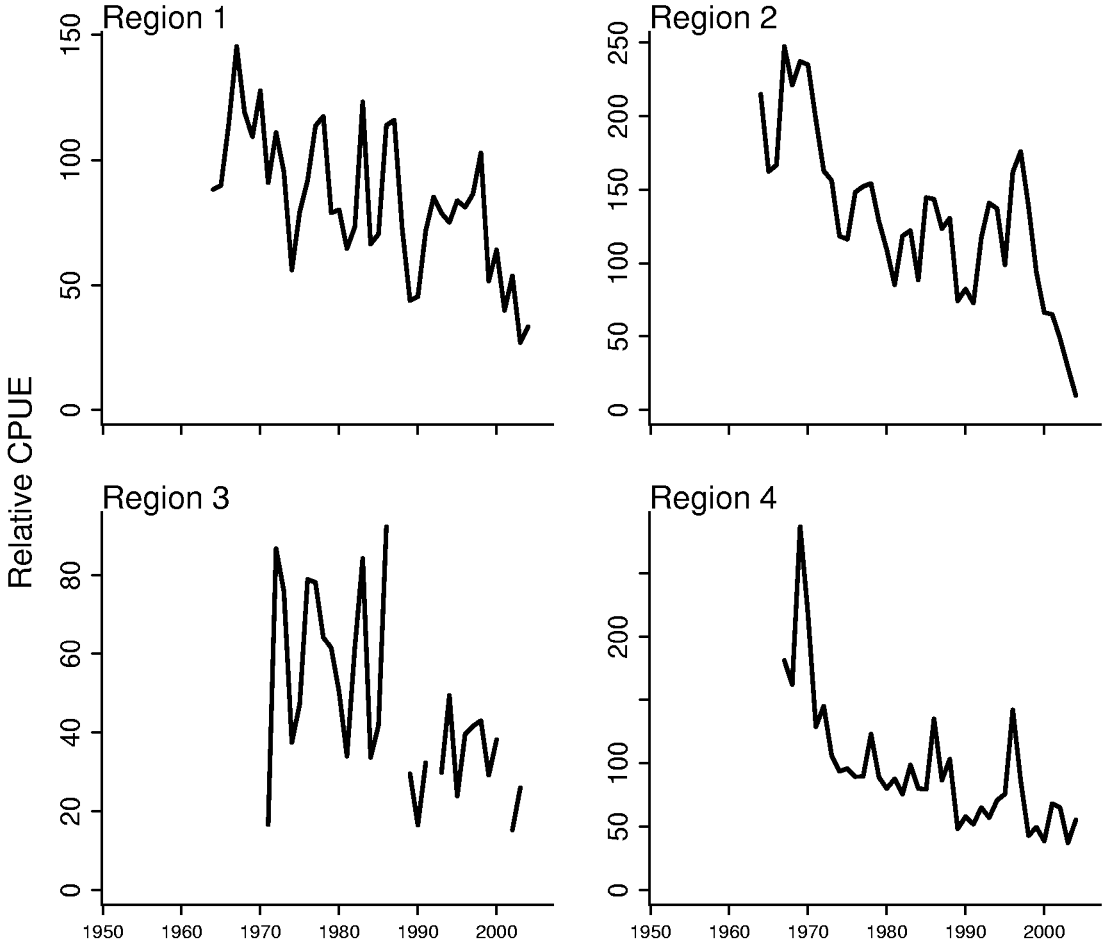


Figure 54. Trends in nominal South Pacific albacore tuna CPUE for Chinese Taipei longliners by MFCL sub-area (see Figure 53).

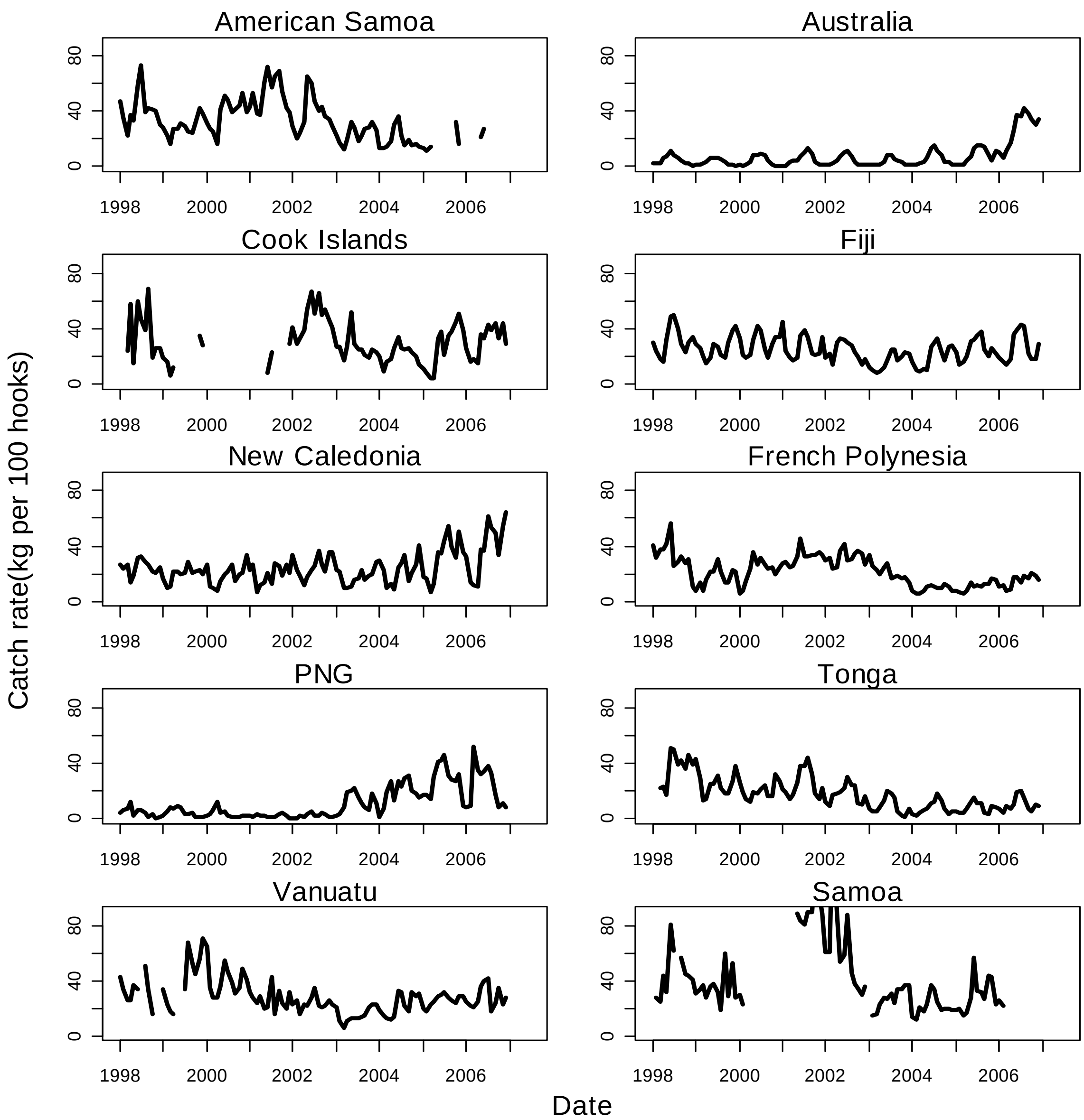


Figure 55. Monthly albacore catch rates (kg per 100 hooks) of the Pacific domestic longline fleets by EEZ from 1998 to 2006.

The CPUE for the New Zealand domestic troll fleet tended to increase during the 1980s, but remained relatively stable since then (Figure 56). CPUE for the USA and New Zealand fleets operating in the STCZ is generally higher but more variable, probably indicating a greater impact of environmental variation on the ability of this fleet to locate and catch albacore tuna.

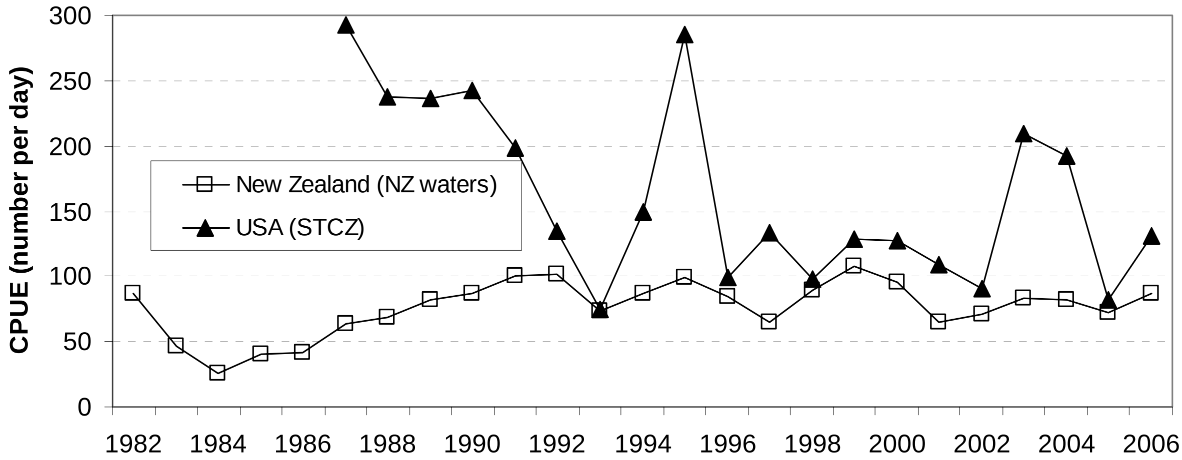


Figure 56. South Pacific albacore tuna CPUE for the New Zealand domestic troll fleet and the USA troll fleet operating east of 180° along the STCZ.

3.4.3 Size of fish caught

Average annual catch-at-size of albacore tuna is shown in Figure 57. The size composition of the longline catch has remained relatively stable over time; this fishery tends to catch adult fish with a distinct mode around 95 cm fork length. The catch from the troll fishery and the surface driftnet fishery (when it was operating) is comprised of smaller albacore in the size range 50–80 cm; the similar size range of fish taken in these fisheries reflects the overlap in the area fished (Figure 53).

3.4.4 Stock assessment

The last formal stock assessment of South Pacific albacore was presented to the Scientific Committee of the WCPFC in 2005 (Langley & Hampton 2005). Further analyses of the assessment model, updated to include an additional year's data, were undertaken in 2006 to investigate the sensitivity of the model to some of the key biological parameters (natural mortality, growth, and age of maturity) (Langley & Hampton 2006).

The assessment is conducted using MULTIFAN-CL and adopts a single-region spatial structure, although the fisheries are delineated spatially into four sub-areas (see Figure 53). The model encompasses the time period 1952–2005, stratified by quarter. The model structure includes annual recruitment, 20 annual age classes, von Bertalanffy growth parameterisation, and structural time-series variation in catchability for all fisheries, except for the Chinese Taipei longline fisheries.

Catch, effort and length data, stratified by quarter, from 23 fisheries (eight distant-water longline fisheries, 11 domestic longline fisheries, two troll fisheries, and two historical driftnet fisheries) were incorporated in the analysis. The trends in catch and effort data from the four Chinese Taipei longline fisheries represented the principal indices of stock abundance included in the model. Tagging data from several regional tagging programmes were also incorporated into the analysis. A more detailed description of the data, the model structure employed for the analysis and the complete set of results is given in Langley & Hampton 2005 (http://www.wcpfc.int/sc1/pdf/SC1_SA_WP_3.pdf). More recently, the MULTIFAN-CL South Pacific albacore model was compared to a model implemented in Stock Synthesis 2 (SS2) software (Hoyle & Langley 2007).

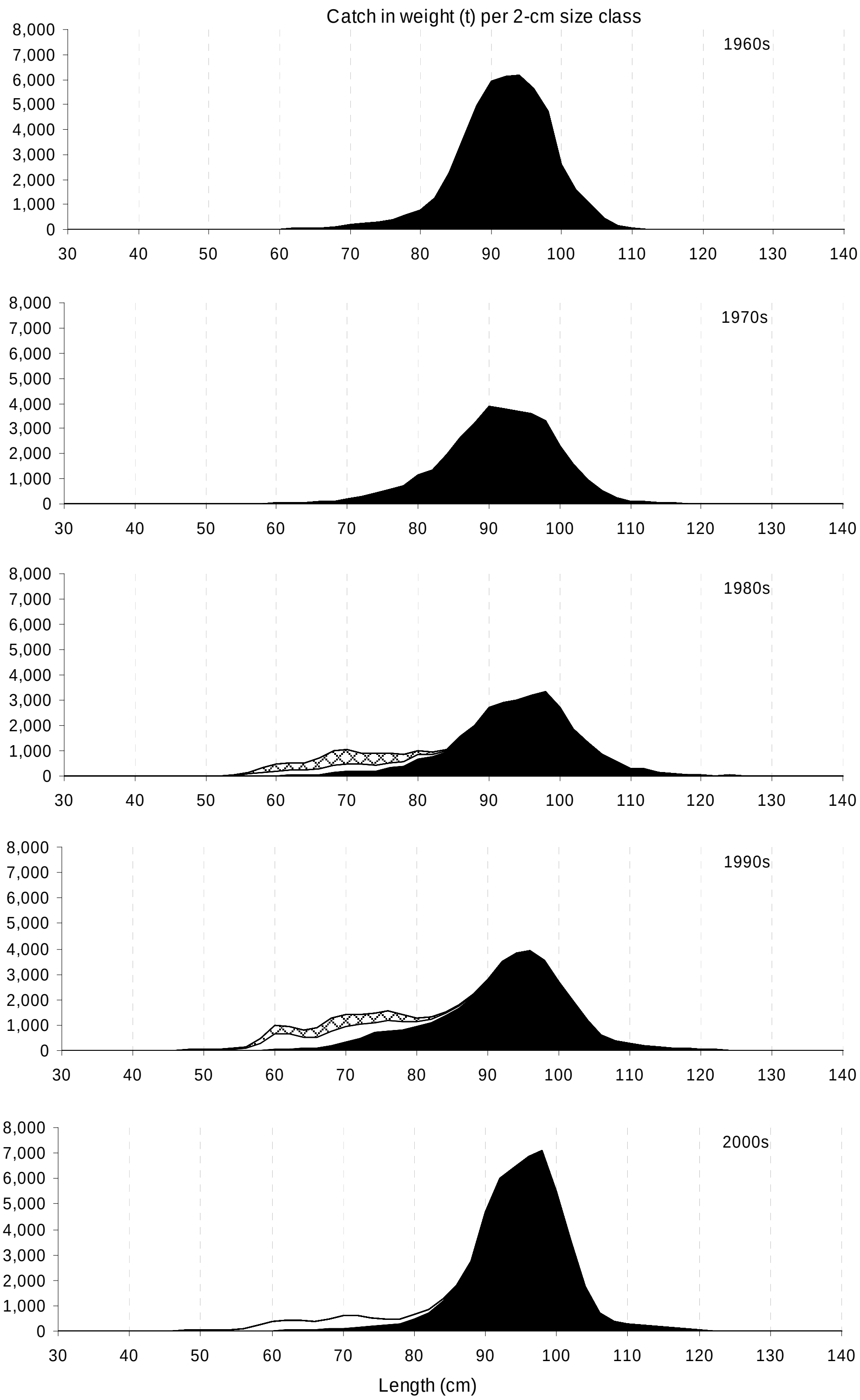


Figure 57. Average annual catches of albacore in the South Pacific by size and gear type during decadal periods **(black – longline; white – troll; hatching – surface driftnet).**

Annual average **fishing mortality rates** for juvenile (less than 100 cm) and adult bigeye tuna for the WCPO are shown in Figure 58. Overall, fishing mortality (exploitation) rates for adult and, particularly, juvenile albacore are estimated to have remained low throughout the history of the fishery. Fishing mortality rates for the component of the stock vulnerable to the domestic longline fisheries (greater than seven-year-old fish) have a marginally higher overall exploitation rate than adult fish.

Annual **recruitment** estimates for South Pacific albacore are presented in Figure 59. There is considerable temporal variation in recruitment over the model period. Annual recruitment is estimated to have been low prior to 1960, high during the 1960s and early 1970s, higher in the late 1980s and early 1990s, and relatively low in the subsequent period. The recruitment estimates have broad confidence intervals indicating substantial model uncertainty, particularly during the early period (1960s and 1970s).

The estimated **biomass** trajectory for South Pacific albacore is shown in Figure 60. The annual trends in total and adult biomass are consistent with the temporal trend in recruitment. Biomass was estimated to be low during the 1950s, increasing during the 1960s in response to increased recruitment, high through the 1970s and early 1980s, and then subsequently declining. There is a high level of uncertainty associated with the annual biomass estimates, particularly for the 1970s and early 1980s.

The **impact of fishing** on adult albacore has increased over the last decade and is estimated to be about 15%, i.e. adult biomass has been reduced by 15% due to the impact of fishing (Figure 61). The current level of impact on the juvenile component of the stock is negligible (about 1%). The level of impact on the component of the stock vulnerable to the longline fisheries (longline exploitable biomass) is considerably higher than for adult fish, increasing from about 15% in the 1980s to about 30% in recent years.

Conclusion

The assessment indicates that the current level of exploitation of the total biomass is very low ($F_{CURRENT} << F_{MSY}$) and, consequently, the fishery impacts on the total biomass are low. Biomass levels have declined over the last decade due to a decline in recruitment; however, current biomass levels remain well above the MSY-based reference point ($B_{CURRENT} > B_{MSY}$). Nevertheless, the current level of longline catch is estimated to be having a considerably higher impact on the portion of the stock vulnerable to the longline fishery. The magnitude of this impact is uncertain, although the assessment indicates that the current level of impact is about 30%, having increased sharply in recent years. The impact on the adult component of the stock is considerably less due to the age-specific exploitation pattern of the longline fisheries.

Based on the results of the assessment, the Scientific Committee of the WCPFC noted that current catch levels from the South Pacific albacore stock appear to be sustainable and yield analyses suggest that increases in fishing mortality and yields are possible. However, given the age-specific mortality of the longline fleets, any significant increase in effort would reduce CPUE to low levels with only moderate increases in yields.

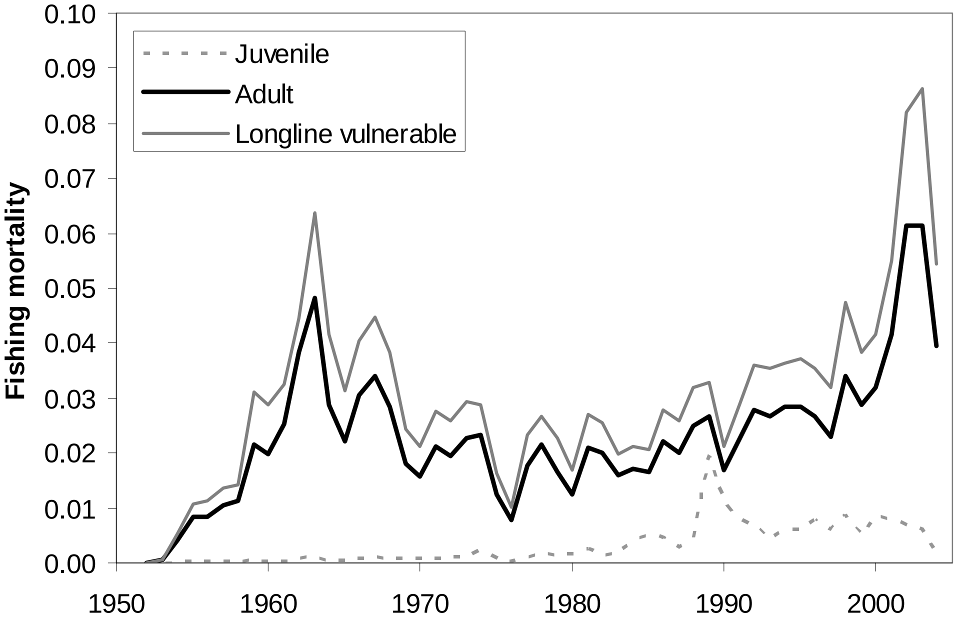


Figure 58. Annual estimates of fishing mortality for juvenile, adult and longline vulnerable South Pacific albacore.

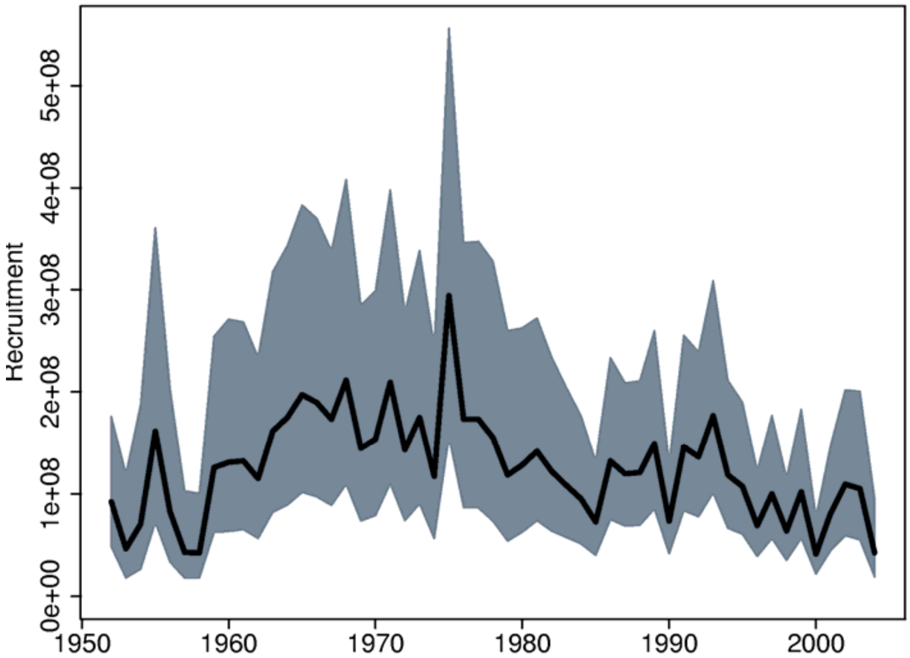


Figure 59. Annual recruitment (number of fish) estimates for South Pacific albacore. **The shaded area indicates the approximate 95% confidence intervals.**

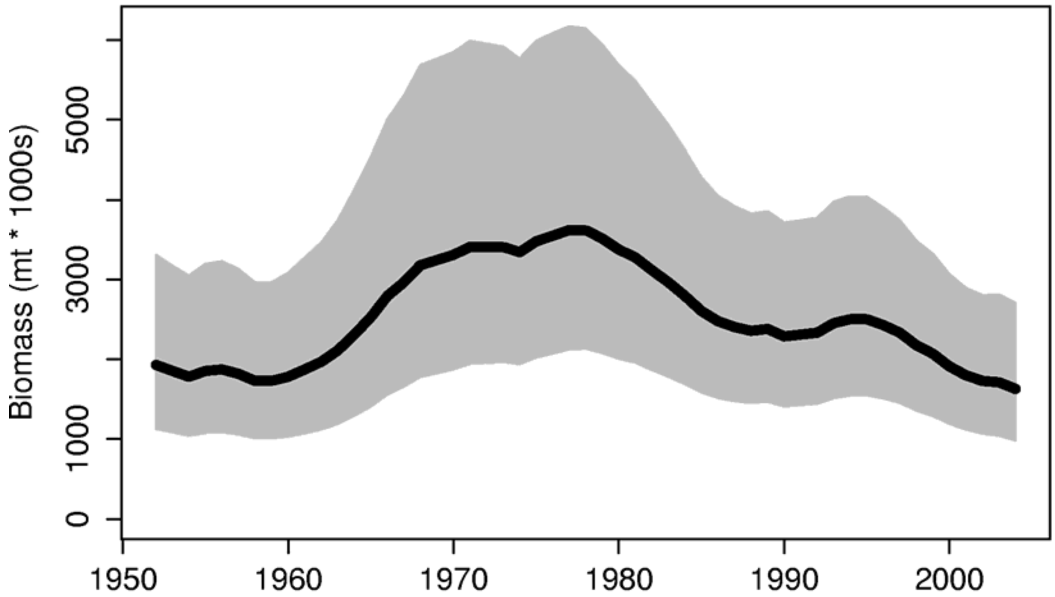


Figure 60. Estimated annual total biomass (thousand mt) of South Pacific albacore. **The shaded area indicates the approximate 95% confidence intervals.**

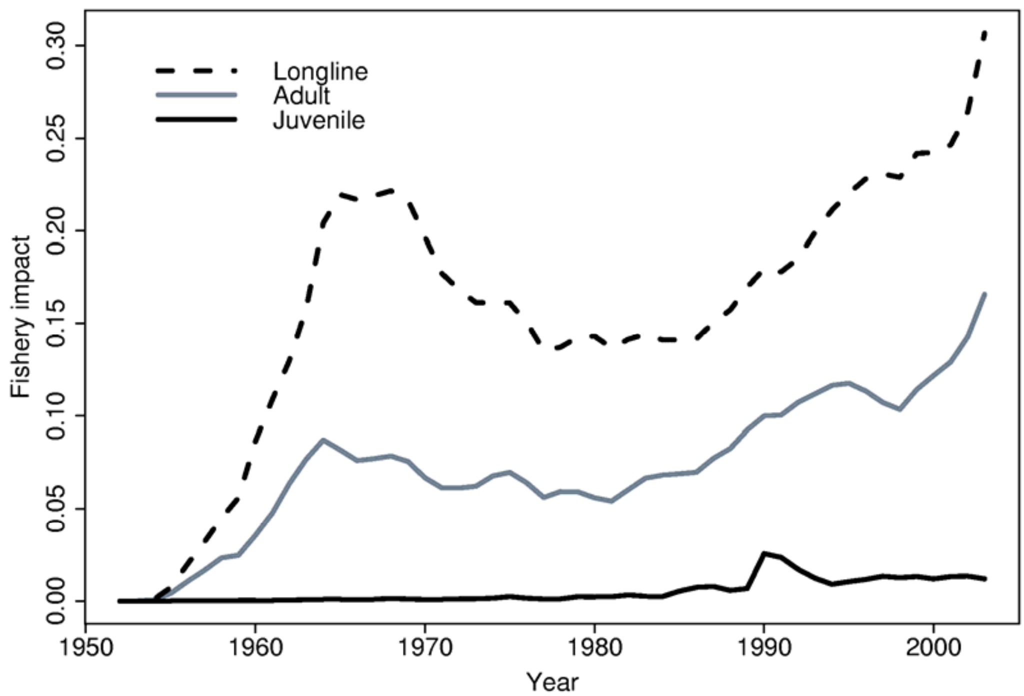


Figure 61. The estimated fishery impact on juvenile and adult biomass of South Pacific albacore and the component of the stock vulnerable to the longline fishery.

4 Ecosystem considerations

4.1 Introduction

The Convention on the Conservation and Management of Highly Migratory Fish Stocks in the Western and Central Pacific Ocean has identified ecosystem issues as an important element of the principles for conservation and management of the tuna resource in the WCP–CA. Specifically, the members of the WCPFC are required to *'assess the impacts of fishing, other human activities and environmental factors on target stocks, non-target species, and species belonging to the same ecosystem or dependent upon or associated with the target stocks'*. The members of the WCPFC are required to *'adopt measures to minimize … impacts on associated or dependent species, in particular endangered species'* and *'protect biodiversity in the marine environment'*.

This section of the report provides a brief summary of the information available from the WCP–CA tuna fishery concerning associated and dependent species, including information on the species composition of the catch from the tuna fisheries and an assessment of the impact of the fishery on these species. It is important to note that most of these species have received limited attention to date and consequently it is possible to provide an assessment of the impact of the fishery for a few species only. Nevertheless, the assessment of the impacts of the WCP–CA fisheries on associated and dependent species will become an increasing focus of research in coming years.

The section also includes a summary of the biophysical conditions in the WCPO and provides a review of recent and current research that is being undertaken to understand the relationship between the main tuna species and the pelagic ecosystem.

4.2 Catch composition

The tuna fisheries of the WCP–CA principally target four main species: skipjack, yellowfin, bigeye and albacore tuna. However, the method fisheries also catch a range of other species in association with these four species. Some of the associated species are of commercial value (by-product), while many others are of no value and are, consequently, discarded. There are also incidents of the capture of species of importance due to their ecological and/or social significance ('protected species'), including marine mammals, sea turtles and some species of shark (e.g. whale sharks).

Until recently, the compilation of catch statistics has concentrated on obtaining reliable estimates of the catch of the main commercial species (see Section 3). For the main tuna species, a reliable catch history has been compiled for the WCP–CA, with the probable exception of the Indonesian and Philippine fisheries. Annual catch estimates have also been derived for the four main billfish species caught (blue marlin, black marlin, striped marlin and swordfish) (OFP 2006). However, limited data exist regarding the magnitude of the catch of the many other associated species caught in the WCP–CA tuna fisheries. Many of these species are discarded and are, therefore, rarely recorded in the commercial catch statistics. We are reliant on the presence of fishery observers on board commercial vessels to record this component of the catch. Comprehensive observer programmes have only been operating in many WCP–CA fisheries during the last 10 years, and observer coverage rates are generally low and vary substantially between individual method and area fisheries. Consequently, for most fisheries, observer data are not adequate to provide comprehensive estimates of the catch of associated species. Instead, these data have been used to provide an indicative species composition of the catch from the recent period for the main method/area fisheries.

4.2.1 Longline

Estimates of the species composition of the catch were determined for three main longline fisheries operating in the WCP–CA: the WTP shallow-setting longline fishery, the WTP deep-setting longline fishery, and the WSP albacore fishery (Figure 62). As outlined in the previous paragraph, the estimates of species composition are based on relatively limited observer data and should be considered as indicative only. However, some clear trends are evident among the three fisheries, as follows:

- The main tuna species account for a high proportion of the total catch (by weight), representing 46%, 72% and 72% of the catch from the WTP shallow, WTP deep and WSP albacore fisheries respectively. The relative proportion of the main tuna species varied in accordance with the targeting practices.

- Blue shark (*Prionace glauca*) was the fourth- or fifth-ranked species in the catch composition of all three fisheries (Figure 62).
- The WTP shallow fishery has the highest proportion of associated species in the catch, principally shark and billfish species.
- Opah (moonfish, *Lampris guttatus*) represents a significant component of the WSP albacore longline catch (Figure 62).
- Striped marlin (*Tetrapturus audax*) and blue marlin (*Makaira nigricans*) dominate the billfish catch from the WSP albacore fishery, while blue marlin is a significant component of the catch from the WTP fisheries, particularly from shallow longline sets.
- The WTP shallow and WSP albacore fisheries catch a higher proportion of surface-orientated species, such as oceanic whitetip shark (*Carcharhinus longimanus*), mako shark (*Isurus* spp.) and striped marlin in both fisheries; silky shark (*Carcharhinus falciformis*) and blue marlin in the WTP; and mahimahi (*Coryphaena hippurus*) and wahoo (*Acanthocybium solandri*) in the WSP albacore fishery (Figure 62).

4.2.2 Purse-seine

Fishery observer data from the equatorial purse-seine fishery for 2001–2006 represent an overall coverage rate of about 8%[5] (of sets) and were analysed to determine the species composition of catches (by weight) from unassociated (free-school) and associated (log, drifting FAD and anchored FAD) sets. All set types were dominated by catches of skipjack and yellowfin, with the two species accounting for 99% of the unassociated sets and 91% of the catch from the associated set types (Figure 63). Bigeye tuna represented less than 1% of the catch from unassociated sets and 6–9% of the catch from associated set types, principally comprised of juvenile fish (see Figure 44). Similarly, juvenile yellowfin represented a significant component of the yellowfin catch from associated sets, while catches from unassociated sets are dominated by adult fish (see Figure 33).

Other species represent a trivial component (less than 0.2%) of the catch from unassociated sets, and only 1–2% of the catch from associated sets, of which rainbow runner (*Elagatis bipinnulata*) is the most significant component (Figure 63). The remainder of the catch is comprised of surface-orientated species that are principally oceanic in habitat (e.g. mackerel scad, *Decapterus macarellus*; frigate tuna, *Auxis thazard*; and mahimahi) or occupy both reef and oceanic habitats (e.g. rainbow runner; oceanic triggerfish, Balistidae; silky shark; and oceanic whitetip shark) (Figure 63). Log sets account for a higher proportion of bycatch than the other associated set types (drifting and anchored FAD sets).

[5] Coverage rates vary significantly among national fleets, with the USA fleet and those Pacific Islands-based vessels fishing under the FSM Arrangement having the highest coverage rates (greater than 20%). The coverage rates of the other main fleets (Taiwan, Korea and Japan) are currently less than 5%.

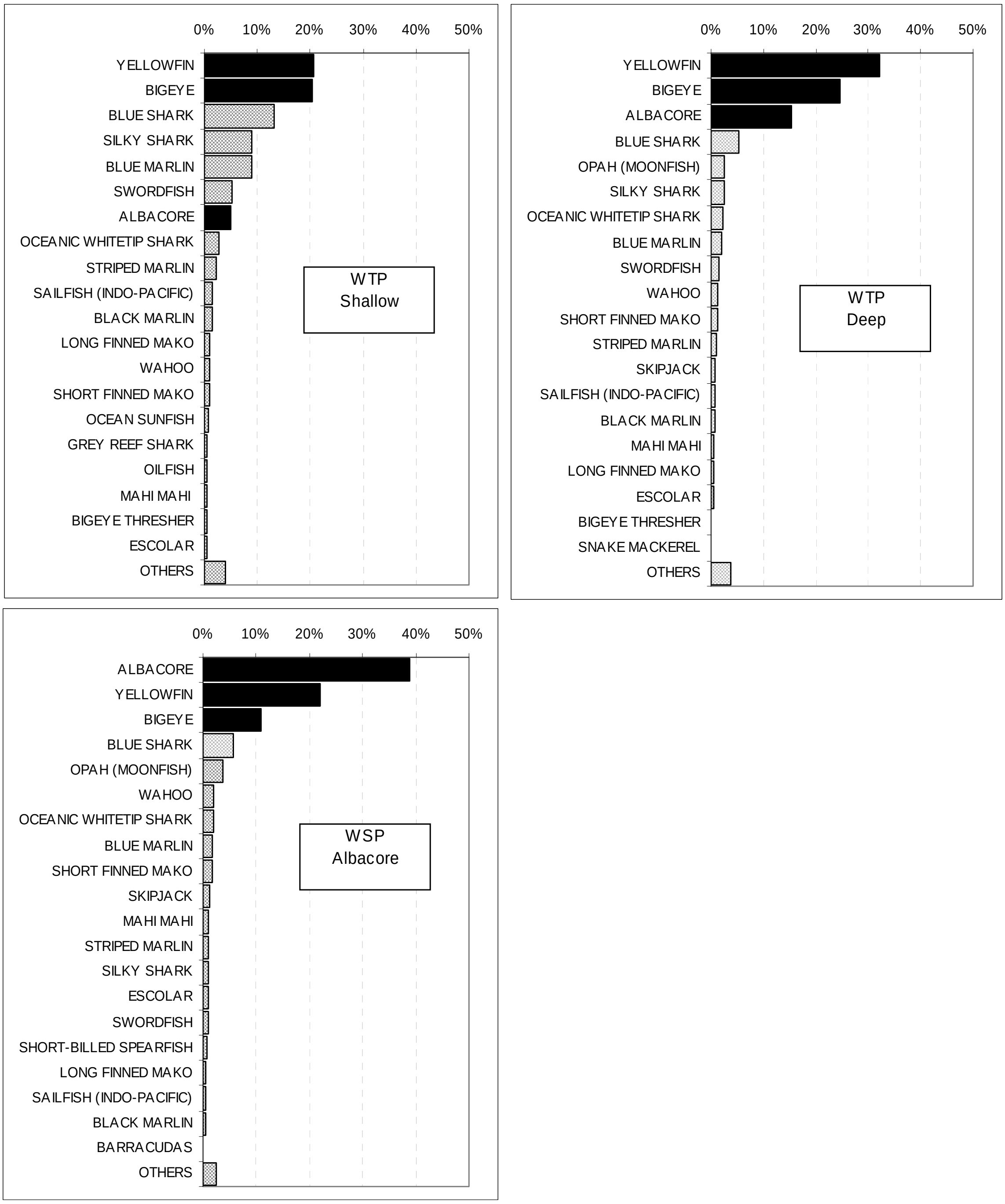


Figure 62. Percentage composition of the 20 main species caught by longline (by weight) for the three main fisheries in the WCP–CA determined from recent observer data (2001–2006). **Fishery codes: WTP shallow/deep = western tropical Pacific shallow/deep longline sets; WSP albacore = western south Pacific albacore target fishery. Number of sets sampled is 294, 4520 and 2528 respectively.**

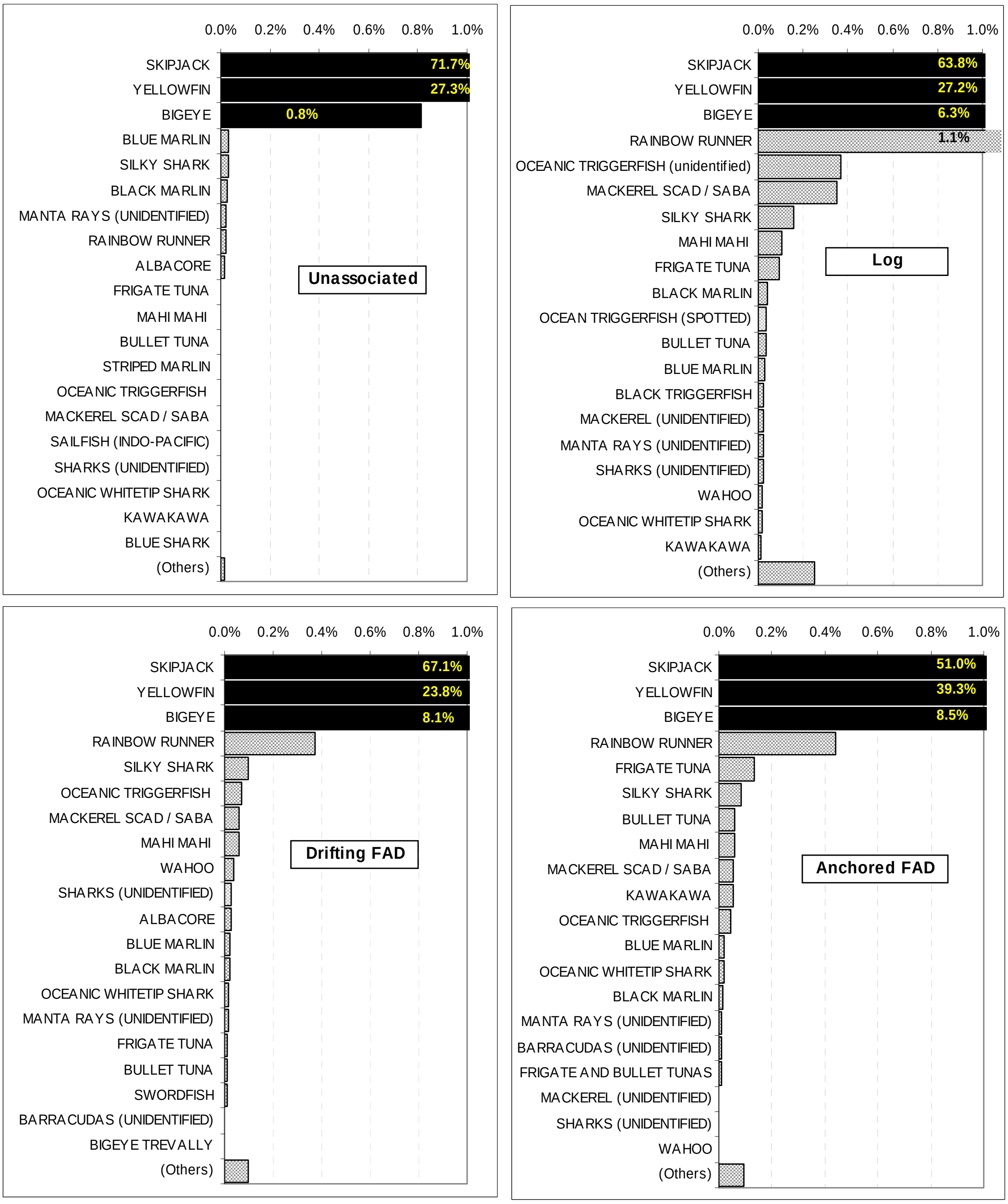


Figure 63. Percentage composition of the 20 main species caught by unassociated, log-drifting FAD and anchored FAD purse-seine sets (by weight) in the WCP–CA determined from recent observer data (2001–2006). **Number of sets sampled is 7605, 3159, 3236 and 4153 respectively.**

4.3 Impact of catches

An assessment of the impact of historical and current catches requires the reliable quantification of the catch for individual species (or, as a minimum, species groups) and the consideration of the magnitude of these catches with respect to the biological characteristics of the species. The assessment of the impact of the level of catch may be conducted in the framework of a formal stock assessment of the species, such as is undertaken for the main tuna species, or in a more qualitative manner taking account of the species distribution, relative abundance, growth rate, age at maturity, reproductive capacity, etc.

For many of the species caught in association with the main tuna fisheries, no formal stock assessment is available, and in many cases, assessments are unlikely to be conducted in the foreseeable future given the limitations of available resources and, more critically, insufficient data to undertake such assessments. For these species, it may be more appropriate to develop a range of fishery performance indicators to monitor recent and future trends in stock status, at least in the medium term (5–10 years) while the key inputs required for a more formal assessment are compiled. These performance indicators are likely to include trends in the incidence of capture, catch rate, and size composition. OFP is also developing the methodology to undertake an ecological risk assessment (ERA) of pelagic species caught in the WCP–CA fishery (Kirby & Molony 2006, Kirby & Hobday 2007). The ERA will assist in the prioritisation of species for future research and, when sufficient data are available, stock assessment.

The remainder of this section provides a brief overview of the stock assessments of the main tuna species and reviews the available assessment information for other associated species. More detailed information regarding the assessments of the tuna species was included in Section 3. The available information concerning the capture of protected species, principally marine mammals and marine turtles, is also presented.

4.3.1 Skipjack

The available fishery indicators suggest skipjack tuna stock biomass in the WCP–CA varies considerably over 3–5-year periods, fluctuating around the overall average level of stock biomass during the last three decades. Biomass levels are estimated to have been at historically high levels during the late 1990s–early 2000s. The percentage reduction in stock biomass attributable to the fishery has been 15% in recent years, although there has been greater impact (25%) in the main area of operation of the purse-seine fishery. Recent catch levels are easily sustainable under current stock productivity conditions. Sibert et al. (2006) suggest that the recent high levels of skipjack biomass may be attributable to a reduction in top-level predator abundance.

4.3.2 Yellowfin

Since 1990, the biomass of yellowfin in the WCPO has steadily declined and fishing mortality rates have increased to the extent that current exploitation rates exceed the F_{MSY} reference point and, therefore, overfishing is occurring (i.e. $F_{CURRENT} > F_{MSY}$). The stock is not yet in an overfished state (i.e. $B_{CURRENT} > B_{MSY}$), although continued fishing at current levels of effort will move the stock to an overfished state. Further, the assessment indicates that the equatorial regions are likely to be overexploited, while exploitation rates in the subtropical regions are relatively low.

4.3.3 Bigeye

The current bigeye assessment indicates the stock is not in an overfished state ($B_{CURRENT} > B_{MSY}$), although current fishing mortality rates are greater than the F_{MSY} level ($F_{CURRENT} > F_{MSY}$) and, therefore, overfishing is occurring. Recent catches have been sustained by higher-than-average levels of recruitment, which have also maintained biomass above the B_{MSY} level. Future levels of recruitment are highly uncertain and a return to long-term average levels of recruitment is predicted to result in a rapid decline in biomass to below the B_{MSY} level.

4.3.4 Albacore

The assessment indicates that the current level of exploitation of the total biomass is very low ($F_{CURRENT} << F_{MSY}$) and, consequently, the fishery impacts on the total biomass are low. Biomass levels have declined over the last decade due to a decline in recruitment; however, current biomass levels remain well above the MSY-based reference point ($B_{CURRENT} > B_{MSY}$).

4.3.5 Blue marlin

Blue marlin is considered to represent a single stock in the Pacific Ocean, although a high proportion (80–90%) of the total annual catch from the Pacific Ocean is taken within the WCP–CA. Annual estimated catches from the WCP–CA steadily increased from the mid-1970s and averaged approximately 15,000 mt during the 1990s (Figure 64). Reported catches have during the last four years have been the highest on record, averaging 21,500 mt in 2003–06, largely due to increased catches by the Chinese distant-water longline fleet and an increase in the catches of blue marlin reported by the Chinese Taipei offshore longline fleet.

An assessment of the Pacific Ocean blue marlin stock was recently conducted using MULTIFAN-CL (Kleiber et al. 2003). Despite the uncertainty associated with the assessment, the most conservative interpretation of the results was that the current level of fishing effort was producing close to the maximum sustainable yield. Further improvements to the assessment were proposed, principally to include additional sources of catch, effort and size data.

4.3.6 Black marlin

The stock structure of black marlin is unclear. Genetic studies have suggested that there are several stocks within the Pacific (eastern, southwestern and northwestern stock units). Other evidence, such as long-distance movement of tagged marlin, suggests a single pan-Pacific stock. During 1980–2000, annual catches of black marlin from the WCP–CA remained relatively stable at about 1000–2000 mt (Figure 64). Catches increased steadily in the subsequent years, averaging 2500 mt in recent years. There has been no assessment of the status of the black marlin stock(s) in the Pacific Ocean.

4.3.7 Striped marlin

The stock structure of striped marlin in the Pacific Ocean is not well known. There are indications that there is only limited exchange of striped marlin between the eastern Pacific and the central and western Pacific Ocean. Genetic studies and tag recoveries suggest that striped marlin in the southwestern Pacific represent a semi-independent stock. The stock structure of striped marlin in the north Pacific is unclear, although there is some evidence to suggest a degree of separation between striped marlin in Hawaiian waters and the northeastern Pacific.

Striped marlin catches in the WCP–CA declined sharply in the 1960s and early 1970s and remained at less than 5000 mt per annum over the subsequent years (Figure 64). The early decline in catches is likely to be at least partly attributable to a shift in the spatial and depth distribution of longline fishing effort.

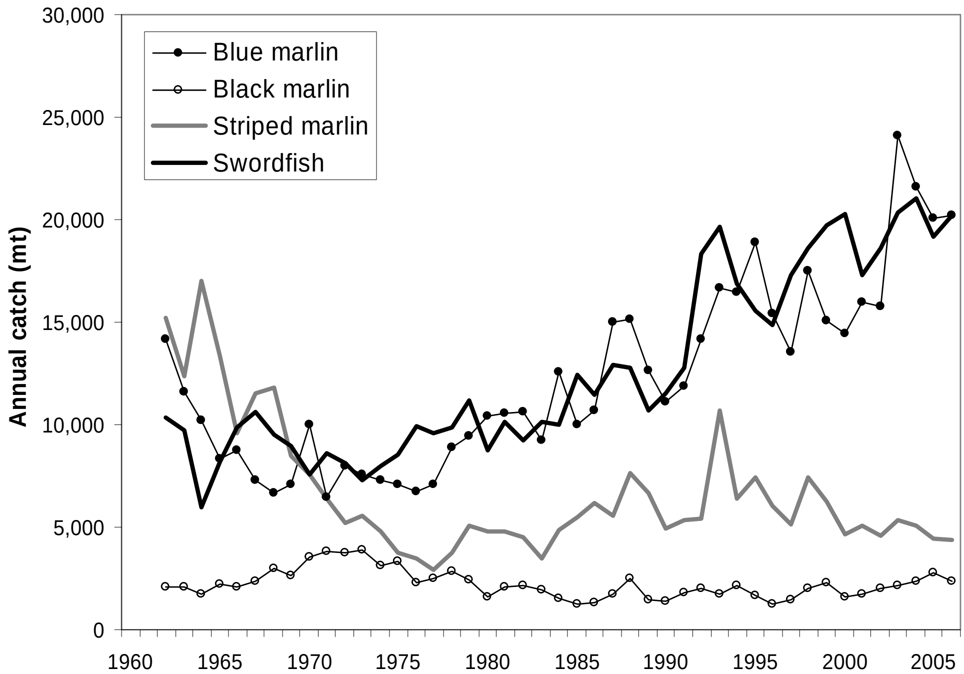


Figure 64. Total annual catches of the four main billfish species from the WCP–CA.

A preliminary stock assessment of striped marlin in the southwestern Pacific stock was conducted in 2005 (Langley et al. 2006). While the current stock status is uncertain, current levels of catch are comparable to the range of MSY estimates from the assessment. On this basis, it appears that there is no potential to substantially increase the current level of yield from the stock. Nonetheless, the fishery has supported catches at about the MSY level for the last 20 years at a relatively constant level of fishing effort, and there is no indication that current exploitation rates are having a deleterious impact on the productivity of the stock.

Several of the plausible model scenarios indicated that current levels of fishing mortality may approximate or exceed the reference level (F_{MSY}) and current biomass levels may approximate or be below the biomass-based reference point (B_{MSY}). On this basis, it is recommended that there be no increase in fishing mortality (fishing effort) on striped marlin in the southwestern Pacific. This recommendation was subsequently adopted by the Scientific Committee of the WCPFC in 2006.

4.3.8 Swordfish

Swordfish are distributed throughout the Pacific Ocean. It has been generally concluded that there are four semi-independent stocks of swordfish within the Pacific: a northern stock, a southwestern stock, and two eastern Pacific stocks. Catches of swordfish from the WCP–CA, principally encompassing the two former stock units, steadily increased from the early 1970s and have exceeded 20,000 mt in recent years (Figure 64).

The results of preliminary modelling (using MULTIFAN-CL) of a north Pacific swordfish stock in areas north of 10°N and west of 135°W indicate that in recent years the biomass level has been stable and well above 50% of the unexploited levels of stock biomass, implying that swordfish in this area are not overexploited at current levels of fishing effort (Kleiber & Yokawa 2002).

The first stock assessment of the swordfish resource in the southwestern Pacific was completed recently (Davies et al. 2006; Kolody et al. 2006). The catch, effort and size data incorporated in the assessment reveals that catch rates and fish size have declined in the core region of the fishery over the last decade (see Campbell & Hobday 2003). The assessment model estimates that there has been a considerable decline in total stock biomass during this period. There is a high level of uncertainty associated with the MSY-related reference points derived from the assessment. However, for the most plausible model options, total biomass and spawning biomass are probably above levels that would sustain MSY and fishing mortality is probably below F_{MSY}. Nevertheless, the results also indicate the possibility that the stock may currently be in an overfished state and that overfishing may be occurring. On this basis, the Scientific Committee of the WCPFC recommended that, as a precautionary measure, there be no increase in fishing mortality on this stock, as this is likely to move the stock towards an overfished state.

4.3.9 Marine mammals

For the WCP–CA, incidences of capture of marine mammals in the equatorial purse-seine and area-specific longline fisheries were summarised from observer data to identify (where possible) the main species caught and provide an indication of the level of fishery interaction. However, it is important to note that no attempt has been made to apply these data to provide overall estimates for the fishery. This work would require a more detailed analysis of observer coverage rates of individual fleets and consideration of appropriate spatial and temporal stratification. It is intended to undertake such an analysis during the next year.

There is a relatively high level of observer coverage in the equatorial purse-seine fishery, with 33,319 sets observed in the last 11 years (1995–2005). Marine mammals were caught in a very small proportion of these observed sets, mainly from sets targeting tuna schools associated with either whales or dolphins. Most of the marine mammals caught in these sets were not identified beyond the taxonomic order and the fate of most of the observed marine mammals was unknown (Table 1). Overall, a small number of dead marine mammals were observed in the fishery.

A small number of marine mammals were also observed caught in the WTP and WSP longline fisheries. In most cases, these marine mammals were alive when released (Table 1). In recent years, there have been increased reports of interactions between tuna longline operations and marine mammals and claims of increased incidence of depredation of the tuna catch, particularly by toothed whales.

Table 1. Total number of marine mammals, marine turtles and seabirds (by species where available) recorded by observers from the main method/area fisheries in the WCP–CA for 1995–2005 years combined. The fate of the individuals is also recorded (alive = released alive; dead = dead; U = unknown). The equatorial area of the purse-seine fishery and the WTP longline fishery is defined by latitudes 10° N/S and longitude 120°E to 150°W. The WSP longline fishery is defined by latitude 10°S to 30°S and longitude 155°E to 155°W. The number of observed sets (N) is given for each fishery. Data from the Australian, New Zealand and Hawaiian observer programmes are excluded from the analysis because these have been analysed in detail by the respective governmental agencies.

Fishery	Family	Common name	Number observed by fate			
			Alive	Dead	Unknown	**Total**
Purse-seine, equatorial N = 33,319	Marine mammals	Bottlenose dolphin	0	0	75	75
		Dolphin (unidentified)	3	4	52	59
		Marine mammal (unidentified)	33	42	1106	1181
		Total	36	46	1233	1315
	Marine turtles	Green turtle	2	0	9	11
		Hawksbill turtle	7	0	7	14
		Leatherback turtle	0	0	3	3
		Loggerhead turtle	0	0	3	3
		Olive ridley turtle	3	4	6	13
		Marine turtle (unidentified)	22	0	89	111
		Total	34	4	117	155
Longline, WTP N = 3674	Marine mammals	Dolphin (unidentified)	1	1	0	2
		Whale (unidentified)	1	1	0	2
		Marine mammal (unidentified)	4	2	0	6
		Total	6	4	0	10
	Marine turtles	Green turtle	24	5	1	30
		Hawksbill turtle	10	4	0	14
		Leatherback turtle	6	1	3	10
		Loggerhead turtle	4	1	0	5
		Olive ridley turtle	36	13	0	49
		Marine turtle (unidentified)	32	19	3	54
		Total	112	43	7	162
	Seabirds	Bird (unidentified)	1	7	0	8
Longline, WSP N = 1496	Marine mammals	Dolphin (unidentified)	2	0	0	2
		Whale (unidentified)	1	0	1	2
		Marine mammal (unidentified)	1	0	0	1
		Total	4	0	1	5
	Marine turtles	Green turtle	1	2	0	3
		Leatherback turtle	2	1	1	4
		Marine turtle (unidentified)	1	1	1	3
		Total	4	4	2	10
	Seabirds	Total	0	0	0	0

4.3.10 Marine turtles

The WCP–CA is home to five species of widely distributed sea turtles: Olive ridley turtle (*Lepidochelys olivacea*), loggerhead turtle (*Caretta caretta*), green turtle (*Chelonia mydas*), hawksbill turtle (*Eretmochelys imbricata*) and leatherback turtle (*Dermochelys coriacea*). All species are long-lived and slow growing and therefore vulnerable to overexploitation. They exhibit complex life cycles involving eggs laid on tropical beaches, natal beach homing and feeding, and breeding migrations that can span the entire Pacific Ocean.

The five species of marine turtle have been observed in the purse-seine fishery; however, most of the turtles caught were not identified by species (Table 1). Following capture, turtles are typically released from the purse-seine net during retrievial. It is difficult for observers to ascertain the fate of the turtles released from purse-seine sets; however, a significant proportion of turtles are alive at release and only a few mortalities have been reported (exclusively hawksbill turtles).

Olive ridley turtle, green turtle and hawksbill turtle were the most common species caught in the tropical longline fishery, while a significant proportion of the individuals caught were not identified by species. Overall, encounter rates were low in observed longline sets and most of the turtles caught were alive at the time of release (Table 1).

A small number of green turtles and leatherback turtles were observed caught by longline in the southwestern Pacific fishery (Table 1).

It is extremely difficult to quantify the effects of the different components of mortality for sea turtles and to suggest specific remedial management actions in a timely manner. Population assessments are not routinely carried out, in part because of the paucity of data on early life history and the wide-ranging distribution of juveniles and adults. The most commonly used indicator of turtle population abundance is the number of nesting females. Nonetheless, integrated research projects are under way, attempting to synthesise available knowledge and data, to quantify more rigorously the population dynamics of these endangered species and to develop a greater understanding of their ecological interactions, requirements and consequent spatial distribution. Community awareness training is also being carried out to ensure that traditional harvesting is sustainable.

Research into modified fishing methods, specifically the use of deep-setting gear and 'circle' rather than 'J' hooks, shows great promise for decreasing turtle catch rates and increasing post-release survival respectively. Extensive adoption of these and related techniques would be the kind of pan-Pacific policy action needed to reduce turtle take in at-sea fisheries, as called for in the Bellagio Blueprint for Action on Pacific Sea Turtles (FAO 2004).

4.3.11 Seabirds

The observer data from the longline fisheries in the equatorial and sub-equatorial regions of the WCP–CA indicate interactions with seabirds are negligible (Table 1). Limited data are available from observers regarding the species caught, although 11 known and potentially vulnerable bycatch species have been identified in the region (of which six are Pacific residents and five migrants) (Wattling 2002). A high proportion of these species are internationally classified as 'threatened' and, therefore, the issue of seabird interactions is more serious than the small number of captures would otherwise indicate (Wattling 2002).

Incidents of seabird capture are more numerous for longline fisheries operating in the higher latitudes of the WCP–CA. Data from observer programmes operating in the Australian, New Zealand and Hawaiian longline fisheries have been applied to estimate encounter rates for vulnerable bird species. These results have been documented by the respective governmental agencies and are not included in this report.

4.3.12 Other protected species

Within the WCP–CA, a range of other species or species groups are afforded special significance for ecological, cultural, and economic reasons. Such species include a number of the large elasmobranch species, such as whale sharks (*Rhincodon typus*) and manta rays (Mobulidae), and shark species associated with coastal reef systems. These species have been termed 'protected species' although in reality there may be no legal protection of the species or the level of protection may be limited to a small area of the species' range. In some areas, the protection of these species may be important to the development of dive-based tourism operations, while in other areas the concern may reflect wider issues concerning the impact of industrial-scale fishing activities on local fish resources. These issues are frequently addressed through the introduction of areas closed to large-scale fishing activity. The regional observer programmes also provide some information concerning the overall magnitude of the catch of these species, although information at the local scale is often lacking.

4.3.13 Other associated species

For most of the elasmobranch and teleost species caught in association with the main tuna fisheries, there is limited information available concerning the magnitude of the catch, in particular for the period prior to the implementation of comprehensive fishery observer programmes and for those fisheries where observer coverage has been minimal. Further work will be undertaken to apply the available data to derive best estimates of the recent and historical catch of the main associated species taken in the WCP–CA fisheries, although in the first instance this study will concentrate on the species of commercial value for which more data are available.

4.4 Physical environment

The physical oceanography of the tropical Pacific is strongly dominated by the equatorial current systems (Figure 65). Driven by the prevailing trade winds blowing from east to west, surface water is transported westwards through the equatorial Pacific (North and South Equatorial Currents: NEC and SEC). En route, the temperature of the surface water increases, resulting in the formation of a thick layer of warm water above 29°C on the western side of the oceanic basin (the ‘warm pool’). In the eastern and central Pacific, this dynamic creates a divergence at the equator, with an upwelling of deep and relatively cold water and a shallower thermocline. The upwelled water is rich in nutrients and increases the primary (algal) production in the surface layer, creating a productive ‘cold tongue’ of surface water, easily visible from satellite and contrasting with the lower productivity of the north and south subtropical gyres and the western equatorial warm pool.

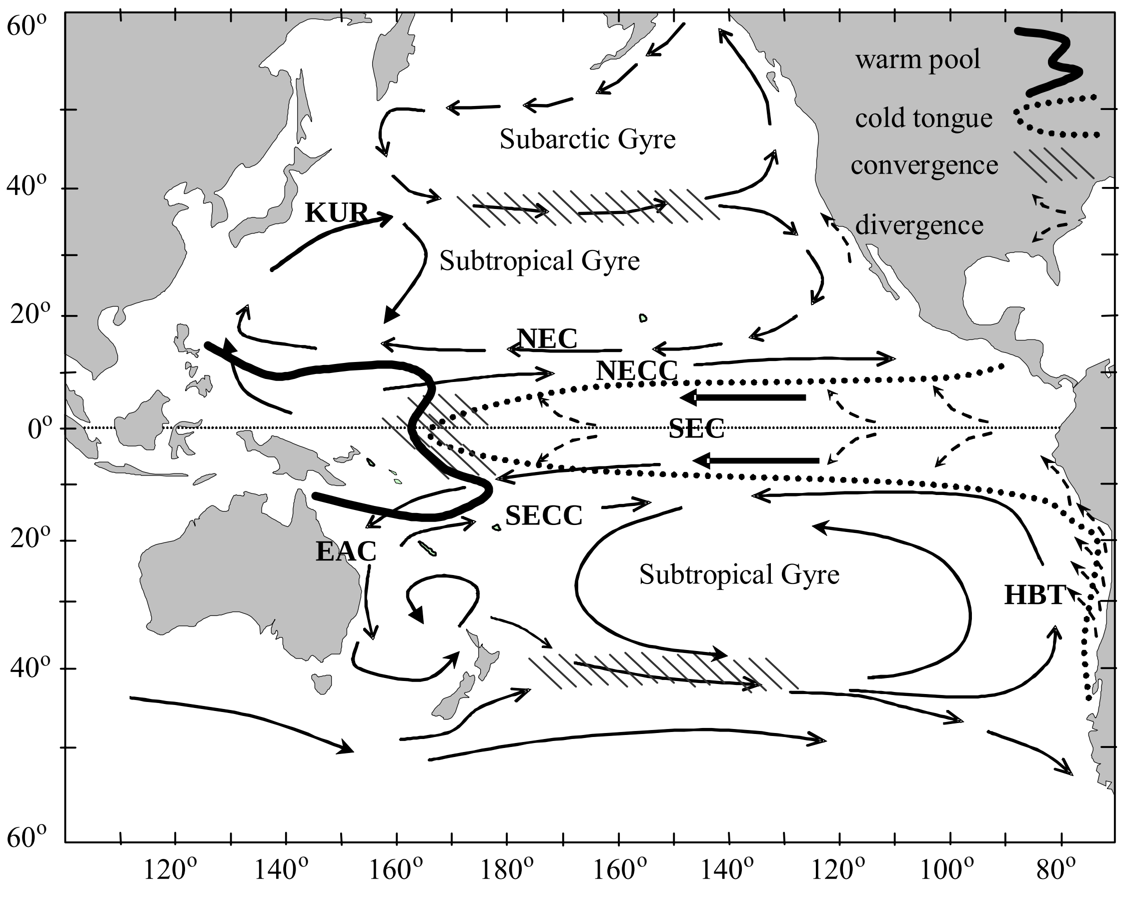


Figure 65. The main oceanographic features of the Pacific Ocean. **SEC = South Equatorial Current; NEC = North Equatorial Current; SECC = South Equatorial Counter-Current; NECC = North Equatorial Counter-Current; KUR = Kuroshio Current; EAC = East Australian Current; HBT = Humboldt Current.**

The general east–west water transport is counterbalanced by the North and South Equatorial Counter-Currents (NECC and SECC), the equatorial under-current (EUC) and the retroflexion currents that constitute the western boundaries (Kuroshio and East Australian Currents) of the northern and southern subtropical gyres. The warm pool is associated with important atmospheric convection and heavy precipitation in the western Pacific, in contrast to the colder and drier conditions in the eastern Pacific. There is limited seasonal variation in the prevailing oceanographic conditions in the tropical Pacific, although there is strong interannual variability in conditions principally linked to the El Niño Southern Oscillation (ENSO).

ENSO is an oscillation between a warm (El Niño) and cold (La Niña) state that evolves under the influence of the dynamic interaction between atmosphere and ocean, with an irregular frequency of 2–7 years. During the last 20 years, powerful El Niño events have occurred in 1982–83, 1986–87, 1991–92 and 1997–98 and La Niña events in 1988–89, 1996–97 and 1998–2000. Briefly, the system takes its energy from the contrasted situation between the east and west of the equatorial Pacific.

A La Niña situation is an intensification of the average state described above. Stronger trade winds increase the intensity of the SEC and push the warm pool to the extreme west of the equatorial Pacific. Upwelling intensity in the east also increases, elevating the thermocline closer to the surface while it deepens in the warm pool. Conversely, during El Niño events, the trade winds relax and allow the warm waters of the warm pool to spread far to the east in the central Pacific. In general, the most powerful events reach the west coast of California and Peru in the Christmas season and create catastrophic conditions, with devastating storms and floods. The upwelling decreases in intensity and the thermocline deepens in the central and eastern Pacific while it rises abnormally in the western Pacific. These zonal (east–west) displacements of the warm pool are accompanied by changes in the Walker circulation that are reflected by the Southern Oscillation Index (SOI), calculated from the difference in sea-level atmospheric pressure between Tahiti and Darwin. A strong negative index indicates an El Niño while a positive index reveals a La Niña event.

With the seasonal and interannual (ENSO) variability, another climate fluctuation at a lower frequency has been recently identified: the Pacific Decadal Oscillation (PDO). As for ENSO, warm and cold phases can be defined for the PDO in association with positive and negative values of climate indices, based on surface temperature and sea-level pressure (Figure 66). Positive PDO indices (warm phases) correspond to warm SST anomalies along the northeastern Pacific coast, cool SST anomalies in the central north Pacific, and below-average sea-level pressure (SLP) over western North America and the subtropical Pacific. The reversed anomalies occur for negative values of PDO indices (cold phases). In the past century, just two PDO cycles of 20–30 years have been identified. The cool phase prevailed 1890–1924 and 1947–1976, and the warm phase 1925–1946 and from 1977 through the end of the century. Since 1998, recent changes in Pacific climate suggest a possible reversal to cool PDO conditions, coinciding with the end of the 1997–98 El Niño event that was, with the 1982–83 event, one of the most powerful in the past century.

A correlation between both ENSO and PDO signals is evident for the last 50 years (Figure 66). Until 1976, cold La Niña events were dominant in the tropical Pacific, while the situation reversed from 1977 to 1998 with fewer and weaker La Niña events and stronger, more frequent El Niño events. Whether ENSO fluctuations are influenced by or the cause of the PDO is still unclear, and the question is an exciting challenge for the scientific community as it has been shown that including PDO climate information in ENSO statistical predictive models may improve climate forecasts. In particular, El Niño and La Niña typical patterns would appear only when ENSO and PDO signals are in phase; that is, when El Niño events occur during a warm phase of PDO, or conversely La Niña events during a cool phase of PDO. Under this hypothesis, the limited development of the two last El Niño events that occurred in 2002 and 2004 could be seen as another indication that PDO effectively shifted to a new cool phase after 1998.

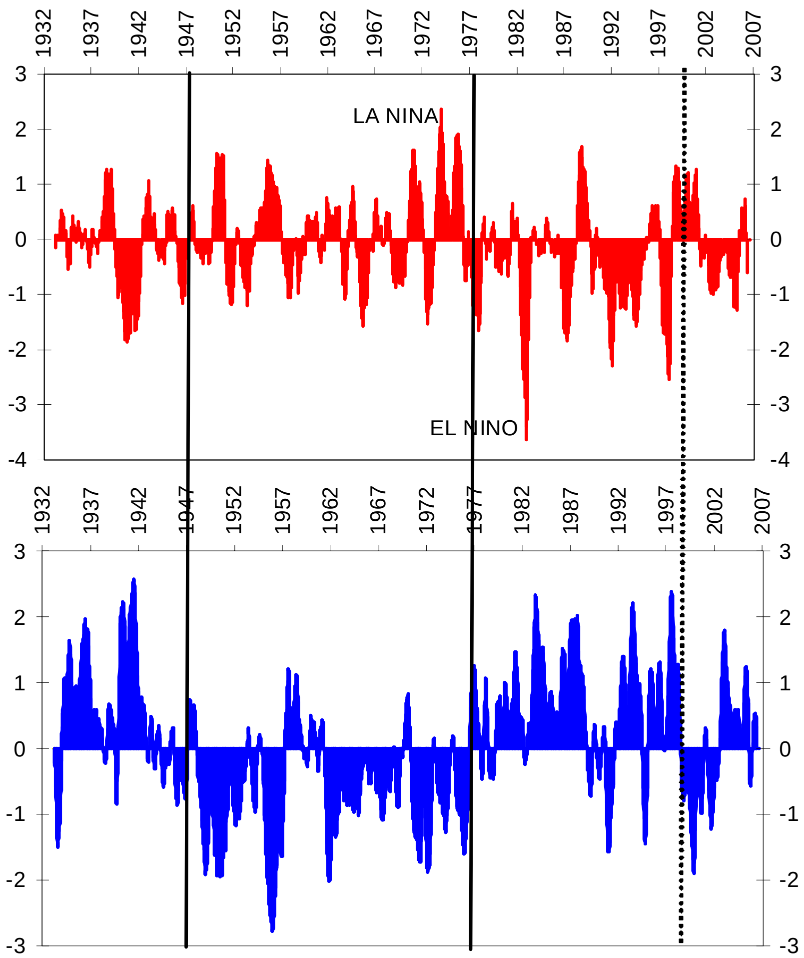


Figure 66. Monthly trends in the Southern Oscillation Index (top) and Pacific Decadal Oscillation (bottom).

4.5 Influence of climate on the ecosystem

Understanding and predicting climate fluctuations is of fundamental interest to biologists as they have direct impacts on the productivity of the ocean and the operation of the many important commercial fisheries. In particular, the development of El Niño events with the associated decline in the intensity of the trade winds and equatorial upwelling results in lower primary productivity in the cold tongue. The cold tongue retreats eastwards, while warmer waters extend to the central Pacific. There is also an increase in primary production in the western equatorial Pacific, in response to stronger winds.

The impact of El Niño events on the productivity of traditional fisheries exploiting small pelagics (anchovies, sardines) along the South American coast is well understood. There is also an increased understanding of the importance of El Niño or La Niña events to the dynamics of the Pacific tuna fisheries. These include direct effects on the spatial and vertical distribution of tuna. For example, the distribution of purse-seine catch in the central western Pacific is generally displaced eastwards during El Niño conditions, indicating a spatial shift in the distribution of skipjack tuna. As skipjack inhabit the epipelagic (surface) layer, changes in catchability due to changes in the vertical thermal structure are negligible for this species. But this is not the case for yellowfin and bigeye, as the adults are also caught by deep fishing gear (longline). In the western Pacific, the vertical change in the thermal structure during El Niño (La Niña) events result in the rising (deepening) and vertical extension (contraction) of their temperature habitats. This change would increase (decrease) purse-seine and pole-and-line catch rates of yellowfin and longline catch rates of bigeye.

Delayed effects are also observed, as inferred from stock assessment analyses. The assessment results indicate that recruitment in tuna populations is influenced by ENSO variability, although the conditions favouring recruitment vary between species. El Niño events appear to result in higher recruitment for skipjack and yellowfin, while South Pacific albacore recruitment is higher under La Niña conditions. There also appears to be a strong relationship between the recruitment patterns of yellowfin and bigeye tuna (Figure 33 and Figure 44) and the PDO (Figure 66).

The impact of recruitment variation on the adult populations also varies considerably between species. Skipjack are fast growing and have a short lifespan (4–5 years) and, consequently, the impacts of recruitment variation on adult abundance occur with a short time lag. In contrast, albacore are characterised by slower growth and long lifespans (about 15 years). Therefore, the effects of a strong El Niño (La Niña) event that is favourable (unfavourable) to skipjack will be quickly (in the next 6–12 months) experienced by the purse-seine fisheries, while for albacore the impact will occur after 5–6 years, in the longline fisheries. For yellowfin, it will be rapid in the purse-seine fishery and delayed by 2–3 years in the longline fishery.

4.6 Trophic structure

To understand of the effect of environmental conditions (such as El Niño) and the impact of fisheries on the different components of the ecosystem, it is necessary to acquire a better understanding of the functioning of the ecosystem. Knowledge on the trophic structure, interaction between trophic levels and feedbacks of the pelagic ecosystem (i.e. who is eating who in the food web and how influential is the biomass of a species or trophic group upon others in the web) provides the information necessary to comprehend ecosystem functioning.

A large sampling programme has been in place in the WCPO since 2001 to collect stomach and tissue samples of pelagic predators to determine the trophic structure of the ecosystem through analyses of their diets. A preliminary analysis has been conducted on the diet of four species. The diets of mahimahi, wahoo and lancetfish were studied at the regional level. They show different feeding strategies: mahimahi is strictly a surface piscivorous predator; wahoo also consumes small amounts of mesopelagic prey, is mainly piscivorous, but diversifies its diet by eating small quantities of cephalopods and shrimps; and lancetfish feeds at the surface and in deeper waters on fish and molluscs but also on small quantities of crustaceans and invertebrates (Allain 2003). The diet of yellowfin tuna was also examined in different areas of the WCPO. Differences were highlighted in the diet of yellowfin in New Caledonia (epipelagic and mesopelagic fish), Polynesia (epipelagic fish and crustaceans, juvenile reef fish) and PNG–Solomon Islands (epipelagic fish and crustaceans, juvenile reef fish) (Allain 2004). A comparison with data from the EPO shows important differences between the western and eastern Pacific, probably linked to the depth of the thermocline, to the minimum oxygen zone in the eastern Pacific and to the presence of numerous coral islands in the western Pacific.

Diet information of the main predators has been compiled into a diet matrix describing the prey-predator interactions. Recently, this was incorporated into an ecosystem model of the western and central Pacific using the Ecopath with Ecosim software (http://www.ecopath.org/). The model demonstrated sensitivity to groups in the lower trophic groups (e.g. bathypelagic foraging species and molluscs) and simulations identified that the higher order trophic levels are sensitive to changes in fishing harvest rate, except for skipjack which remained stable. The construction process revealed a disagreement in the input data: the estimates of forage biomass extracted from the literature and other models of the WCPO ecosystem (e.g. SEAPODYM) could not sustain the biomass of tuna estimated from the stock assessment model MULTIFAN-CL. Four hypotheses could be considered to explain this discrepancy:

i. the system is not well captured because of too much grouping of species in the model;
ii. there is an underestimation of forage, particularly epipelagic and mesopelagic component and possibly a bad repartition of the diet proportions among the different forage components;
iii. there is an overestimation of tuna biomass;
iv. a potential importation of forage/zooplankton from the eastern Pacific that would interact with the western Pacific is not captured in the model.

The modelling process identified potential consequences of data uncertainty and knowledge gaps. Skipjack appear to have a key role in the system because of its high biomass, high production, and high consumption. This species was the most difficult to parameterise and the changes carried out on this group had important impacts on the other components of the system. The skipjack consumption rate was high in order to maintain their high productivity and because cannibalism is high, the species exerts important pressure on its juveniles. Juvenile skipjack was also a major source of food for all the top predators. Consequently, in the model skipjack occupied a central position in the system that might be comparable in a way to the position of *Auxis sp.* in the eastern Pacific. Given this construct, skipjack was driving our Ecopath model and draft Ecosim simulations showed a very high resilience of this species to perturbations. It was nearly impossible to eliminate this species from the system with a top-down control (e.g. fishing harvest). Skipjack resiliency is probably related to the high production rate and the internal density-dependence induced by cannibalism.

The ultimate goal of this exercise was to provide ecosystem models with the capacity for testing different fishing policies and environmental change scenarios to assist managers with identifying robust and reliable management options that will achieve their objectives. Before reaching this end point, further model development is required, including an investigation of model uncertainty, model validation, and the testing of management options and environmental impact.

4.7 Ecosystem modelling

To explore the underlying mechanisms by which the climate and environmental variability affect the pelagic ecosystem and tuna populations, a spatial ecosystem and population dynamics model (SEAPODYM) has been developed (Lehodey 2004a, 2004b). The model uses an input data set describing the oceanic environment with the variables temperature, currents and oxygen concentration over three integrated layers: 0–200 m (epipelagic), 200–500 m (mesopelagic) and 500–1000 m (bathypelagic); and also primary production integrated over all the vertical layers. The input data set (physical and primary production data) included in the most recent simulations is provided by a coupled 3D physical-NPZD (nutrients-phytoplankton-zooplankton-detritus) model covering the last 50 years. From this input, the transfer in the food chain is simulated with six different kinds of forage (prey) organisms living at different depths and having one of two vertical migration behaviours (migrating or not, during the night to the upper layer).

The populations of tuna species are then added to the model and evolve according to their own preferences for temperature and oxygen conditions and their ability to access these different prey components. The model is spatial and dynamic, meaning that forage organisms and tuna move according to changes in the environment and their physical aptitudes – e.g. tuna larvae or small prey drift with the currents, but adult tuna can swim by following positive gradients in their preferred habitat. Finally the fisheries are added – that is, the observed fishing effort is applied in space and time and the catch predicted from the state of the populations simulated by the model at the corresponding time and place of fishing. A comparison of observed and predicted catch is applied to evaluate whether the model produces realistic simulations.

The SEAPODYM model was initially applied to skipjack. The model predicted large interannual variations in the recruitment, increasing during El Niño events (1972, 1982–83, 1987, 1990) and decreasing during La Niña events (1988–89), as observed from the statistical estimates (MULTIFAN-CL) (Figure 67). This is attributable to the extension of the spawning ground with the warm waters during the development of El Niño, in association with a higher primary production in the western Pacific that increases spawning success. An exceptional catch record of skipjack at the end of 1998 seems to support this mechanism. The catch was concentrated in a relatively small area centred on the equator at 165°E and contained an unusually large number of juveniles (20–35 cm in length). Four to eight months before, a huge phytoplankton bloom was observed with SeaWiFS satellite images at the same location (http://oceancolor.gsfc.nasa.gov/SeaWiFS/).

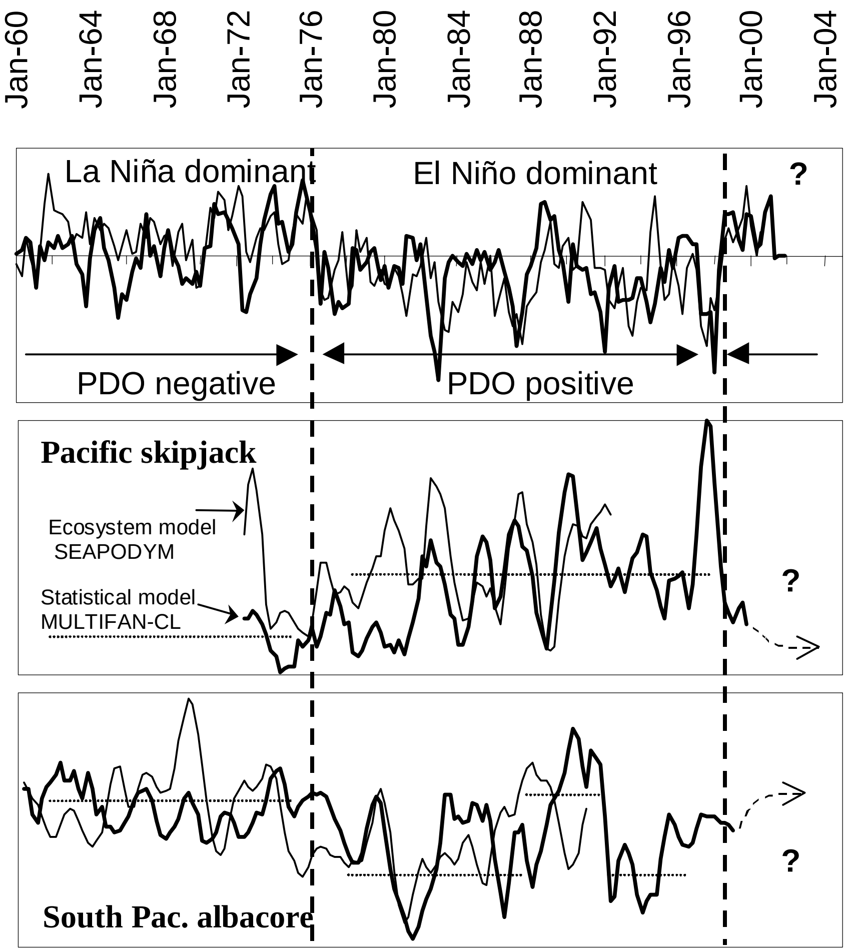


Figure 67. **Climate oscillations and tuna recruitment in the Pacific. Fluctuation of the Southern Oscillation Index (thick curve) and Pacific Decadal Oscillation (thin curve) (top). Recruitment series of skipjack from the statistical model MULTIFAN-CL and the spatial ecosystem model SEAPODYM for skipjack (centre) and South Pacific albacore (bottom). There is a direct and opposite correlation between the interannual ENSO and decadal PDO signals and the recruitment of these species that suggests a possible new regime for the immediate future.**

While the main skipjack spawning grounds appear to be associated with the warm pool, the spawning grounds for albacore extend through the tropical Pacific on both sides of the equator, and consequently are under the influence of the productivity of the equatorial cold tongue. This would explain why albacore recruitment is higher (lower) during La Niña (El Niño) events when the primary production and the spawning habitat index are high (low). The first simulation for albacore also shows a clear regime shift in the abundance of juveniles due to the decadal change in primary production that is reproduced by the NPZD model (Figure 67). These preliminary results are extremely encouraging, as recruitment mechanism is the key process for fish stock prediction.

Once the SEAPODYM model has been parameterised for an individual tuna species, the model can be applied to investigate trends in abundance and spatial distribution of the species under different environmental conditions.

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