THE WESTERN AND CENTRAL PACIFIC TUNA FISHERY: 2003 OVERVIEW AND STATUS OF STOCKS

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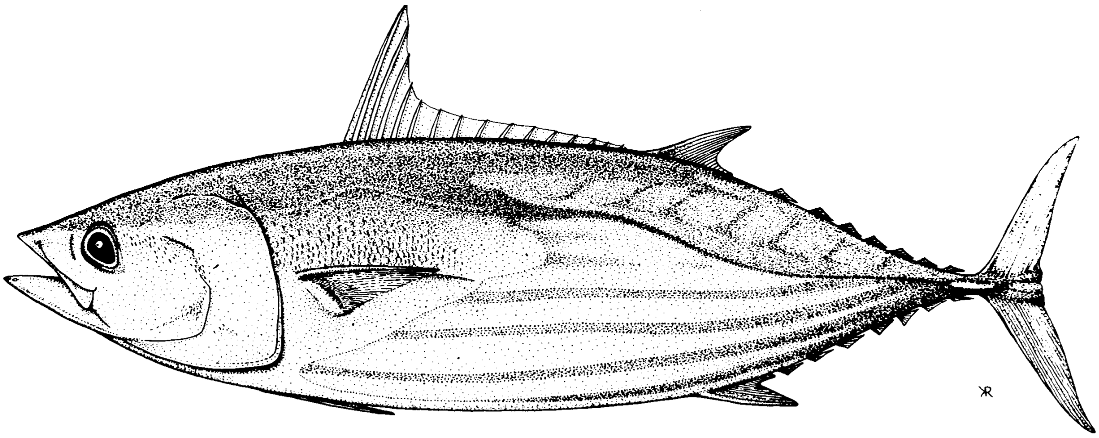

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Preface

Tuna Fisheries Assessment Reports provide current information on the tuna fishery of the western and central Pacific Ocean and the fish stocks, mainly tuna, which 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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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 poissons, principalement des thonidés. Le présent rapport porte essentiellement sur les principaux stocks de thonidés ciblés par cette activité: la bonite (*Katsuwonus pelamis*), le thon jaune (*Thunnus albacares*), le thon obèse (*T. obesus*) et le germon du sud (*T. alalunga*).

Ce rapport comprend trois parties. La première fait un tour d'horizon de la pêche thonière et met l'accent sur les développements intervenus ces dernières années, la deuxième fait le point sur l'état des stocks, et la troisième résume les informations concernant les interactions 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 y être apportées pour les années récentes. Les renseignements ayant servi à l'évaluation des stocks présentée ici sont les plus récents dont on dispose et sont périodiquement actualisés pour chaque espèce, au fur et à mesure des nouvelles 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, west of 150°W) is diverse, 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*).

Annual total catches of the four main tuna species remained relatively stable during most of the 1990s, increased sharply in 1998 and have remained at this elevated level during the subsequent years. The total WCPO tuna catch during 2003 was estimated at 1,973,665 mt, the second highest annual catch recorded after 1998 (1,985,121 mt) and marginally higher than the 2002 catch. The purse-seine fishery accounted for an estimated 61% of the total catch, pole-and-line 15%, and longline 11%, with the remainder (13%) taken by troll gear and a variety of artisanal gears, mostly in eastern Indonesia and the Philippines. The WCPO tuna catch represented 72% of the total estimated Pacific Ocean catch of 2,725,202 mt in 2003, and close to 50% of the provisional estimate of the global tuna catch (4,099,140 mt).

The 2003 catch was dominated by skipjack (64% of the total) and the annual catch of 1,271,292 mt represented the third highest catch for the species. The WCPO yellowfin catch (464,510 mt; 24%) was the highest catch in five years and only 1,000 mt less than the record catch in 1998 (465,643 mt). The bigeye catch for 2003 (103,833 mt; 5%) was lower than the record catch level recorded in 2002. Similarly, the WCPO albacore catch (North and South Pacific) (134,003 mt; 7%) was slightly lower than the record level in 2002 (139,745 mt).

The provisional 2003 **purse-seine** catch of 1,195,021 mt was the second highest on record (after 1998) and represented the second successive year of catches approaching 1,200,000 mt. Skipjack tuna (954,490 mt; 80%) continued to be the basis of the fishery and the 2003 catch was slightly less than the record annual catch for the fishery. The yellowfin tuna catch (219,846 mt; 18%) recovered from the lower catches in 2002 and the bigeye tuna catch (20,185 mt; 2%) declined for the fourth successive year as a result of reduced fishing associated with drifting FADs. Catches for all distant-water fleets decreased in 2003, although the Taiwanese fleet remained the highest producer (18.4%) for the sixth successive year. A significant component (14.4%) of the 2003 catch was taken by the Papua New Guinea domestic fleet.

The 2003 **pole-and-line** catch of 294,753 mt (preliminary estimate) constituted 15% of the total WCPO catch. Annual catches have remained relatively stable at this level for the last four years. Skipjack tuna comprised the vast majority of the catch (82%); albacore tuna taken by the Japanese coastal and offshore fleets in the temperate waters of the North Pacific (12%), yellowfin tuna (5%) and a small component of bigeye tuna (1%) made up the remainder of the catch. The Japanese distant-water and offshore fleets (144,638 mt in 2002) and the Indonesian fleet (145,597 mt in 2003) account for most of the WCPO pole-and-line catch. The Solomon Islands fleet (10,797 mt) continues to recover from low catch levels experienced in recent years.

The provisional 2003 **longline** catch of 222,810 mt accounted for 12% of the total WCPO catch, but rivals the much larger purse-seine catch in terms of catch value. Since 1992, annual catches from the longline fishery have steadily increased and the 2003 catch was slightly lower than the record catch achieved in 2002 (231,898 mt). The proportion of albacore in the total WCPO longline catch (38%) increased further in 2003 at the expense of yellowfin tuna (32%) and bigeye tuna (29%) and the total longline catch of both yellowfin and bigeye continued the declining trend of recent years. As in previous years, most of the catch was taken by the large-vessel, distant-water fleets of Japan, Korea and Taiwan. These fleets operate throughout the WCPO targeting bigeye and yellowfin tuna for the frozen sashimi market, and albacore tuna in the more temperate waters for canning. In recent years, the developing domestic longline fisheries of Pacific Island countries have accounted for approximately 15% of the WCPO longline catch, including around 50% of the South Pacific albacore catch.

The 2003 **troll** catch of South Pacific albacore tuna (5,308 mt) was comparable to the average annual catch from the fishery during the previous six years. For this method, catch and effort is concentrated in two main areas — in coastal waters around New Zealand, and in the south central Pacific in the vicinity of the Sub-Tropical Convergence Zone.

Status of Tuna Stocks

Skipjack Tuna

The last formal assessment of skipjack in the WCPO was conducted in 2003 and included data from 1972–2002. The conclusion of the assessment was that the skipjack tuna stock of the WCPO is not overfished owing to recent high levels of recruitment and a modest level of exploitation relative to the stock's biological potential. It was further concluded that continued catches at the 1.2 M mt level are sustainable with continued high levels of recruitment. The stock assessment of skipjack is scheduled to be updated in 2005.

Yellowfin Tuna

The assessment reaffirms the result of the previous assessment that the yellowfin stock in the WCPO is presently not being overfished (i.e., current fishing mortality is below the overfishing benchmark) and that it is not in an overfished state (i.e., current biomass is above the overfished benchmark). However, the stock is likely to be nearing full exploitation and any future increases in fishing mortality would not result in any long-term increase in yield and may move the yellowfin stock to an overfished state. The assessment indicates that the equatorial regions are likely to be fully exploited, while the temperate regions are likely to be under-exploited. While these spatial patterns of exploitation remain uncertain, if true, this may indicate the potential need for different management in different regions. Furthermore, the attribution of depletion to various fisheries or groups of fisheries indicates that the Indonesian fishery has the greatest impact on the stock, particularly in its home region. The purse-seine fishery also has high impact, particularly in the equatorial regions.

Bigeye Tuna

The current bigeye assessment indicates the stock is not in an overfished state although current fishing mortality rates are approaching or exceeding the overfishing benchmark. The current level of exploitation appears not to be sustainable in the long term, unless the high recent recruitment is maintained in the future. Lower future recruitment is a possibility if the recruitment trends for bigeye in the EPO are mirrored in the WCPO. On this basis, the SCTB recommended that, as a minimum measure, there be no further increase in the fishing mortality rate for bigeye tuna from the recent level.

South Pacific Albacore Tuna

The last formal stock assessment of South Pacific albacore was presented to the SCTB in 2003. Based on the results of this assessment, the SCTB concluded that is was unlikely that the stock is being overfished or is in an overfished state. However, the assessment is considered highly uncertain due to the lack of informative data concerning stock size.

Recently, the assessment has been updated and many of the underlying structural assumptions of the previous model have been investigated. The results of the new assessment differ from the previous analysis in terms of the magnitude of the total stock biomass and current exploitation rates, although the overall conclusion of the assessment remains unchanged, i.e., that current levels of catch are sustainable and current stock biomass is substantially higher than all accepted biological reference points. However, the results of the new assessment have yet to be formally reviewed and, consequently, are not documented in this report.

Ecosystem Considerations

The scope of this document has been expanded to include 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 sharks (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%, 74%, and 62% 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 and North Pacific swordfish) or are scheduled (southwest Pacific swordfish and striped marlin), although these assessments are hampered by limited information concerning species biology and stock structure. Nevertheless, the assessments for Pacific-wide blue marlin and North Pacific swordfish both indicate the 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. While 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 affects 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 diet of the main predator species and these 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 dans l’’océan Pacifique occidental et central (à l’’ouest du 150° O) est très diversifiée; 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 pêcheries sont la bonite (*Katsuwonus pelamis*), le thon jaune (*Thunnus albacares*), le thon obèse (*T. obesus*) et le germon (*T. alalunga*).

Après être demeurées relativement stables pendant la plus grande partie des années 90, les prises annuelles des quatre principales espèces de thonidés ont accusé une augmentation importante en 1998, et sont restées à ce haut niveau pendant les années suivantes. Les prises totales dans cette région du Pacifique en 2003 sont estimées à 1 973 665 tonnes, deuxième chiffre le plus élevé après celui de 1998 (1 985 121 t.) et légèrement plus élevé que celui de 2002. La pêche à la senne a représenté environ 61% du total des prises, celle à la canne 15%, et celle à la palangre 11%, les 13% restants étant les produits de la pêche à la traîne et de divers types d’’engins de pêche artisanale, utilisés principalement en Indonésie orientale et aux Philippines. Les prises de thonidés dans le Pacifique occidental et central ont constitué 72% du total estimé des prises dans l’’océan Pacifique, lesquelles ont atteint le chiffre de 2 725 202 tonnes, et près de 50% des prises mondiales de thonidés, estimées provisoirement à 4 099 140 tonnes.

Les prises de 2003 ont été essentiellement constituées de bonites (64% du total), et les prises annuelles d’’un poids de 1 271 292 t. se rangent en ordre d’’importance à la troisième place des prises de cette espèce. Les prises de thons jaunes (464 510 t; 24%) ont atteint le chiffre le plus élevé de ces cinq dernières années, à peine inférieur de 1 000 t à la prise record de 1998 (465 643 t). Les prises de thons obèses en 2003 (103 833 t; 5%) ont été moindres que les prises record enregistrées en 2002. De même, les prises de germon dans cette partie du Pacifique (Pacifique nord et sud) (134 003 t; 7%) ont été légèrement inférieures à leur chiffre record de 2002 (139 745 t).

En 2003, selon les données provisoires, les prises des **senneurs** se sont élevées à 1 195 021 tonnes, chiffre le plus élevé après le record de 1998; c’’est la deuxième année consécutive que les prises annuelles approchent les 1 200 000 tonnes. Cette pêcherie reste axée sur la bonite (954 490 tonnes, 80%), dont les prises en 2003 ont été légèrement inférieures au niveau record de cette pêche. Les prises de thon jaune (219 846 tonnes, 18%) ont remonté par rapport au faible résultat de 2002, et celles de thon obèse (20 185 tonnes, 2%) ont baissé pour la quatrième année consécutive en raison de la diminution de l''effort de pêche autour de DCP dérivants. Les prises de toutes les flottilles hauturières ont diminué en 2003, mais la flottille taiwanaise est restée le plus gros producteur (18.4%) pour la sixième année consécutive. Une part importante des prises de 2003 a été effectuée par la flottille nationale de la Papouasie-Nouvelle-Guinée.

Les prises des **canneurs** de 2003 sont estimées provisoirement à 294 753 tonnes, soit 15% des prises totales dans le Pacifique occidental et central. Les prises annuelles sont demeurées relativement stables au cours des quatre dernières années. La bonite a représenté la grande majorité des prises (82%), le germon pris par les flottilles côtières et au large japonaises dans les eaux tempérées du Pacifique Nord (12%), le thon jaune (5%) et une faible proportion de thons obèses (1%) représentant le reste. Si l''on effectue la ventilation par flottille, ce sont la flottille japonaise pratiquant la pêche hauturière et au large (144 638 tonnes en 2002) et la flottille indonésienne (145 597 tonnes en 2003) qui devraient encore une fois réaliser la majorité des prises des canneurs dans l''océan Pacifique occidental et central. La flottille des Îles Salomon (10 797 tonnes) poursuit son redressement après les faibles prises enregistrées ces dernières années.

Selon les chiffres provisoires, les prises de 2003 réalisées par les flottilles de **palangriers**, soit 222 810 tonnes, représentent 12% du total des prises réalisées dans le Pacifique occidental et central, mais, sur le plan de la valeur marchande, elles rivalisent avec celles des senneurs, pourtant bien plus importantes. Depuis 1992, les prises ont régulièrement augmenté, mais celles de 2003 ont été légèrement inférieures aux prises record de 2002 (231 898 t). Dans les prises réalisées à la palangre dans l''océan Pacifique occidental et central en 2003, la proportion des prises de germon a augmenté (38%), aux dépens du thon jaune (32%) et du thon obèse (29%). Les prises totales à la palangre de thons jaunes et de thons obèses continuent de diminuer. Comme les années passées, la majeure partie des prises a été réalisée par les gros bateaux du Japon, de la Corée et de Taiwan pratiquant la pêche hauturière. Ces flottilles opèrent dans tout l''océan Pacifique occidental et central car elles ciblent le thon obèse et le thon jaune pour le marché du sashimi congelé, et le germon dans les eaux plus tempérées pour la conserverie. Depuis quelques années, les flottilles nationales des États et territoires océaniens représentent environ 15% des prises à la palangre, dont la moitié est constituée des prises de germons du sud.

En 2003, les prises **à la traîne** de germon du sud (5 308 t) ont été comparables à la moyenne annuelle des six dernières années de cette pêcherie. Les prises et l''effort de pêche se concentrent sur deux principales zones: les eaux côtières entourant la Nouvelle-Zélande et le Pacifique central méridional, aux abords de la zone de convergence subtropicale.

État des stocks de thonidés

Bonite

La dernière évaluation officielle de l''état du stock de bonites dans l''océan Pacifique occidental et central a été conduite en 2003 et a pris en compte des données relatives à la période 1972–2002. Elle a conclu que le stock de bonites dans cette partie du Pacifique ne souffre pas de surpêche, vu les taux élevés des récents recrutements et le maintien à un niveau raisonnable de l''exploitation par rapport au potentiel biologique de ce stock. Il est possible de continuer de capturer 1,2 million de tonnes de cette espèce et de maintenir le recrutement aux mêmes hauts niveaux. L''évaluation du stock de bonite devrait être actualisée en 2005.

Thon jaune

L''évaluation a confirmé l''évaluation précédente, à savoir que le stock de thon jaune du Pacifique central et occidental n''est pas actuellement surexploité (mortalité due à la pêche actuelle < indicateur correspondant découlant d''une surpêche), et ne se trouve pas dans un état d'appauvrissement (biomasse actuelle > indicateur correspondant découlant d'une surpêche). Toutefois, il est probable que ce stock approche du seuil maximal d'exploitation et que toute future augmentation de la mortalité due à la pêche risquerait de compromettre les rendements à long terme et de mener à l'appauvrissement du stock. L'évaluation montre aussi que les stocks des régions équatoriales sont susceptibles d'être exploités au maximum, et ceux des régions tempérées sous-exploités. Bien que la répartition spatiale de cette exploitation demeure incertaine, si cette hypothèse s'avère, cette situation pourrait justifier le besoin d'adopter des stratégies de gestion différentes selon les régions. Qui plus est, en examinant le rôle joué par des pêcheries ou groupes de pêcheries dans l'appauvrissement des stocks, on constate que les pêcheries indonésiennes ont l'impact le plus grand, en particulier dans leurs eaux nationales. La pêche à la senne a également une forte incidence, en particulier dans les régions équatoriales.

Thon obèse

La présente évaluation révèle que le stock de thon obèse ne se trouve pas dans un état de surexploitation bien que son taux de mortalité due à la pêche approche ou dépasse l'indicateur correspondant au résultat d'une surpêche. Le degré actuel d'exploitation ne semble pas pouvoir être soutenu à long terme, à moins que le taux élevé de recrutement ne se maintienne. Or il y a un risque que ce taux diminue à l'avenir si la tendance observée dans l'océan Pacifique oriental gagne l'océan Pacifique occidental et central. Le Comité permanent sur les thonidés et marlins a donc recommandé qu'à titre de précaution minimale, on évite toute augmentation du taux de mortalité du thon obèse due à la pêche.

Germon du sud

La dernière évaluation officielle du stock de germon du sud a été présentée au Comité permanent des thonidés et marlins en 2003. Au vu des résultats, le Comité a conclu qu'il est peu probable que ce stock souffre de surexploitation et soit en déclin. Toutefois, cette évaluation est à considérer avec une grande prudence en raison du manque d'informations pouvant renseigner sur la taille du stock.

Récemment, cette évaluation a été actualisée et bon nombre des hypothèses d'ordre structurel qui la sous-tendaient ont été vérifiées. Ainsi, les résultats de la nouvelle évaluation diffèrent de ceux de l'analyse précédente sur les plans de l'ordre de grandeur de la biomasse totale du stock et des taux d'exploitation actuels. Néanmoins, la conclusion générale de l'évaluation reste la même, à savoir que les taux de prises actuels ne compromettent pas la pérennité du stock et que les indicateurs relatifs à la biomasse du stock dépassent substantiellement tous les points de référence biologiques convenus. Cependant, il reste encore à examiner officiellement les résultats de la nouvelle évaluation et c'est pourquoi ceux-ci ne sont pas rapportés ici.

Étude de l'écosystème

On a souhaité élargir la portée du présent document en y ajoutant un résumé des informations disponibles, issues des pêcheries thonières de l'océan Pacifique occidental et central, concernant les espèces associées et dépendantes, y compris des informations sur la composition par espèce des prises effectuées 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 dont on dispose au sujet de la composition des prises des principales pêcheries thonières opérant 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 des écosystèmes

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.

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List of Abbreviations

CPUE	catch per unit of fishing effort
ENSO	El Niño Southern Oscillation
EPO	eastern Pacific Ocean
FAD	fish aggregation device
GRT	gross registered tonnes
IATTC	Inter-American Tropical Tuna Commission
MSY	maximum sustainable yield
MULTIFAN-CL	a length-based, age-structured computer model used for fish stock assessment
OFP	Oceanic Fisheries Programme of the Secretariat of the Pacific Community
RTTP	Regional Tuna Tagging Project
SCTB	Standing Committee on Tuna and Billfish
SPC	Secretariat of the Pacific Community
STCZ	Sub-Tropical Convergence Zone
WCPFC	Western and Central Pacific Fisheries Commission
WCPO	western and central Pacific Ocean

Introduction

The tuna fishery in the western and central Pacific Ocean (WCPO) is diverse, 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 on the 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*); 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 2003, and current information on the status of the stocks of the target tuna species. We also provide for the first time 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 the SPC's Oceanic Fisheries Programme (OFP), particularly the 2003 Tuna Fishery Yearbook (Lawson 2004), and on material presented at the August 2004, 17th meeting of the Standing Committee on Tuna and Billfish (SCTB), held in Majuro, Republic of the Marshall Islands (see the SCTB homepage at http://www.spc.int/OceanFish).

1 Total Catch in the Western and Central Pacific Ocean

Each of the four tuna stocks is 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 parts of the Pacific. Also, in the case of skipjack and yellowfin tuna, mixing of stocks between the western and eastern Pacific is believed to be low. For these reasons, when describing the tuna fisheries of the Pacific, we normally define the western and central Pacific Ocean and the eastern Pacific Ocean (EPO) as being separated by 150°W longitude (Figure 1). We continue to use this definition here, although it is noted that the area now covered by the newly created Western and Central Pacific Fisheries Commission includes part of the EPO in the southern hemisphere (see the dashed lines in Figure 1).

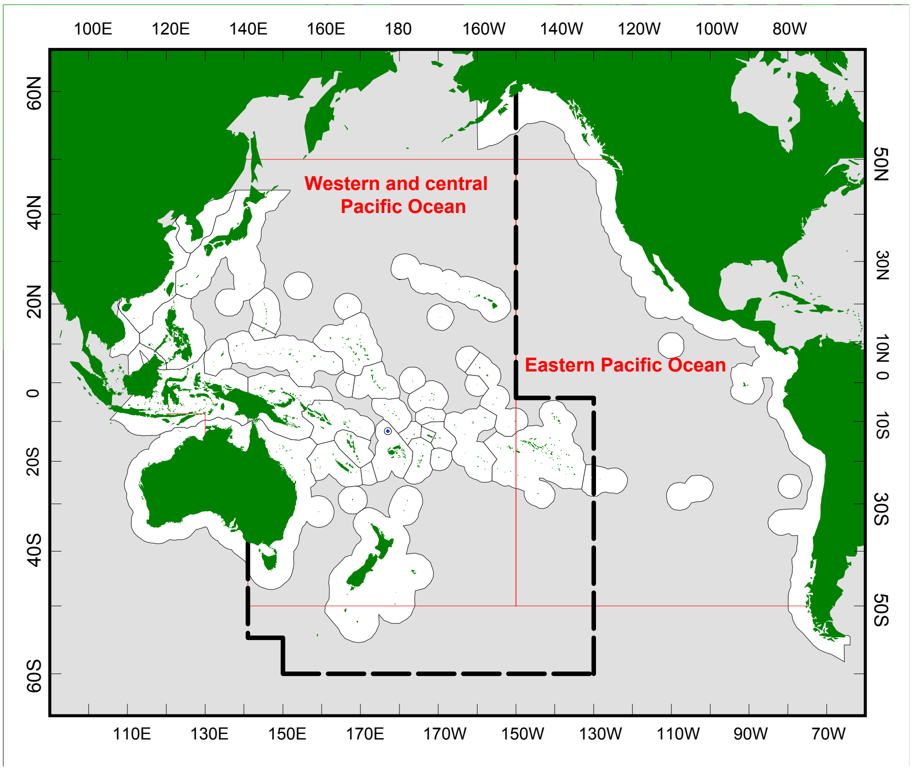


Figure 1. The western and central Pacific Ocean and the eastern Pacific Ocean.

Annual total catches of the four main tuna species (skipjack, yellowfin, bigeye and albacore) remained relatively stable during most of the 1990s, increased sharply in 1998 and have remained at this elevated level since (Figures 2 and 3). The total WCPO tuna catch during 2003 was estimated at 1,973,665 mt, the second highest annual catch recorded after 1998 (1,985,121 mt). During 2003, the purse-seine fishery accounted for an estimated 1,195,021 mt (61% of the total catch), with pole-and-line taking an estimated 295,753 mt (15%), the longline fishery an estimated 222,810 mt (11%), and the remainder (13%) taken by troll gear and a variety of artisanal gears, mostly in eastern Indonesia and the Philippines.

The WCPO tuna catch represented 72% of the total estimated Pacific Ocean catch of 2,725,202 mt in 2003, and close to 50% of the provisional global catch estimate (4,099,140 mt) for these four species. The EPO catch in 2003 (784,537 mt) was the highest ever and contributed to producing a record total tuna catch for the whole Pacific Ocean. The provisional global catch of the four main species for 2003 was also the highest ever.

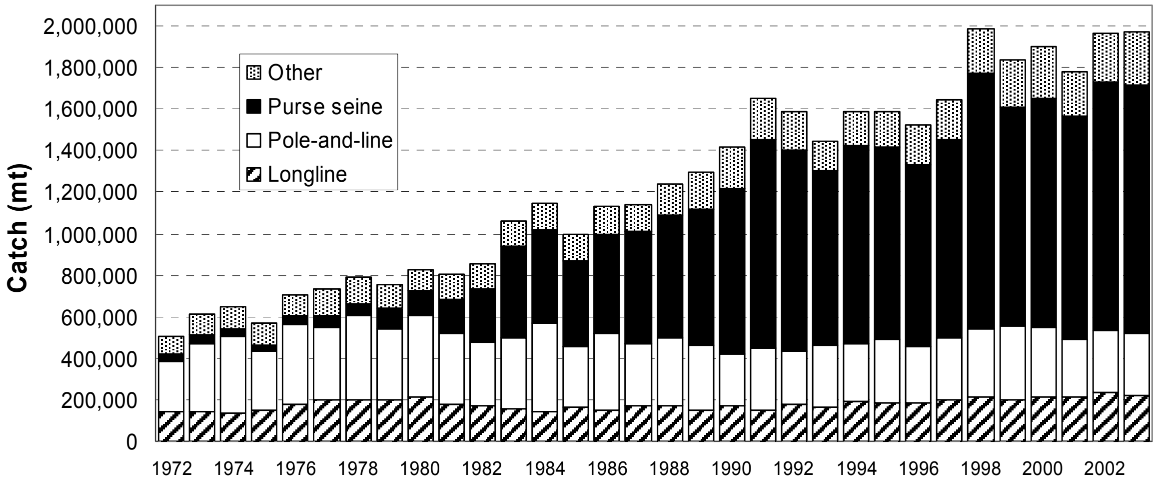


Figure 2. Annual total catch of skipjack, yellowfin, bigeye and albacore tuna, by fishing method, in the WCPO.

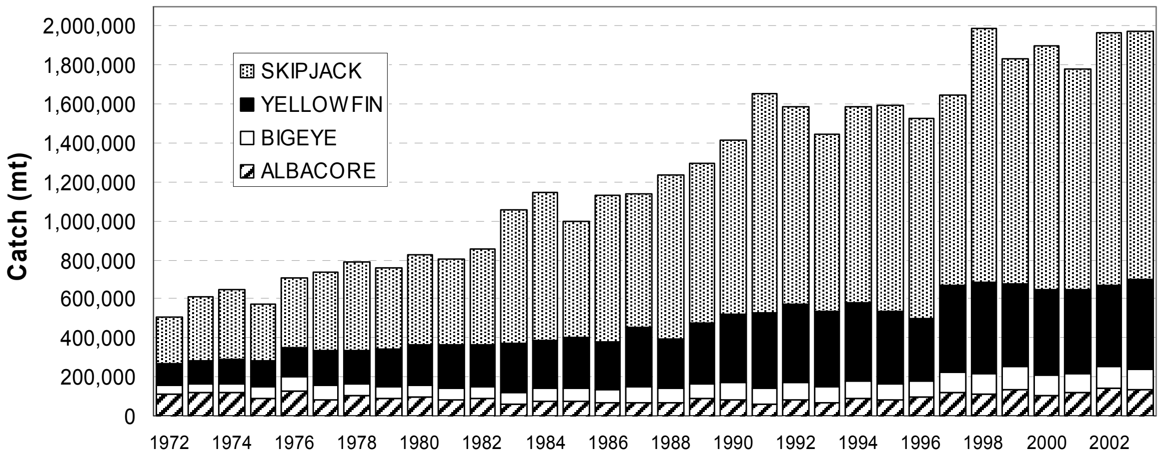


Figure 3. Annual total catch, by species, in the WCPO.

The WCPO catch by species has always been dominated by skipjack (64% in 2003). The 2003 WCPO catch of skipjack (1,271,292 mt) was the third highest ever (the highest recorded skipjack catch was in 1998 – 1,301,054 mt). The WCPO yellowfin catch (464,510 mt; 24%) was the highest catch in five years and only 1,000 mt less than the record catch in 1998 (465,643 mt). The WCPO bigeye catch for 2003 (103,833 mt; 5%) was lower than in 2002, and the WCPO albacore[1] catch (134,003 mt; 7%) was about 6,000 mt less than the record level in 2002 (139,745 mt).

2 Tuna Fishery by Gear Type

2.1 Purse-seine

2.1.1 Historical Overview

The purse-seine fishery has accounted for around 55–60% of the WCPO total catch since the early 1990s, with annual catches in the range 790,000–1,200,000 mt. The majority of the WCPO purse-seine catch is taken by the four main distant-water fishing fleets (Japan, Korea, Taiwan and USA), which currently number around 140 vessels.

There has been an increasing contribution from the growing number of Pacific Island domestic vessels (Figure 4) in recent years (48 vessels in 2003), with the balance from Philippines fisheries and a variety of other fleets, including a small seasonally active Spanish fleet.

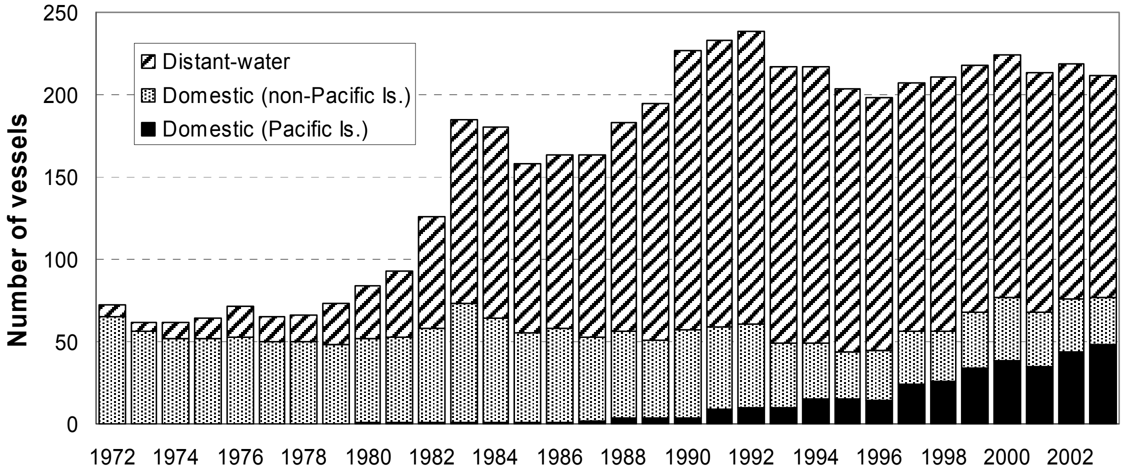


Figure 4. Number of purse-seine vessels operating in the WCPO. **Domestic (non-Pacific Is.) includes vessels based in Australia, Japan and New Zealand, but not Philippines domestic vessels.**

The WCPO purse-seine fishery is essentially a skipjack fishery, unlike those of other ocean areas. Skipjack tuna regularly account for 70–80% of the purse-seine catch, with yellowfin accounting for 20–25% and bigeye accounting for only a small proportion (Figure 5). Purse-seine catches in recent years have been the highest ever — the WCPO historical high catch was in 1998 (1,233,424 mt), and catches have been over 1 million mt in the subsequent years, despite the unfavourable economic conditions in the fishery in recent years (Williams and Reid, 2004).

Features of the purse-seine fishery during the past decade include:

- Annual skipjack catches fluctuating between 600,000 and 700,000 mt prior to 1998. Catches increased in 1998 and were maintained above 800,000 mt in all subsequent years.
- Annual yellowfin catches fluctuating considerably between 120,000 and 270,000 mt. The proportion of yellowfin in the catch is generally higher during El Niño years (Figure 5) and lower during La Niña years (1995/96 and to a lesser extent 1999/2000).
- Increased bigeye tuna purse-seine catches, first in 1997 (30,502 mt) and then a peak in 1999 (35,920 mt) due to the increased use of drifting FADs since 1996. In recent years, there has been a gradual decline in both the use of drifting FADs and the catch of bigeye.

[1] Includes catches of North and South Pacific albacore tuna west of 150°W, which comprised 84% of the total Pacific Ocean albacore tuna catch of 156,253 mt in 2003.

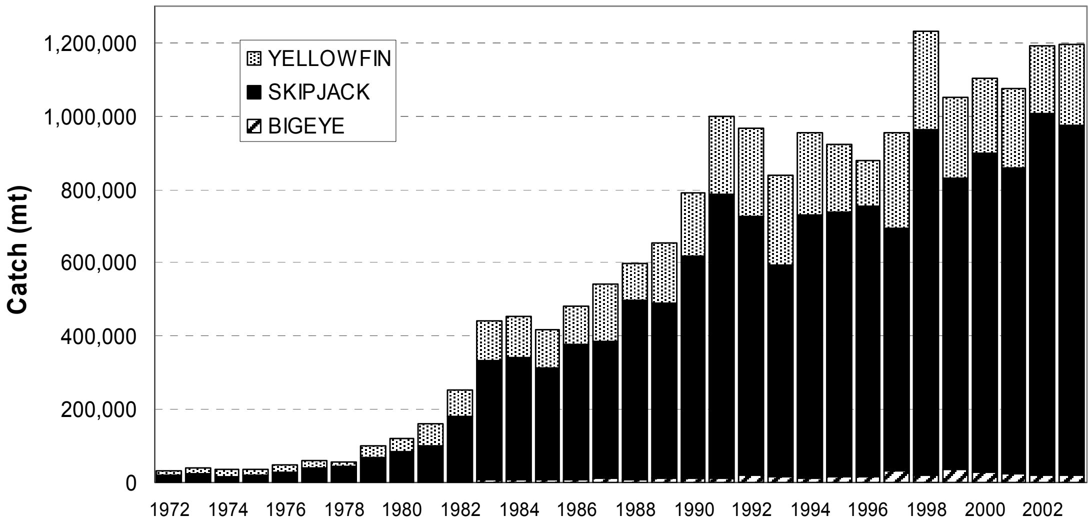


Figure 5. Annual purse-seine catches of skipjack, yellowfin and bigeye tuna in the WCPO.

2.1.2 The Year 2003 Fishery

Catch estimates and fleet sizes

The provisional 2003 purse-seine catch of 1,195,021 mt was the second highest on record (after 1998) and represented the second successive year of catches approaching 1,200,000 mt.

The purse-seine skipjack catch for 2003 (954,490 mt – 80%) was 32,000 mt less than the record for this fishery (in 2002 – 986,456 mt). The purse-seine yellowfin catch for 2003 (219,846 mt – 18%) rebounded from relatively poor catches experienced in 2002 (only 185,388 mt). The estimated purse-seine bigeye catch for 2003 (20,185 mt – 2%) continues the declining trend in catches since the record 1999 catch (35,920 mt), primarily due to the reduction in fishing effort on drifting FADs during recent years.

Catches for all distant-water fleets decreased in 2003, although the Taiwanese fleet remained the highest producer for the sixth successive year. The steady increase in catch by the PNG fleet in recent years is noteworthy; this fleet now catches more than the US purse-seine fleet and took a similar total catch as the Japanese tropical-water purse-seine fleet during 2003.

The number of Pacific-island domestic vessels continued to increase in 2003 (Figure 4). The PNG purse-seine fleet constitutes the largest Pacific-island domestic fleet and is made up of 17 domestically-based vessels fishing in joint-venture arrangements in PNG waters and another 15 vessels that fish over a wider area under the FSM Arrangement. The number of vessels in the FSM and Kiribati fleets remained stable into 2003, while an additional vessel joined the Marshall Islands fleet.

The distant-water Philippine fleet, which operates almost exclusively in PNG waters, comprises 10 vessels and caught almost 30,000 mt during 2003. The domestic Philippine purse-seine and ringnet fleets operate in Philippine and northern Indonesian waters, and catch close to 100,000 mt annually (Lawson, 2004). The recently-established New Zealand (4 vessels in the tropical fishery) and Chinese (4 vessels) purse-seine fleets continued to expand their activities in the WCPO during 2003. There was no indication of activity by the Spanish fleet in the WCPO during 2003.

Unassociated school sets accounted for at least 50% of the total sets for the Asian fleets during 2003 (Figure 6) and, for the first year since 1998, log sets were more common than drifting FAD sets for all fleets. The lower percentage of drifting FAD sets in 2003 is thought to be related to a general change in the area fished by all fleets; that is, for the first time in several years, most of the fishing effort was concentrated in the area west of 160°E (Figure 7) which is distinct from the area where drifting FADs have been used in the past (i.e., to the east of 160°E).

Geographical distribution

Catch distribution in tropical areas of the WCPO is strongly influenced by El Nino–Southern Oscillation Index (ENSO) events. Figure 7 demonstrates 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 WCPO experienced an ENSO–transitional (or neutral) period during 2001, an El Nino period during 2002 and into the first quarter of 2003, and then a return to an ENSO–transitional (neutral) period for the remainder of 2003. There was a significant westwards shift in purse-seine effort during 2003 (compared to previous years) despite it not being a La Nina year, suggesting a more in-depth review of the determinants driving the distribution of effort in 2003 will be required once all fishery and environmental data for 2003 have been received and processed.

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 three 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 (Williams and Reid, 2004). The continued reduction in the use of drifting FAD sets during 2003 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.

There was a clear shift in fishing activities to the broad area west of 160°E longitude by all distant-water purse-seine fleets in 2003 compared to the previous few years (Figure 7; Williams and Reid, 2004). During 2002, there was little overlap in the area fished by the US purse-seine fleet and the area fished by the other major DWFN fleets. In 2002, the US fleet fished in an area further to the south and east to the other fleets, but this was not the case during 2003 with a greater overlap in operating area of all fleets.

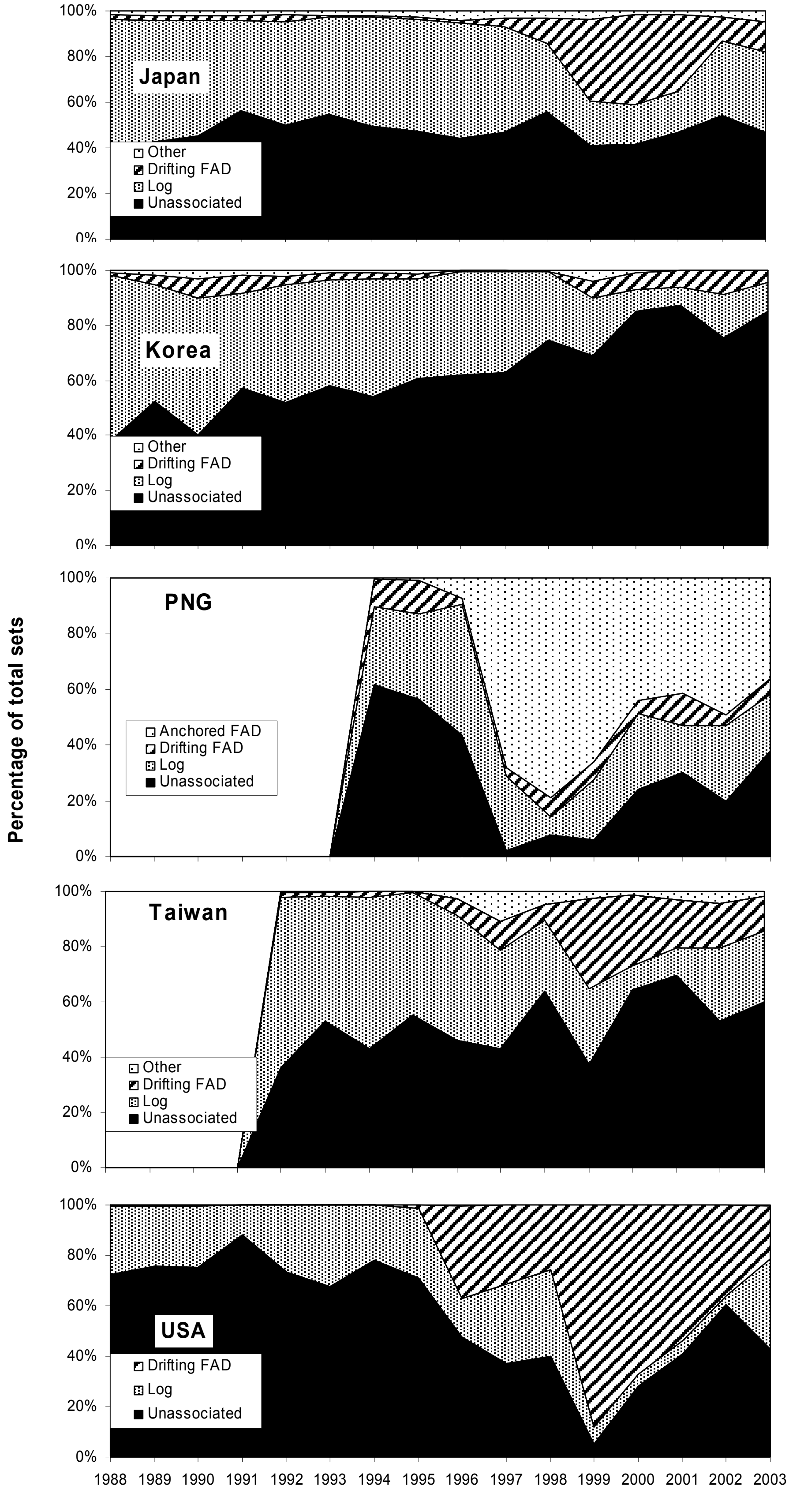


Figure 6. The percentage of total sets by set type for the major purse-seine fleets operating in the WCPO.

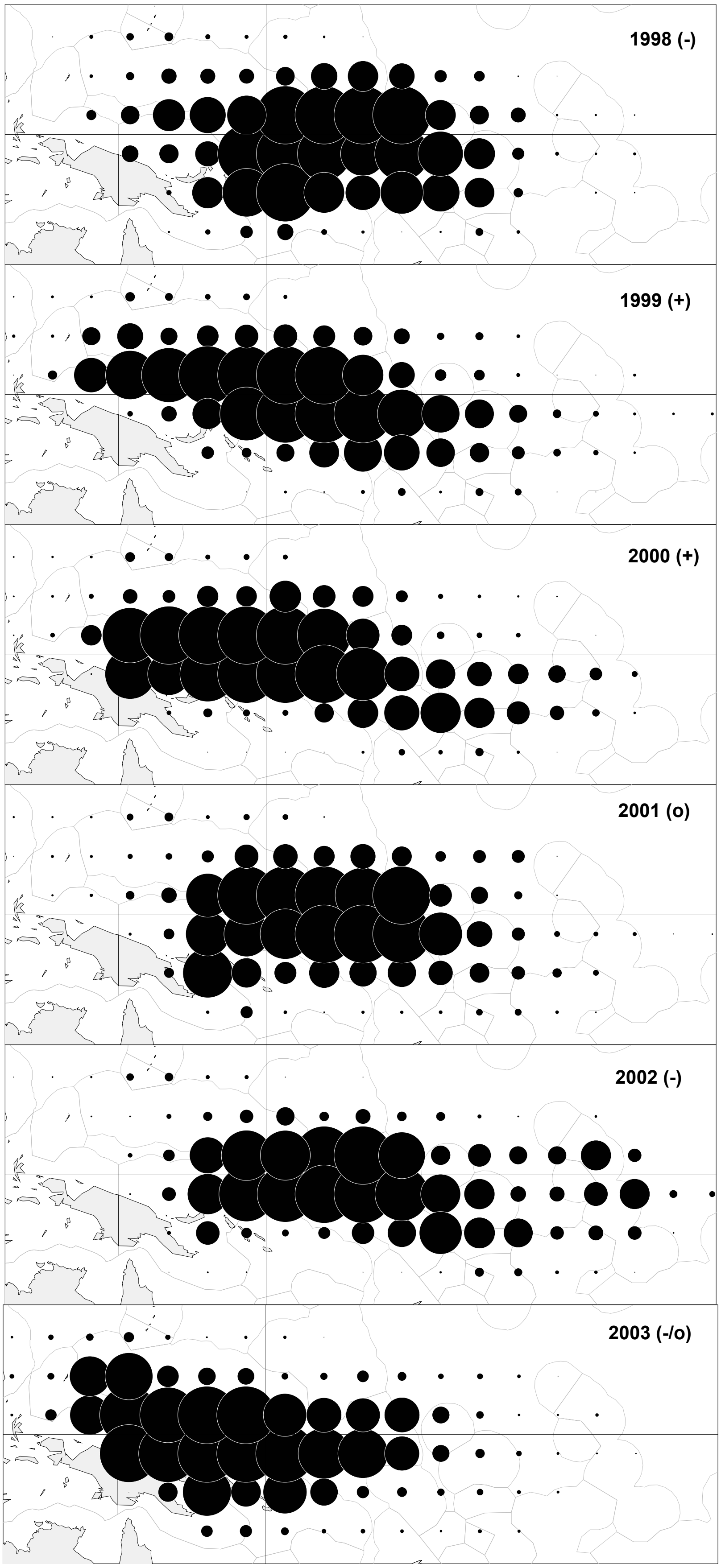


Figure 7. Distribution of purse-seine effort (days fishing and searching), 1998–2003. **ENSO periods are denoted by: '+' = La Niña; '-' = El Niño; '--' = strong El Niño; '0' = transition period. The vertical line is the 160°E longitude.**

2.2 *Pole-and-line*

2.2.1 Historical Overview

The WCPO pole-and-line fishery includes:

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

Economic factors and technological advances in the purse-seine fishery (primarily targeting the same species, skipjack) have seen a gradual decline in the number of vessels in the pole-and-line fishery (Figure 8) and stabilisation in the annual pole-and-line catch during the past decade (Figure 9). The gradual reduction in numbers of vessels has occurred in all pole-and-line fleets over the past decade. Pacific Island domestic fleets have declined in recent years – fisheries formerly operating in Palau, Papua New Guinea and Kiribati are no longer active, only one or two vessels are now operating in Fiji, and there have been problems in the Solomon Islands' fishery over the past 3 years. Several vessels continue to fish in Hawai'i, and the French Polynesian *bonitier* fleet remains active, but more vessels are turning to longlining activity. Against this trend, there has been a reported increase in Indonesian catches since 1999, apparently as a result of increased demand for catch and, possibly, technological advances.

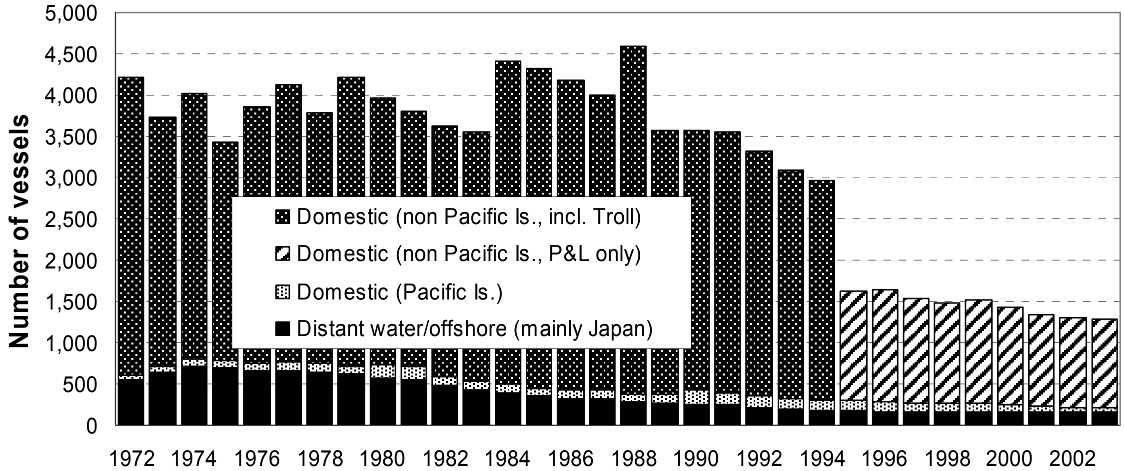


Figure 8. Pole-and-line vessels operating in the WCPO. Distinction between troll and pole-and-line gears in the Japanese coastal fleet was not possible for years prior to 1995.

2.2.2 The Year 2003 Fishery (*provisional*)

Catch estimates

The preliminary pole-and-line catch estimate for 2003 (294,753 mt, 15% of total WCPO catch) is lower than the 2002 catch (303,986 mt); although the Japanese fleet catch estimate for 2003 has yet to be provided. As in previous years, skipjack accounts for the vast majority of the catch (82%). 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 (12%), yellowfin (5%) and a small component of bigeye (1%). The Japanese distant-water and offshore fleets (144,638 mt in 2002) and the Indonesian fleet (145,597 mt in 2003) typically account for most of the WCPO pole-and-line catch. The Solomon Islands fleet (10,797 mt in 2003) continues to recover from low catch levels experienced in recent years (only 2,778 mt in 2000), but was still far from the level of annual catches taken between 1980 and 2000 (at least 17,000 mt per annum).

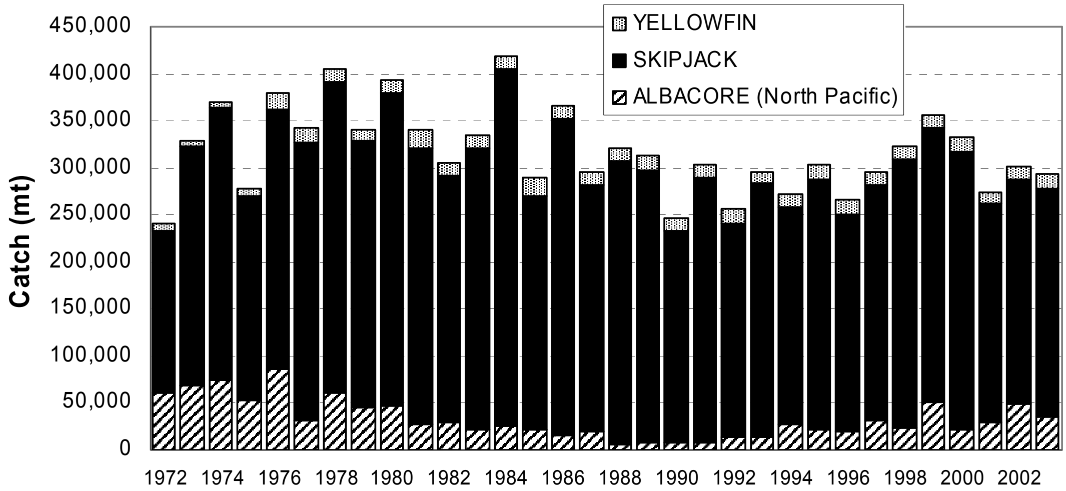


Figure 9. Pole-and-line catch in the WCPO.

Geographical distribution

Figure 10 shows the average distribution of pole-and-line effort for the period 1995–2002. Effort in tropical areas is usually year-round and includes the domestic fisheries in Indonesia and the Solomon Islands and the Japanese distant-water fishery. The pole-and-line effort in the vicinity of Japan by both offshore and distant-water fleets is seasonal (highest effort and catch in the 2nd and 3rd quarters). There was also some seasonal effort by pole-and-line vessels in Fiji and Australia during this period. The effort in French Polynesian waters is essentially the bonitier fleet. Effort by the pole-and-line fleet based in Hawai'i is absent from this figure.

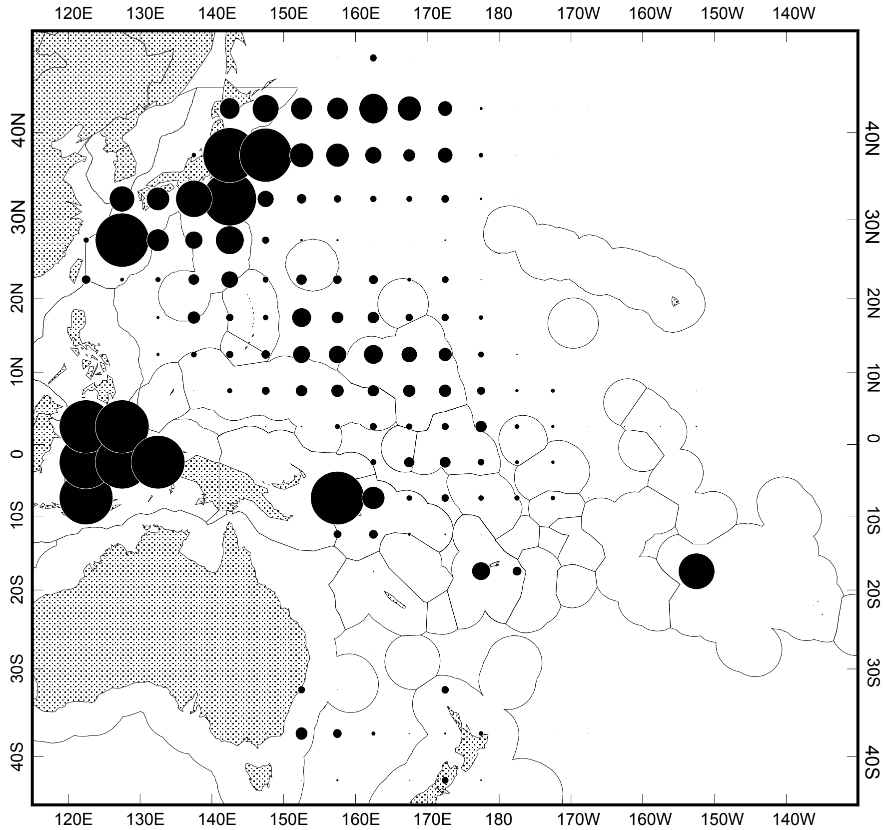


Figure 10. Average distribution of WCPO pole-and-line effort, 1995–2002.

2.3 Longline

2.3.1 Historical Overview

The longline fishery continues to account for around 10–12% of the total WCPO catch (Lawson, 2004), but rivals the much larger purse-seine catch in landed value. It provides the longest time series of catch estimates for the WCPO, with annual estimates available since the early 1950s. The total number of vessels involved in the fishery has fluctuated between 4,000 and 5,000 for much of this period (Figure 11).

The fishery involves two main types of operation:

- Large (typically greater than 250 GRT) **distant-water** freezer vessels, which undertake long voyages (months) and operate over large areas of the region (distant-water vessels). These vessels may target either tropical (yellowfin and bigeye tuna) or subtropical (albacore tuna) species. Some voluntary reduction in vessel numbers by one major fleet (Japan distant-water) has occurred in recent years.
- Smaller (typically less than 100 GRT) **offshore** vessels, usually **domestically based**, with ice or chilling capacity, and serving fresh or air-freight sashimi markets. These vessels operate mostly in tropical areas.

Additionally, small vessels in Indonesia and the Philippines (not included in Figure 11) target yellowfin and bigeye by handlining and small vertical longlines, usually around numerous arrays of anchored FADs in these waters. These fisheries have similar species composition as longliners operating in the same area.

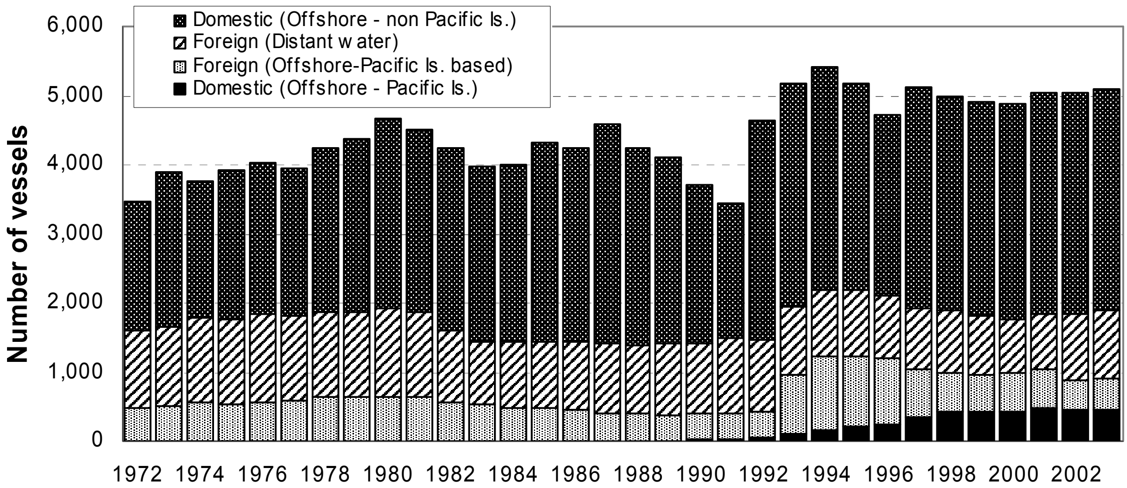


Figure 11. Longline vessels operating in the WCPO.

There have been significant changes in fleet operations and composition during the past two decades. For example, a feature of the 1980s was an increase in depth of deployment of longline gear to target higher-valued bigeye in preference to yellowfin. During the 1990s, there was a gradual increase in the number of **Pacific-Islands domestic vessels**, such as those from American Samoa, Cook Islands, Fiji, French Polynesia, New Caledonia, Samoa and Solomon Islands; these fleets operate in subtropical waters, with albacore the main species taken. This component of the fleet now accounts for **over 16%** of the total WCPO longline catch. The entrance into the fishery and subsequent decline of the smaller "offshore" sashimi longliners of Taiwan and mainland-China, based in Micronesia, during the past decade is also noteworthy. There has also been a trend towards flexibility in species targeting in some fleets, notably those with ultra-low temperature freezing capacity – for example, some vessels in the distant-water Taiwanese fleet have recently switched from albacore targeting in the South Pacific to targeting bigeye and yellowfin in the eastern regions of the tropical WCPO. Large, distant-water Chinese longliners targeting albacore in the high seas areas of the South Pacific, and bigeye and yellowfin tuna in the central tropical Pacific are a recent addition to the WCPO longline fishery and there has been rapid development of the longline fishery in at least one south-east Asian country (i.e., Vietnam, although catch estimates for this fleet are not yet available).

The WCPO longline tuna catch steadily increased from the early years of the fishery (i.e. the early 1950s) to a peak in 1980 (212,585 mt), but declined in the following five years to 145,153 mt in 1984 (Figure 12). From 1984, catches steadily increased over the next 15 years and in 2000 catch levels had recovered to the 1980 level. However, the composition of the catch in 1980 (ALB–20%;BET–25%;YFT–55%) was very different to the composition of the catch taken in recent years (ALB–38%;BET–29%;YFT–32% in 2003) due to differences in targeting and the spatial distribution of the fishery.

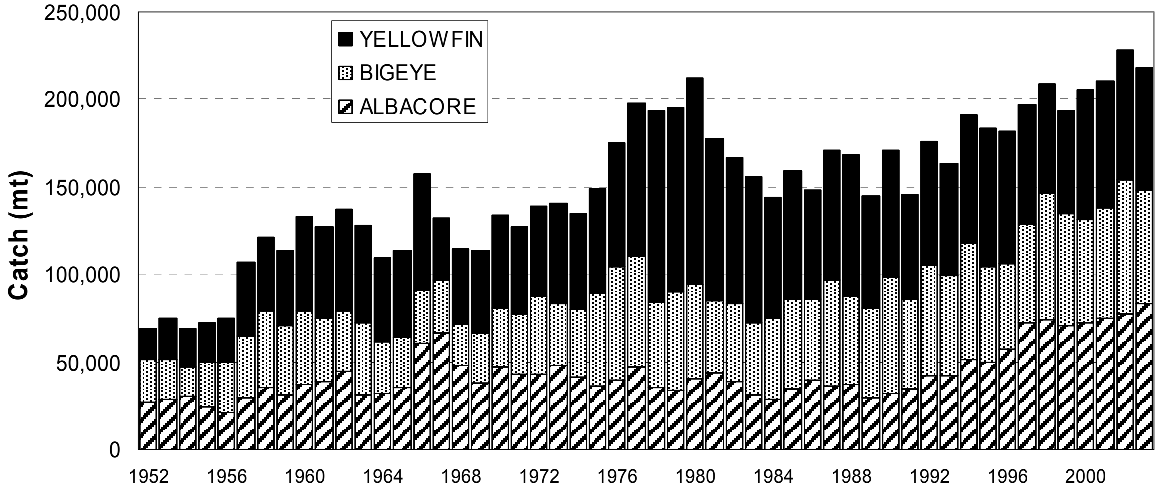


Figure 12. Longline catch in the WCPO.

2.3.2 The Year 2003 Fishery

Catch estimates and fleet sizes

For 2003, the provisional WCPO longline catch (222,810 mt) was around 9,000 mt lower that the highest on record, which was attained in 2002 (231,898 mt). The WCPO albacore longline catch (83,752 mt) was easily the highest on record (the South Pacific albacore catch of 49,059 mt was the second highest on record after the 2002 catch) and again reflected the continued development of Pacific Island domestic fisheries (e.g. American Samoa, Cook Islands, Fiji, French Polynesia, Samoa and Tonga). The bigeye catch (64,059 mt) for 2003 was the lowest for three years, and the yellowfin catch (70,408 mt) was the lowest since 1999 (the yellowfin catch in 1999 was the lowest for nearly 30 years).

The most significant change in the WCPO longline fishery over the past 5 years has been the growth of Pacific-Islands domestic albacore fisheries, which went from taking 30% of the total South Pacific albacore longline catch in 1999, to accounting for around 50% of the catch for the past three years. The Taiwanese distant-water longline fleet had been the dominant fleet in the South Pacific albacore fishery for more than two decades, but there have been recent changes in the species and areas targeted by this fleet (more vessels are now targeting bigeye in the eastern equatorial waters of the WCPO), which have resulted in a reduced contribution to the overall albacore catch in recent years.

Domestic fleet sizes continue to increase at the expense of foreign-offshore and distant-water fleets (Figure 11), although the Taiwanese distant-water longline fleet has increased by 70% (to 142 vessels in 2003) over the past two years. The evolution in fleet dynamics no doubt has some effect on the species composition of the catch. For example, the increase in Pacific-Islands domestic fleets has primarily been in albacore fisheries, while the decrease in vessel numbers from distant-water fleets (essentially Japan) has principally been in yellowfin and bigeye fisheries.

Geographical distribution

Figure 13 shows the distribution of effort by category of fleet for the period 1998–2001 (representing the most recently available data for all fleets, but reflecting the likely distributions for 2002 and 2003).

Effort by the distant-water fleets is widespread, as sectors of these fleets target bigeye and yellowfin for the frozen sashimi market, and albacore in the more temperate waters for canning. Activities by the foreign-offshore fleets from Japan, mainland China and Taiwan are restricted to the tropical waters, where they target bigeye and yellowfin for the fresh sashimi market; these fleets tend to have limited overlap with the distant-water fleets. The substantial "offshore" effort in the west of the region is primarily by Indonesian and Taiwanese domestic fleets targeting yellowfin and bigeye (note that Figure 13 does not include effort by the coastal Japanese fleet and the Vietnamese longline fleet fishing in the South China Sea, and the Taiwanese distant-water fleet fishing in the north Pacific Ocean). 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 Cook Islands fleet. As noted above, some vessels in the distant-water Taiwanese longline fleet are now targeting bigeye in the eastern equatorial areas of the WCPO.

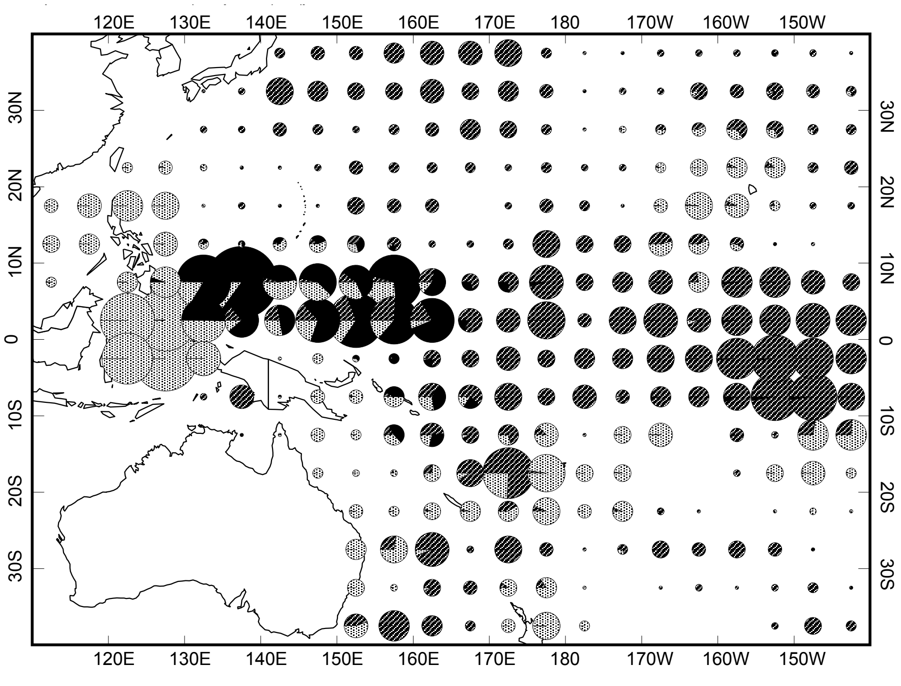


Figure 13. Distribution of longline effort for distant-water fleets (dark grey stripes), foreign-offshore fleets (black) and domestic fleets (light grey) for the period 1998–2001.

Figure 14 shows species composition by area for 2001 (2002 and 2003 data incomplete). The majority of the yellowfin catch is taken in tropical areas, especially in the western parts of the region, with smaller amounts in the often-seasonal subtropical fisheries. Most of the bigeye catch is also taken from tropical areas, but in contrast to yellowfin, mainly in the eastern parts of the WCPO, adjacent to the traditional EPO bigeye fishing grounds. The albacore catch, in contrast, is taken in subtropical and temperate waters in both hemispheres.

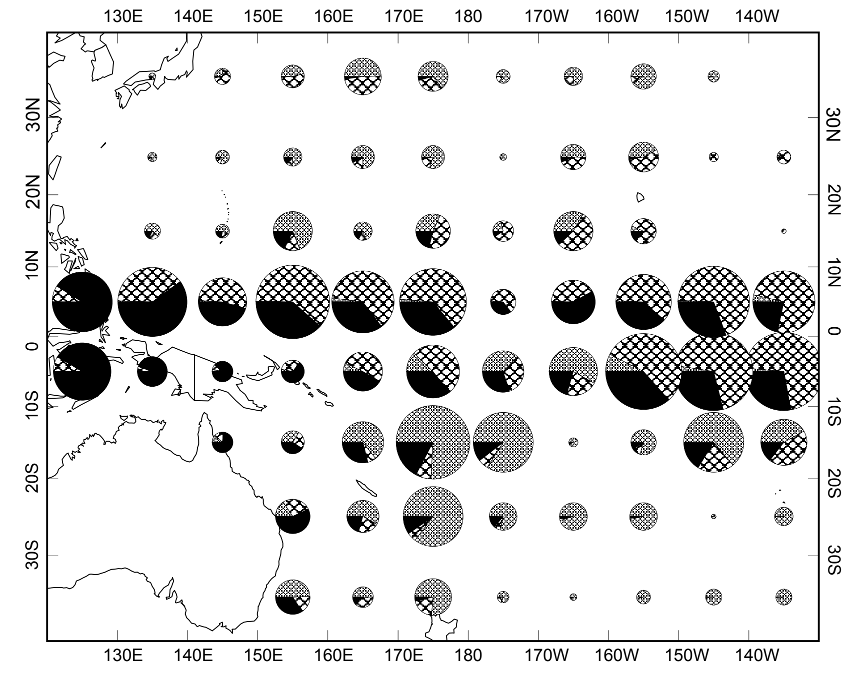


Figure 14. Distribution of longline catch, by species, during 2001
(black = yellowfin tuna; hatching = bigeye tuna; grey = albacore tuna).

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 waters located near 40°S). The fleets of New Zealand and United States have historically accounted for the great majority of the catch that consists almost exclusively of albacore tuna.

The fishery expanded following the development of the STCZ fishery after 1986, with the largest annual catch (around 8,200 mt) taken in 1989 (Figure 15; Lawson 2004). Since then, annual catches have varied between 3,000 and 8,000 mt. The level of effort expended by the troll fleets each year tends to reflect the price commanded for the product (albacore for canning) to some extent, and by expectations concerning likely fishing success.

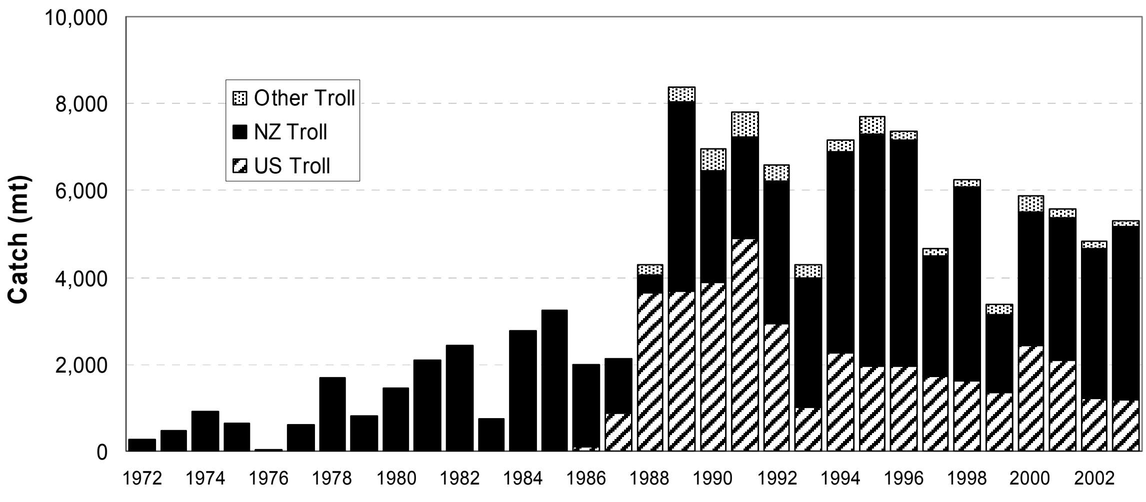


Figure 15. Annual troll catches of albacore tuna in the south Pacific Ocean.

2.4.2 The Year 2003 Fishery

The 2003 troll albacore catch (5,308 mt) was around 500 mt more than in 2002, despite fewer vessels operating during 2003 (Lawson, 2004). As usual, the fleets of New Zealand (3,979 mt) and USA (1,205 mt) accounted for most of this catch, with minor contributions coming from vessels from Canada and Australia. Figure 16 shows the distribution of effort for troll fleets for 2002 (2003 data are incomplete) which, as in previous years, constitutes effort off the coast of New Zealand and in the Sub-tropical convergent zone (STCZ). Catch rates of juvenile albacore in the troll fishery during 2003 were the highest for a number of years.

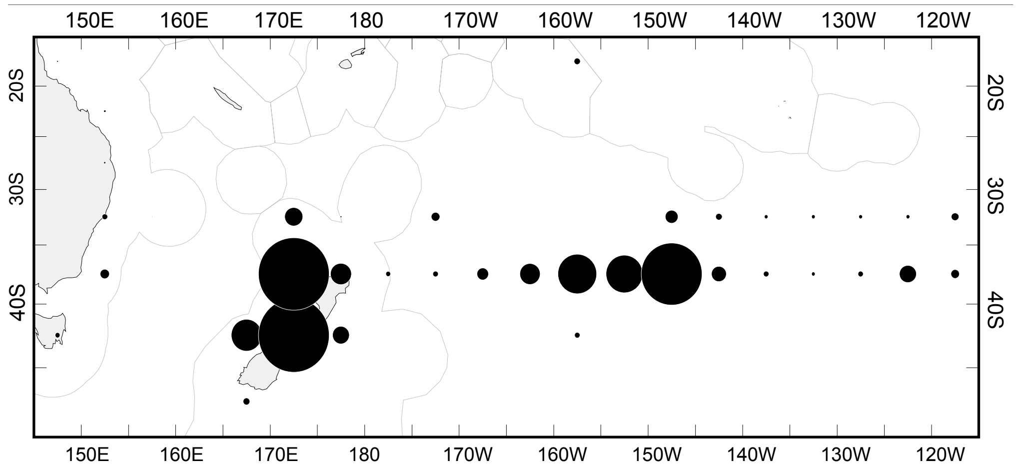


Figure 16. Distribution of South Pacific albacore tuna troll fishery effort during 2002.

3 Status of Tuna Stock

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 continue the past practice of considering the entire Pacific Ocean south of the equator.

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 should be stressed that these analyses 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 western and central Pacific Ocean (WCPO) tuna catch accounting for nearly two-thirds of the target tuna species catch over the past decade (Lawson 2004). This species is taken primarily by purse-seine and pole-and-line gear, with smaller catches by other artisanal gears in eastern Indonesia and Philippines.

Catches in the WCPO increased steadily since 1970, more than doubling during the 1980s, and continuing to increase in the subsequent years. Annual catches exceeded 1.2 million mt in three of the last five years (Figure 17). Pole-and-line fleets, primarily Japanese, initially dominated the fishery, with the catch peaking at 380,000 mt in 1984. The relative importance of this fishery, however, has declined over the years primarily due to economic constraints. The skipjack catch increased during the 1980s due to growth in the international purse-seine fleet, combined with increased catches by domestic fleets from Philippines and Indonesia (which accounted for 20–25% of the total WCPO skipjack catch in recent years).

The 2003 skipjack catch of 1,271,292 mt was the third highest annual catch and only 30,000 mt less than the highest catch attained in 1998 (1,301,054 mt). The 2003 skipjack catch was again dominated by the purse-seine gear (954,490 mt, 75% of total), with the balance mainly taken by the pole-and-line gear (243,230 mt, 19%) and unclassified gears in Indonesia, Philippines and Japan (~70,000 mt, 6%). The longline fishery accounts for less than 1% of the WCPO skipjack catch.

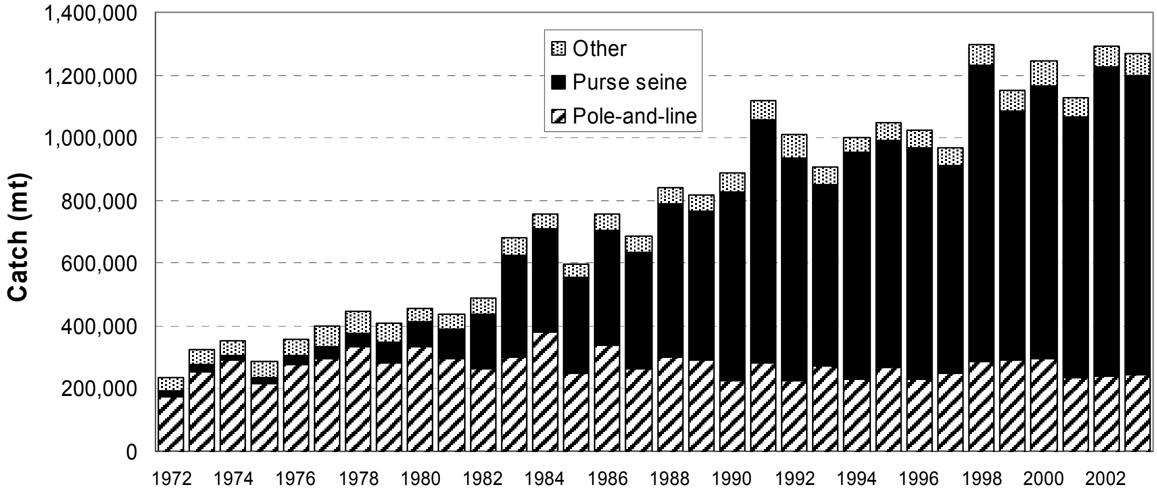


Figure 17. WCPO skipjack tuna catch, by gear.

The vast majority 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 18). The domestic fisheries in Indonesia (pole-and-line) 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 WCPO. The spatial distribution of skipjack catch and effort by purse-seine vessels in equatorial region is influenced by the prevailing ENSO conditions.

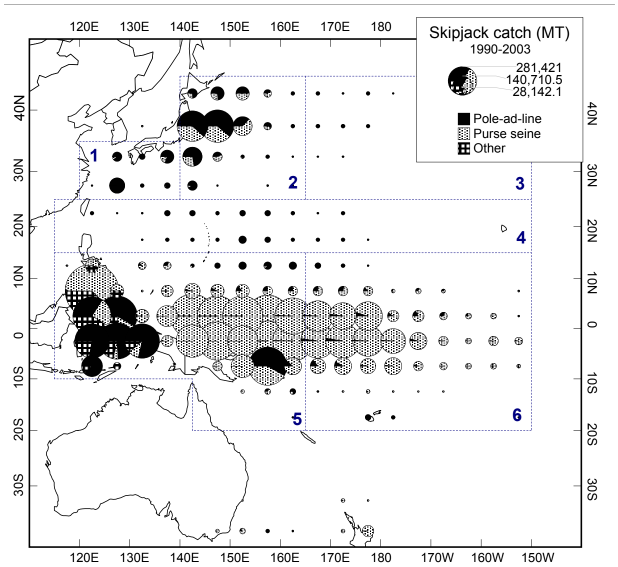


Figure 18. Distribution of skipjack tuna catch, 1990–2003. **The six-region spatial stratification used in stock assessment is shown.**

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 Taiwanese purse-seiners by major set types are shown in Figure 19. These fleets are the major purse-seine fleets fishing in the WCPO.

Skipjack tuna CPUE was generally stable during the period 1988–1997 for all fleets and set types. The slight increase in skipjack CPUE for free-school sets over the past six years is possibly related to technological advances enabling better detection of free-swimming schools. The trends in CPUE for log and FAD sets were very similar over the past six years and generally higher than in previous periods.

The 2003 skipjack CPUE from unassociated sets by the Asian purse-seine fleets remained high, while the skipjack CPUE for associated sets for all fleets dropped in 2003, resulting in a decline in overall skipjack CPUE. The 2003 skipjack CPUE for the US fleet was again clearly lower than the other three fleets. This was partly explained by the oceanographic conditions in the main area of operation by the US fleet (Langley 2004a).

The relatively poor skipjack catch (experienced by all fleets) in the second half of 2003 is reflected in Figure 20, although there was some evidence of a recovery by the end of the year. The consistency in the skipjack CPUE trends for the Korean and Taiwanese fleets in recent years is thought to be primarily due to the similar area fished by these fleets. The trend for the Korean and Taiwanese fleets is sometimes evident in the skipjack CPUE trend for the US fleet, although the skipjack CPUE for the US fleet was clearly lower for most of this time series, and is thought to reflect the availability of skipjack in the different areas fished by these fleets (Williams and Reid, 2004).

Nominal skipjack CPUE for the offshore Japanese pole-and-line fleet has remained relatively constant since 1991, while nominal CPUE for the distant-water fleet has declined steadily during the period (Figure 21). The skipjack CPUE for the offshore fleet, active in and around the Japanese home fishery, shows an oscillating pattern (between 4–6 mt/day) for most of the 1990s. In contrast, the distant-water fleet, primarily active in tropical waters, consistently accounted for a higher CPUE (between 6–8 mt/day) during the 1990s. In contrast to the industrial purse-seine fleets, the Solomon Islands pole-and-line fleet has been operating in the region for many years using fairly consistent fishing practices and technology. Skipjack CPUE in the Solomon Islands domestic pole-and-line fishery tends to be stable but lower than the Japanese fleets. Nominal skipjack CPUE for the Japanese offshore and Solomon Island fleets tend to follow similar patterns from year to year, suggesting that stock-wide effects are involved.

Some increases in CPUE by the Japanese fleet have coincided with substantial effort reduction and the departure of less competitive boats from the fishery, as well as the acquisition of improved technology, e.g. bird radar. Ogura and Shono (1999) considered several of these factors in estimating the standardised CPUE for the Japanese pole-and-line fleets (Figure 22). The importance in considering these factors is demonstrated when comparing nominal (Figure 21) and standardised (Figure 22) CPUE for the Japanese distant-water fleet where, for example, the trend in nominal CPUE over the past decade is downwards while there is no clear trend in standardised CPUE (low in 1993–97 and 2001–2002; high in 1998–2000).

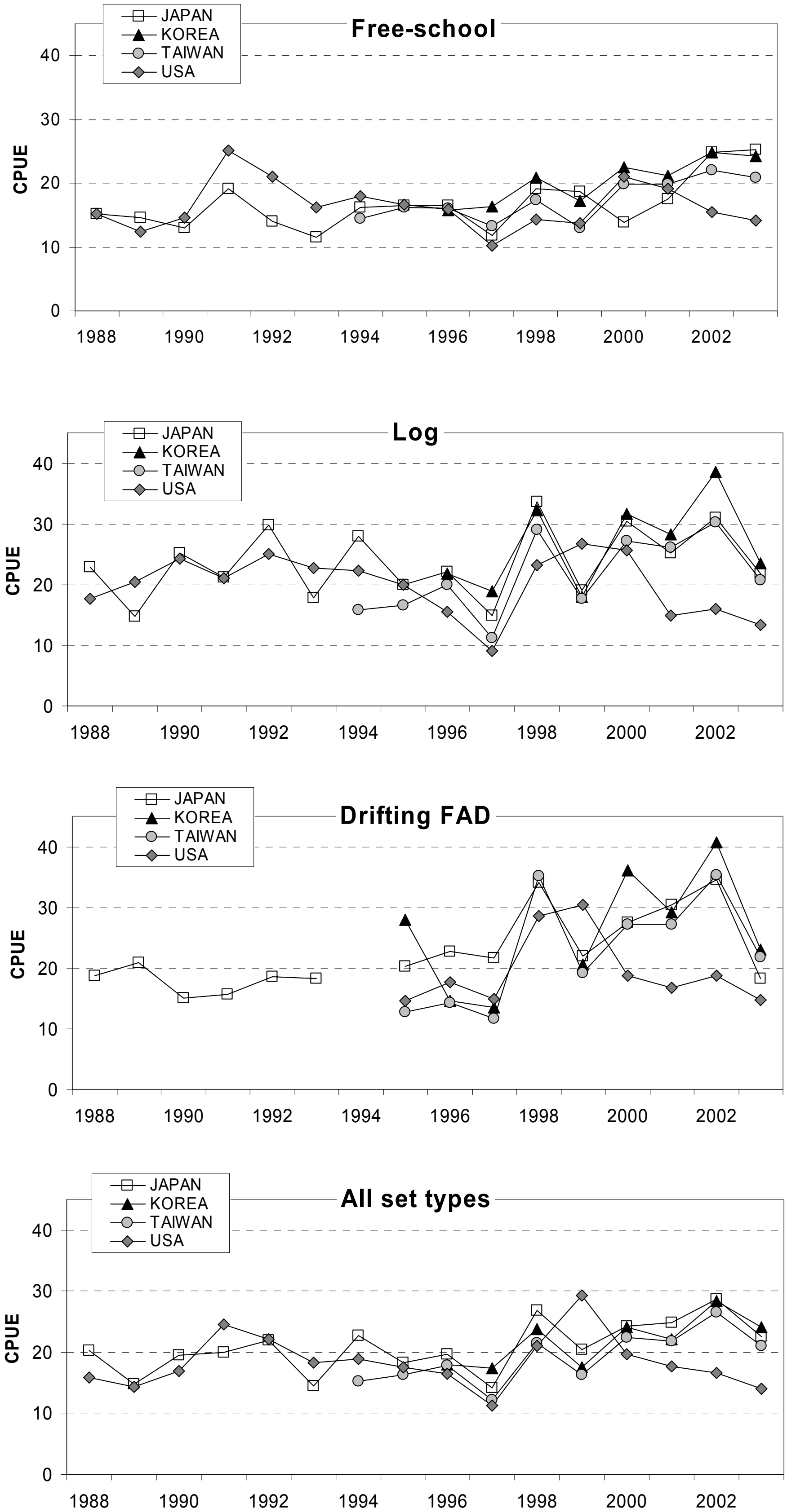


Figure 19. Skipjack tuna CPUE (mt per day) by major set type categories (free-school, log and drifting FAD sets) and all set types for Japanese, Korean, Taiwanese and USA purse-seiners fishing in the WCPO. **Effort and CPUE were partitioned by set type according to the proportions of total sets attributed to each set type.**

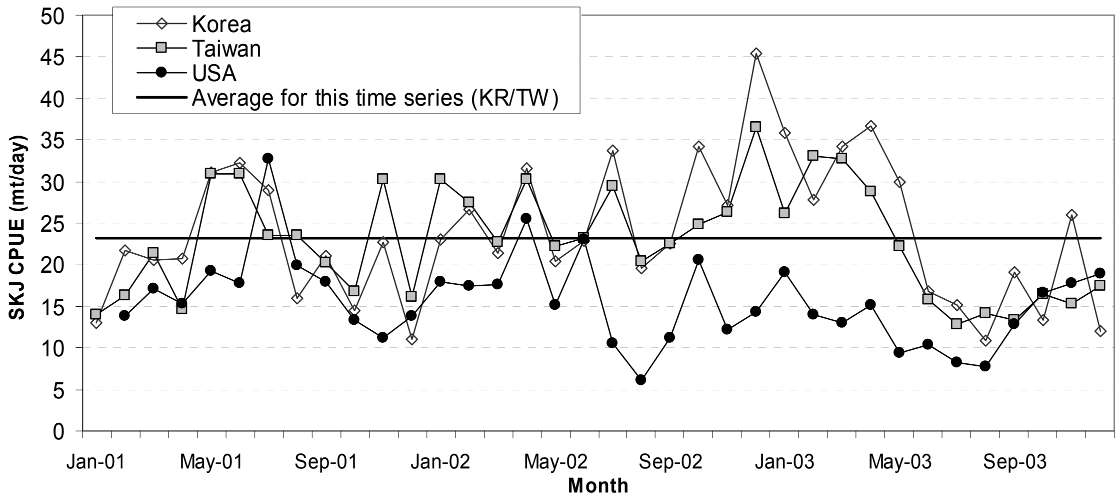


Figure 20. **Monthly trends in nominal skipjack CPUE (mt per day) for Korean, Taiwanese and US purse-seine fleets fishing in the WCPO, 2001–2003.**

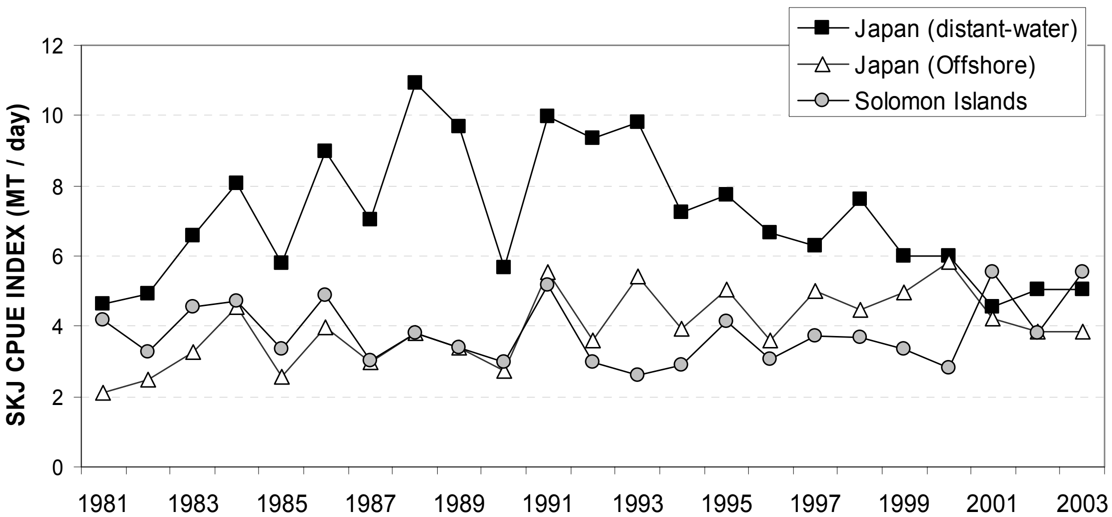


Figure 21. Nominal skipjack tuna CPUE (mt/day) for selected pole-and-line fleets.

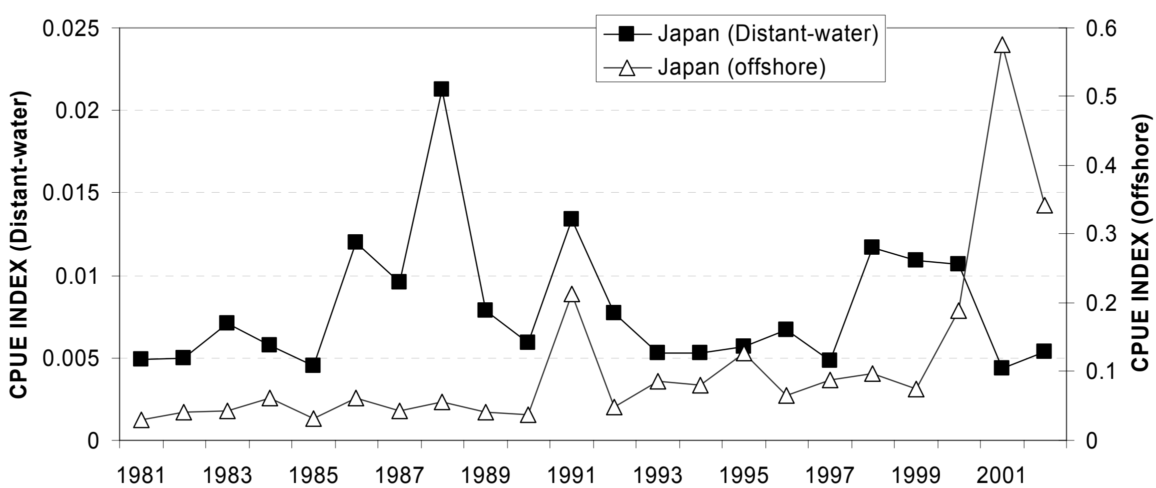


Figure 22. Standardised skipjack tuna CPUE (mt/day) for Japanese pole-and-line fleets.

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/Philippines domestic fisheries and the pole-and-line and purse-seine fleets are shown in Figure 23. The pole-and-line fishery accounted for nearly all of the catch up to the 1980s, but since this time the purse-seine gear and the Indonesian and Philippines fisheries have been more 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 Philippines and Indonesian domestic fisheries take much smaller fish and account for most of the WCPO skipjack catch in 20–40 cm size range. The dominant mode in the overall skipjack catch generally falls in the range 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 (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 18) similar to that employed by Ogura and Shono (1999) is used.

The last formal assessment of skipjack in the WCPO was conducted in 2003 and included data from 1972–2002. The results of the assessment are documented in Langley et al. (2003). Based on the result of this assessment, and other observations from the fishery, the 17^{th} meeting of the SCTB concluded that the skipjack tuna stock of the WCPO is not overfished owing to recent high levels of recruitment and a modest level of exploitation relative to the stock’s biological potential. The SCTB also concluded that continued catches at the 1.2 M mt level are sustainable with continued high levels of recruitment, which are believed to be determined by principally environmental factors and not owing to a strong spawner-recruit relationship.

The stock assessment of skipjack is scheduled to be updated in 2005 and the results of the new assessment will be presented to the Scientific Committee of the WCPFC in August 2005.

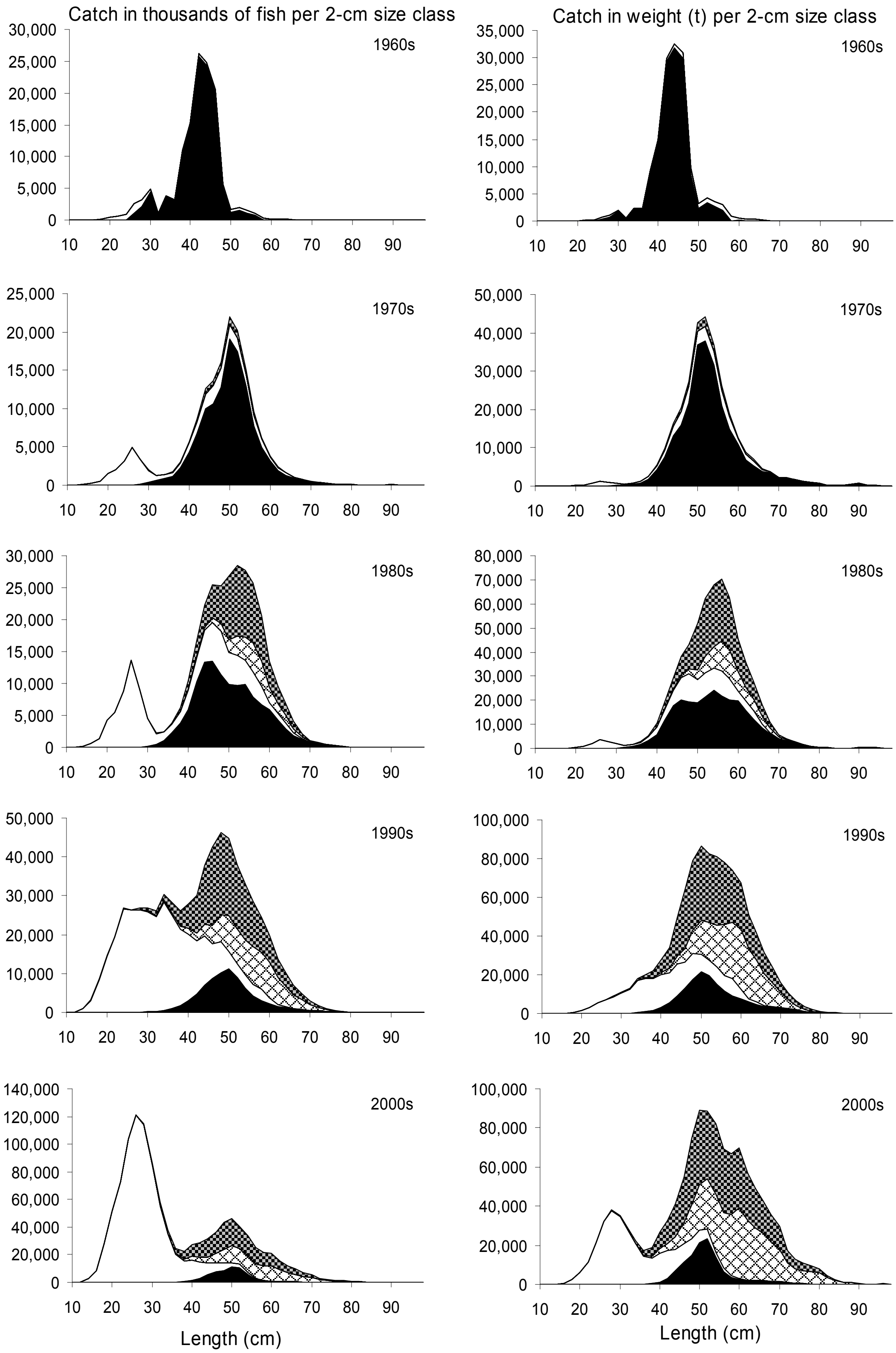


Figure 23. Average annual catches of skipjack tuna in the WCPO by size and gear type during decadal periods (black–Pole-and-line; white–Phil-Indo fisheries; grey–purse-seine associated; hatching–purse-seine unassociated).

3.2 *Yellowfin Tuna*

3.2.1 Catch

Yellowfin tuna, an important component of tuna fisheries throughout the WCPO, 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 takes mostly adult fish. Yellowfin tuna usually represent approximately 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 1990, the estimated yellowfin tuna catch in the WCPO has varied between 320,000–500,000 mt with annual catches exceeding 400,000 mt each year since 1997 (Figure 28). The 2003 yellowfin catch for all gears in the WCPO was 464,510 mt, which was only slightly less than the record catch in 1998 (465,643 mt), and mainly attributable to an increase in the Philippines domestic purse-seine and handline catches. The 2003 Pacific-wide yellowfin catch (all gears) of 881,357 mt was the highest on record.

In the WCPO, purse-seine typically harvests the majority of the yellowfin catch, which for 2003 was 219,846 mt (or 47% of the total WCPO yellowfin catch). The WCPO longline catch in recent years (59,000–74,000 mt) has been well below catches in the late 1970s and 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. For 2003, the longline catch was 70,408 mt, representing 15% of total yellowfin catch.

The pole-and-line fisheries took 14,383 mt (3% of the total yellowfin catch) during 2003, and the 'other' category accounted for 159,873 mt (34% of total) during 2003. Catches in the 'other' category in Figure 24 are largely composed of yellowfin tuna from the Philippines and eastern Indonesia. These catches come from a variety of gear types taking both juvenile (mainly ring nets and seine nets) and adult fish (handline).

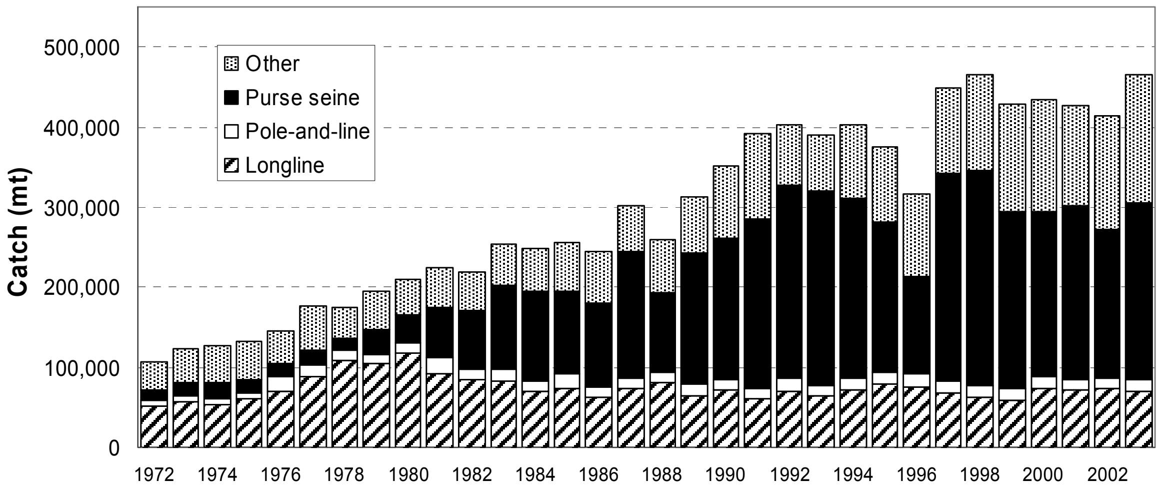


Figure 24. WCPO yellowfin tuna catch, by gear.

Figure 25 shows the average spatial distribution of yellowfin catch by gear type for the period 1990–2003. As with skipjack, the great majority of the catch is taken in equatorial areas by large purse-seine vessels and a variety of gear types in the Indonesian and Philippine fisheries.

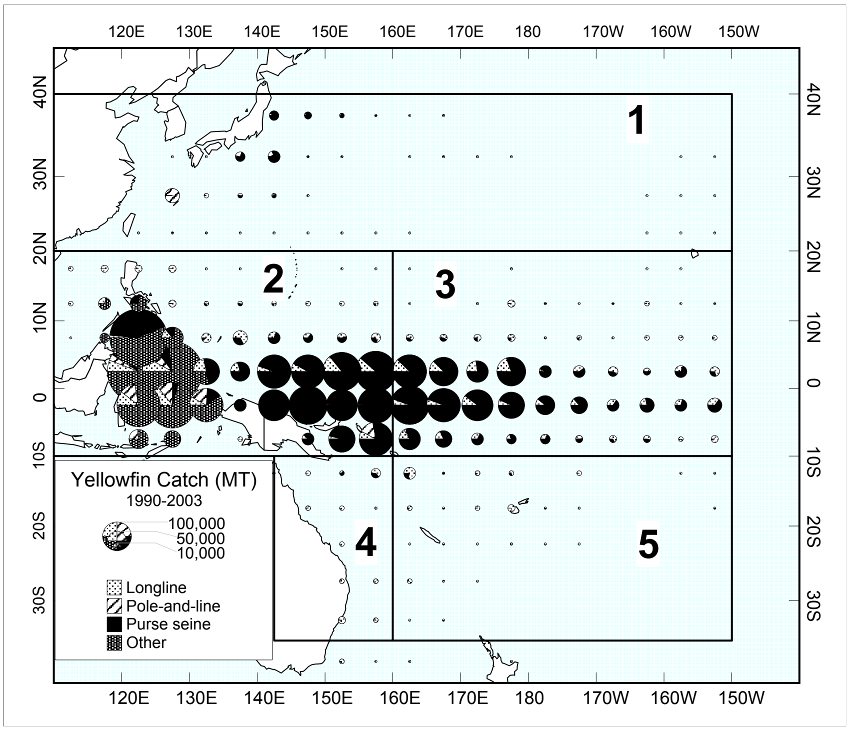
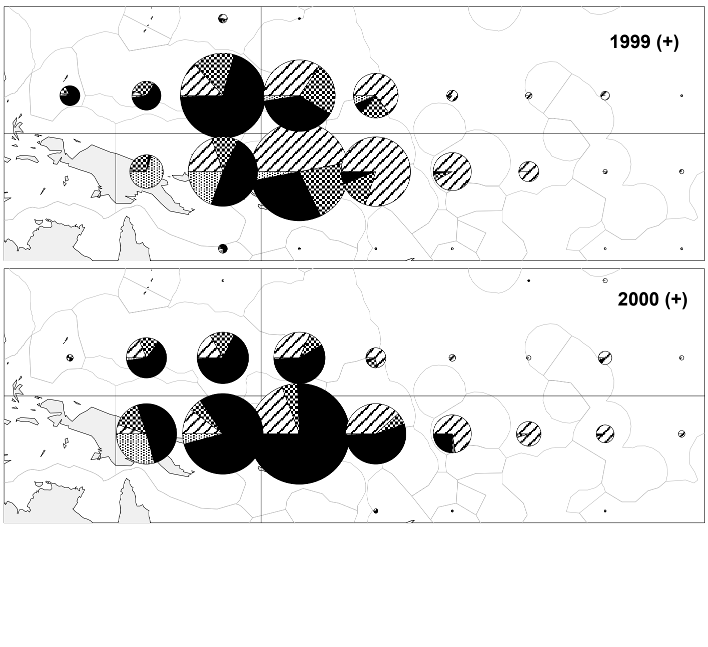


Figure 25. Distribution of yellowfin tuna catch, 1990–2003. **The five-region spatial stratification used in stock assessment is shown.**

The east–west distribution of yellowfin catch is strongly influenced by ENSO events, with larger catches taken east of 160°E during El Niño episodes. Figure 26 highlights the inter-annual variation in the distribution of purse-seine yellowfin catch by set type in recent years. During recent El Nino years, most of the yellowfin catch to the east of 160°E was taken from unassociated schools, with logs sets accounting for most of the remainder. In contrast, during recent La Nina years, drifting FADs were widely used east of 160°E and took a significant proportion of the total purse-seine catch of yellowfin. Anchored FADs are an important component of the PNG domestic purse-seine fishery taking mainly juvenile skipjack and yellowfin. There were relatively poor catches of yellowfin between 160°E–180° during 2002 compared to the previous years, despite substantial effort in this area (Figure 7). During 2003, a higher proportion of the catch of yellowfin was taken in the area west of 160°E compared to the previous years.



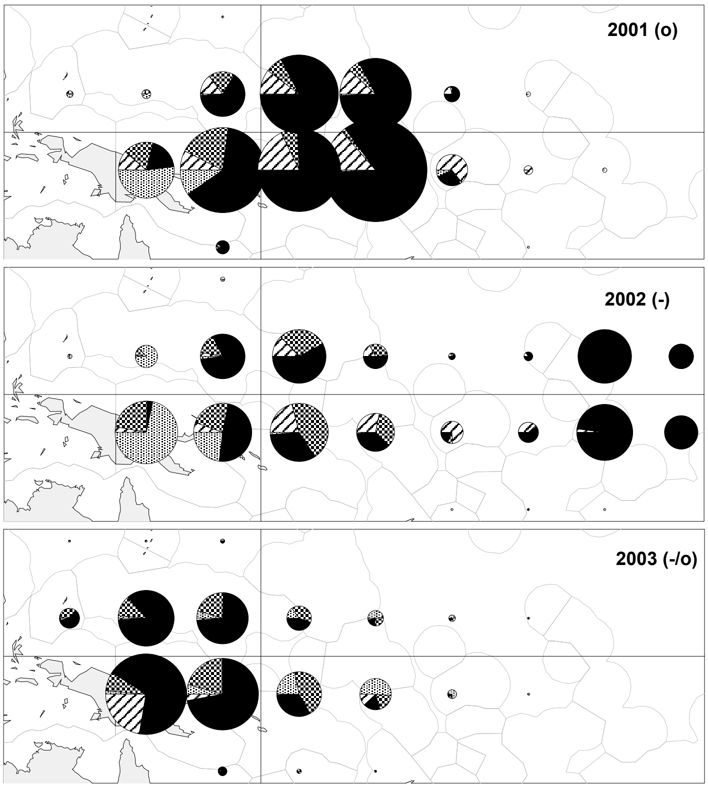


Figure 26. Distribution of purse-seine yellowfin catch by set type, 1999–2003 (Solid–Unassociated; Dark Grey–Log; Striped–Drifting FAD; Light Grey–Anchored FADs). ENSO periods are denoted by "+": La Niña; "-": El Niño; "--": strong El Niño; "0": transitional period. The horizontal and vertical lines represent the Equator and 160°E, respectively.

3.2.2 Catch per Unit of Effort

Yellowfin purse-seine CPUE is characterised by strong inter-annual variability and differences amongst the fleets (Figure 27). 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 recent La Niña periods (1995–96 and 1999–2000), while high CPUE was experienced during previous strong El Niño years (1994–1995 and 1997–98).

In general, yellowfin CPUE by set type and overall CPUE (all sets combined) declined over the last six years, although CPUE did increase slightly in 2003. Associated (log and drifting FAD) sets produce higher catch rates (mt/day) for skipjack than unassociated sets (Figure 19), while unassociated sets produce a higher catch rate for yellowfin than associated sets. This is mainly due to unassociated sets taking large, adult yellowfin in most cases, which account for a larger catch (by weight) than the mostly juvenile yellowfin encountered in associated sets.

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 2004 stock assessment, two approaches were applied to standardise the Japanese longline CPUE time series to account for the temporal changes in fishing operation; a generalised linear modelling approach (GLM) and a statistical habitat based approach (SHBS). The details of the two methods are described in Langley (2003b) and Bigelow et al. (2004), respectively, and the indices derived for each of the main fishery regions (see Figure 25) are presented in Figure 28. These indices were used in the 2004 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).

For each region, the standardisation approaches yielded two broadly comparable sets of indices, although some differences do exist within a region, most notably during the earlier period of the analysis (prior to 1970) and especially in regions 1 and 5. For most regions, standardised catch rates dropped very sharply immediately following the development of the fishery (Figure 28). This decline is considered too great to represent the biomass trend in the entire region; rather it is more likely represent hyperdepletion in localised areas within the region.

The equatorial regions (2 and 3) account for most of the catch from the yellowfin fishery. For both regions, the GLM and SHBS standardised CPUE indices reveal significant differences in the long-term biomass trajectory (Figure 28). The GLM analysis indicates a general decline in yellowfin CPUE over the entire period. In contrast, the SHBS indices indicate a decline in CPUE from the mid 1950s to the mid 1970s, followed by a sharp increase in CPUE in the late 1970s. For region 2, the SHBS indices tend to decline over the subsequent period, while the region 3 indices remain relatively stable during the 1980s and 1990s (Figure 28).

For the other subequatorial regions, most indices reveal a general decline in biomass prior to 1970 and relatively stable CPUE over the remainder of the period (Figure 28).

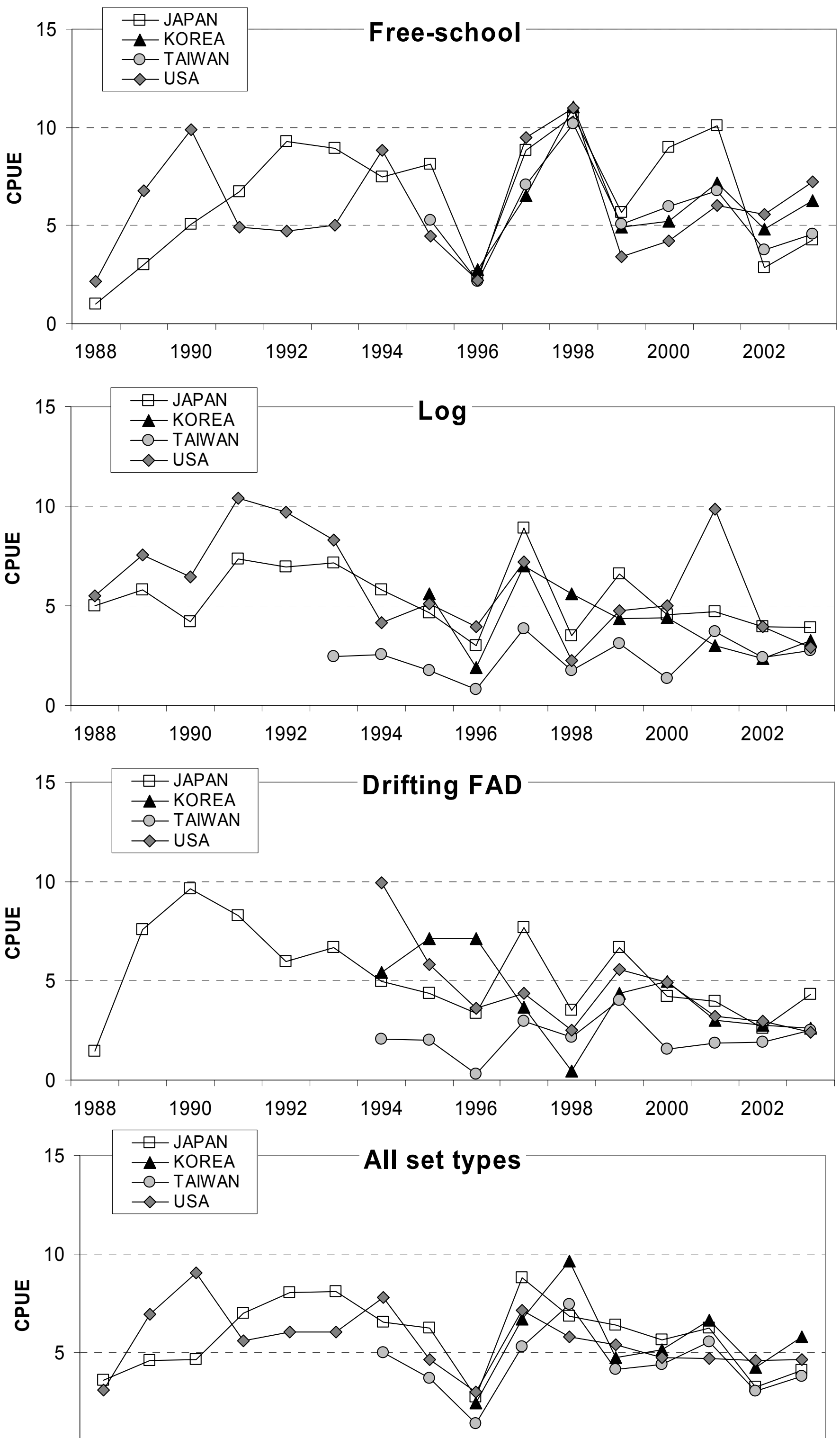


Figure 27. Yellowfin tuna CPUE (mt per day) by major set type categories (free-school, log and drifting FAD sets) and for all sets combined for Japanese, Korean, Taiwanese and USA purse-seiners fishing in the WCPO. **Effort and CPUE were partitioned by set type according to the proportions of total sets attributed to each set type.**

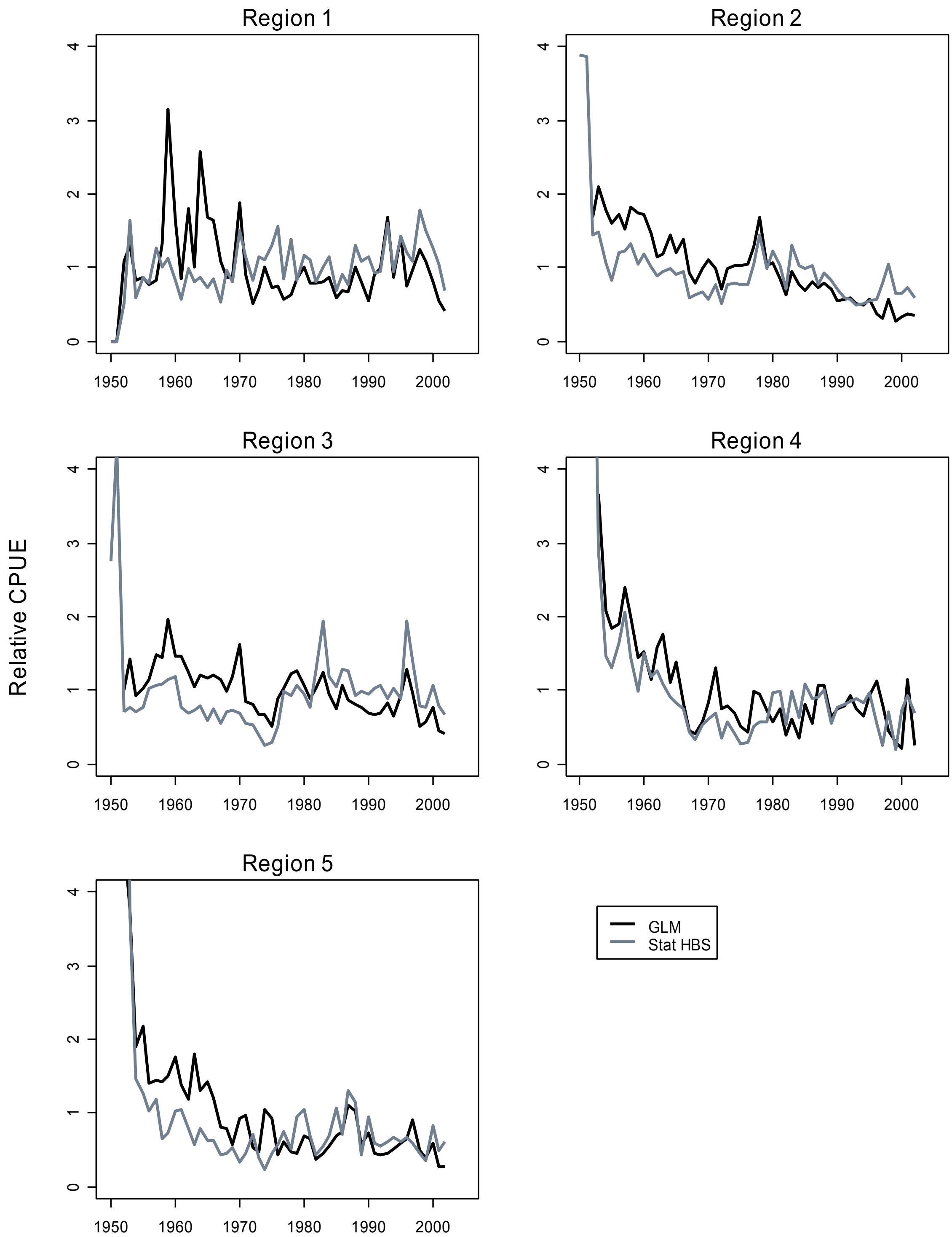


Figure 28: Annual trends in yellowfin standardised CPUE indices (GLM and SHBS) for the Japanese longline fleet by MFCL region. For comparison, all indices have been scaled by the average of the series.

3.2.3 Size of Fish Caught

Average annual yellowfin tuna catch-at-size for the Indonesian/Philippines domestic fisheries and the longline and purse-seine fisheries are shown in Figure 29. 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 range 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.

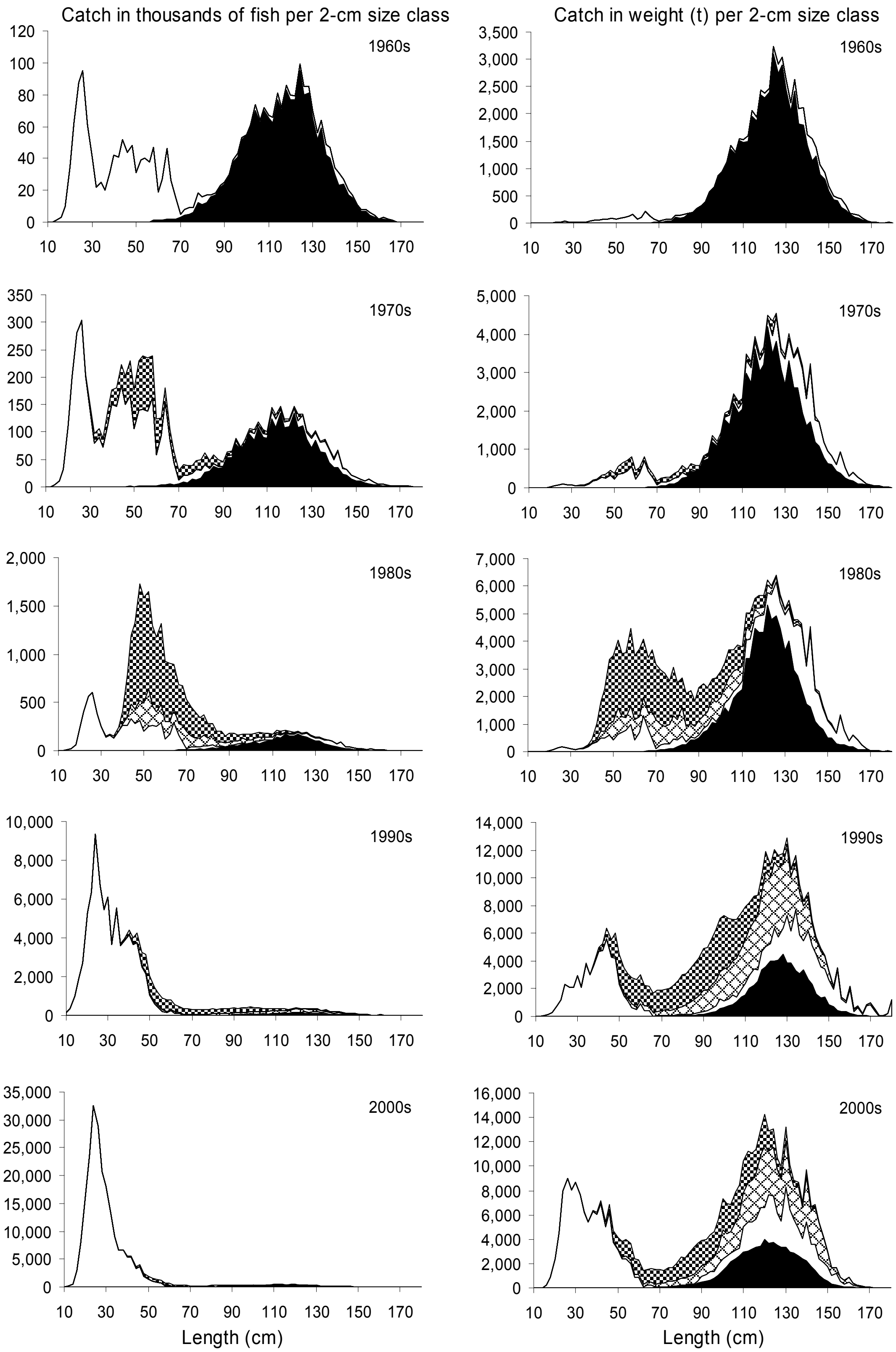


Figure 29. Average annual catches of yellowfin tuna in the WCPO by size and gear type during decadal periods (black–Longline; white–Phil-Indo fisheries; grey–purse-seine associated; hatching–purse-seine unassociated).

3.2.4 Stock Assessment

The most recent application of the MULTIFAN-CL model to yellowfin tuna in the WCPO was based on five regions (see Figure 25). The time period covered by the analysis is 1950–2003 stratified by quarter with the addition of a four-year projection period (2004–07). The model structure adopted included quarterly recruitment, 28 quarterly age classes, independent mean lengths for the first 8 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 age-specific movement among the model regions.

Catch, effort and size data (both length and weight frequency), stratified by quarter, for 17 fisheries (8 longline, 2 Philippine domestic, 1 Indonesian domestic, and 6 purse-seine fisheries classified by log, FAD and school sets) were used in the analysis. For the longline fisheries, several estimates of effective (or standardised) effort were available (Bigelow et al. 2004; Langley 2003b) and separate analyses were undertaken for each longline effort series. Tagging data from the RTTP 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. (2004a) (http://www.spc.int/OceanFish/Html/SCTB/SCTB17/SA-1.pdf).

The stock assessment results presented in this report are from the analysis using the statistical habitat based standardised (SHBS) CPUE time-series. The details of this assessment may differ from the other analyses depending on the respective longline effort series included in the model; however, the overall conclusions of the separate assessments are generally comparable. The stock projections for 2004–07 assume future recruitment is at the level of the long-term average and future method/area fishing effort is comparable to the level of recent years. Consequently, the stock projections are highly uncertain.

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 30. Fishing mortality rates for both juvenile and adult yellowfin tuna increased from 1970 to 2000, 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 recent years, particularly for juvenile yellowfin. However, this is largely attributable to the estimates of very high recruitment in recent years, although these high recruitments are very poorly determined.

Recruitment estimates for the entire WCPO region indicate considerable variation about the level of average recruitment. For the SHBS CPUE assessment, recruitment was estimated to be high in the early model period (1950–60), low between the mid 1960s and mid 1970s, and high since 1980, particularly in the most recent years (Figure 31).

The **biomass** trajectory is comparable to the temporal trend in recruitment. Biomass declined from 1950 to 1970, increased in the late 1970s, and remained relatively stable over the subsequent years (Figure 32). However, there is considerable variation in the biomass trends between areas, with the western equatorial region — the area supporting a high proportion of the total yellowfin catch — showing a steady decline in biomass throughout the model period.

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 33). Fishing is estimated to have reduced the overall stock biomass by about 35% in recent years. The impact is differentially high in the tropical regions (around 60%) compared to the subtropical regions. Furthermore, the attribution of depletion to various fisheries or groups of fisheries indicates that the Indonesian fishery has the greatest impact, particularly in its home region. The purse-seine fishery also has high impact, particularly in the equatorial regions (Figure 34).

Conclusion

The assessment reaffirms the result of the previous assessment that the yellowfin stock in the WCPO is presently not being overfished (i.e. $F_{CURRENT} < F_{MSY}$) and that it is not in an overfished state ($B_{CURRENT} > B_{MSY}$) (Figure 35). However, the stock is likely to be nearing full exploitation and any future increases in fishing mortality would not result in any long-term increase in yield and may move the yellowfin stock to an overfished state. The assessment indicates that the equatorial regions are likely to be fully exploited, while the temperate regions are likely to be under-exploited. While these spatial patterns of exploitation remain uncertain, if true, this may indicate the need for region-specific management.

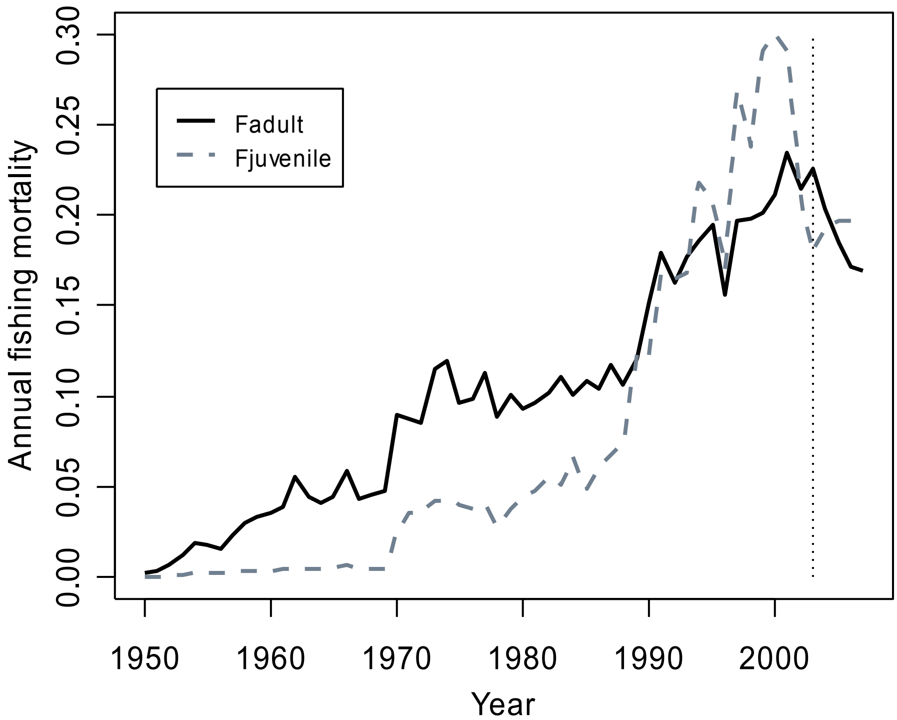


Figure 30. Estimated average annual fishing mortality rates for juvenile (less than 100 cm) and adult yellowfin tuna. **The dotted vertical line indicates the beginning of population projections based on the most recent year's fishing effort.**

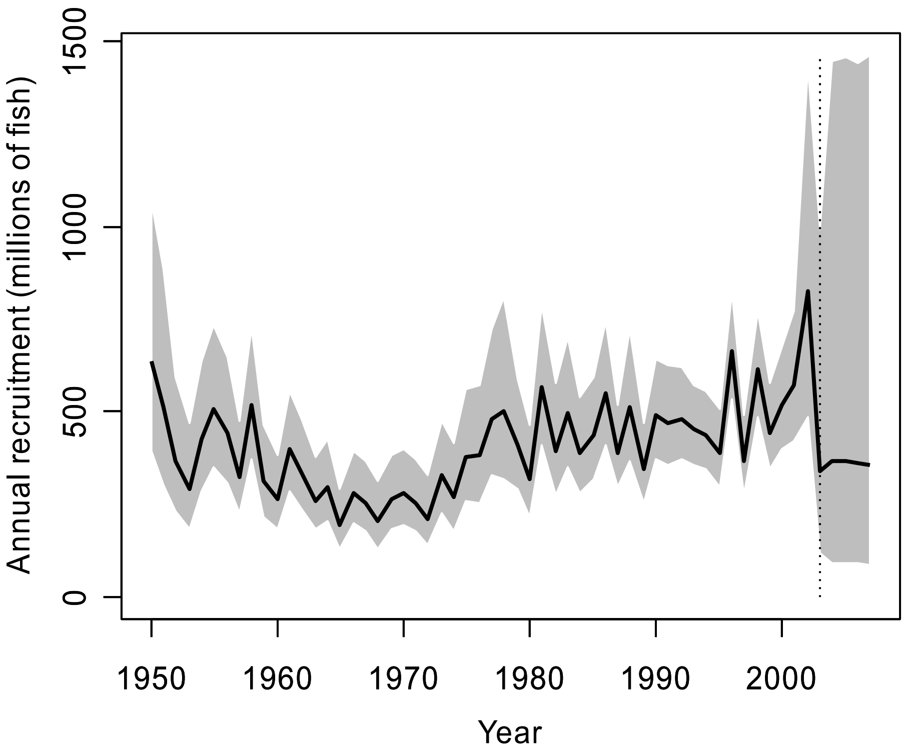


Figure 31. Estimated annual yellowfin tuna recruitment (millions) for the WCPO. The shaded area indicates the approximate 95% confidence intervals. The dotted vertical line indicates the beginning of population projections based on the most recent year's fishing effort.

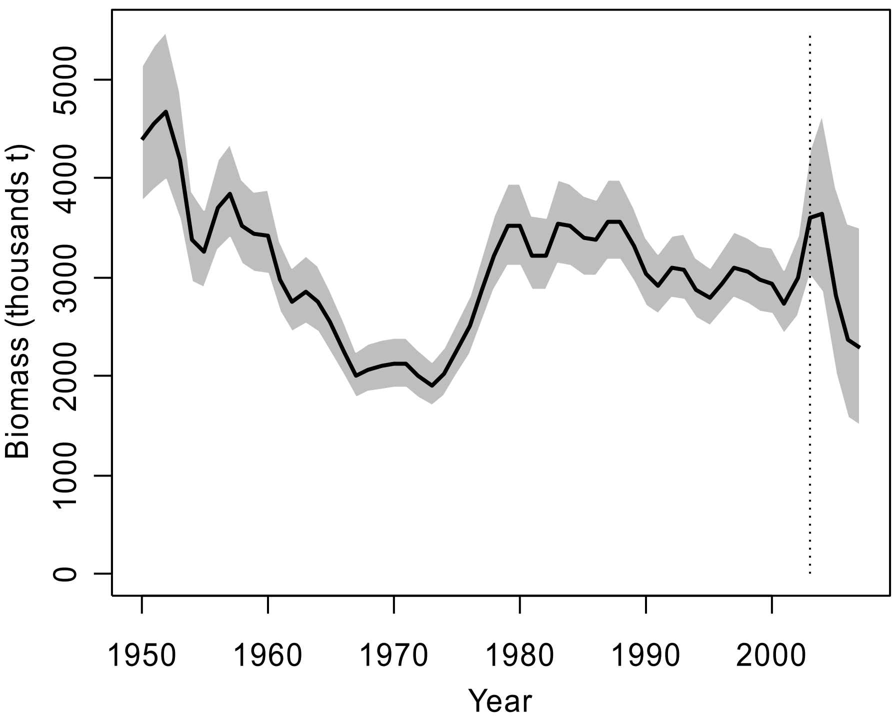


Figure 32. Estimated annual average total yellowfin biomass (thousand t) for the base-case analysis (SHBS longline effort). The shaded areas indicate the approximate 95% confidence intervals. The dotted vertical line indicates the beginning of population projections based on the most recent year's fishing effort.

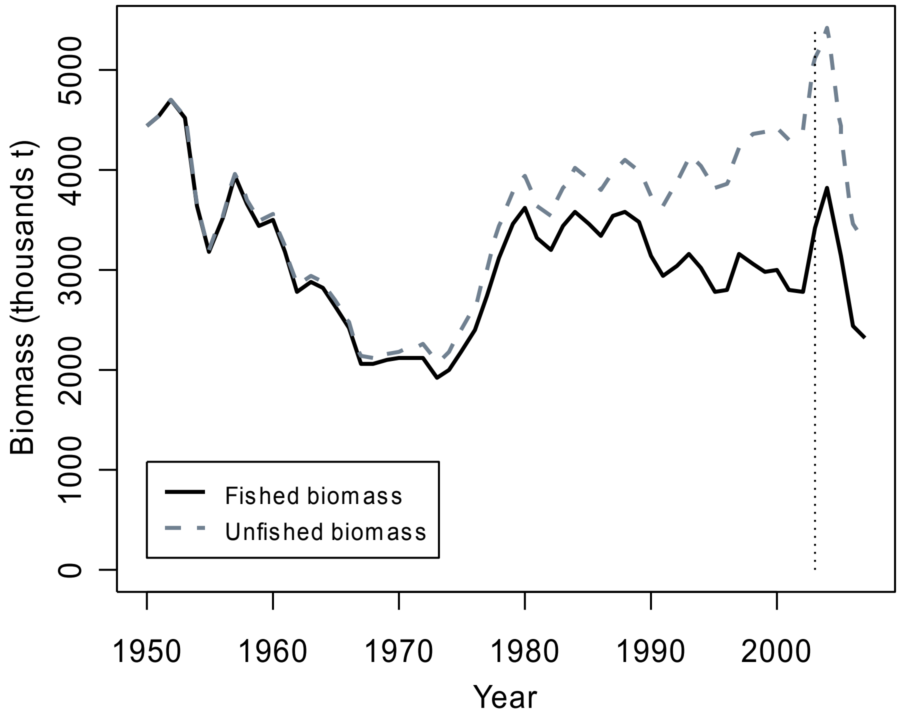


Figure 33. The estimated impact of fishing on yellowfin tuna biomass. **The lower biomass trajectory (darkest line) represents the model estimates of total biomass. The upper trajectory is the estimated biomass that would have occurred in the absence of fishing assuming that recruitment was unaffected by fishing. The dotted vertical line indicates the beginning of population projections based on the most recent year's fishing effort.**

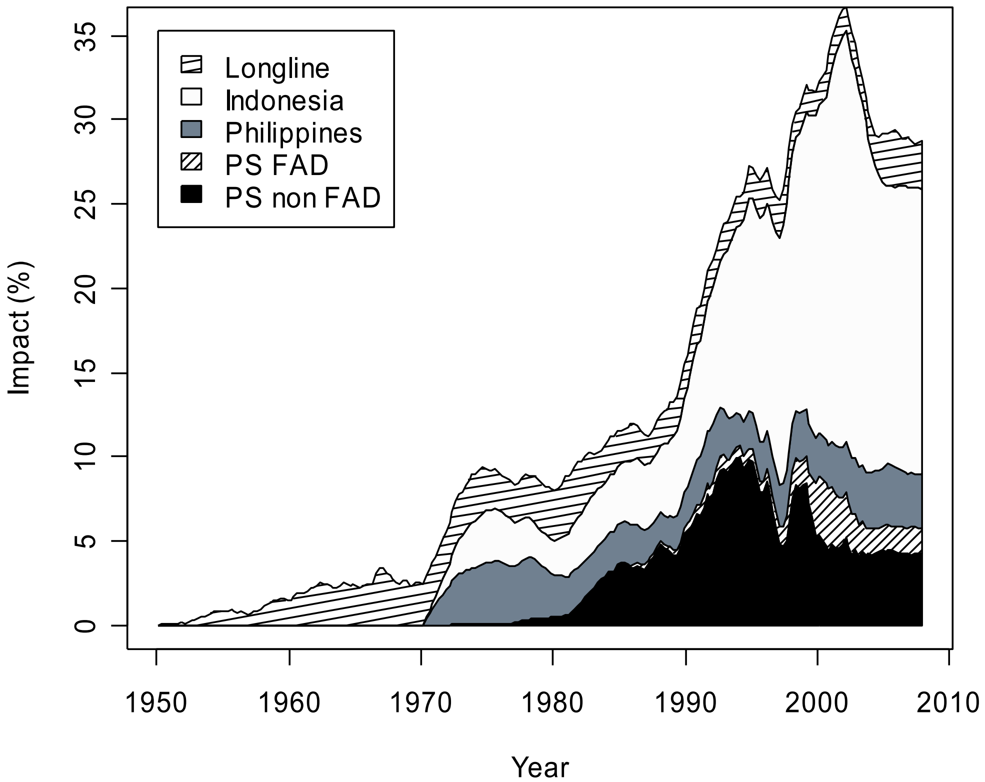


Figure 34. The estimated impact of each fishery on the yellowfin tuna biomass in the WCPO. Impact is expressed as the proportional reduction in biomass attributed to fishing.

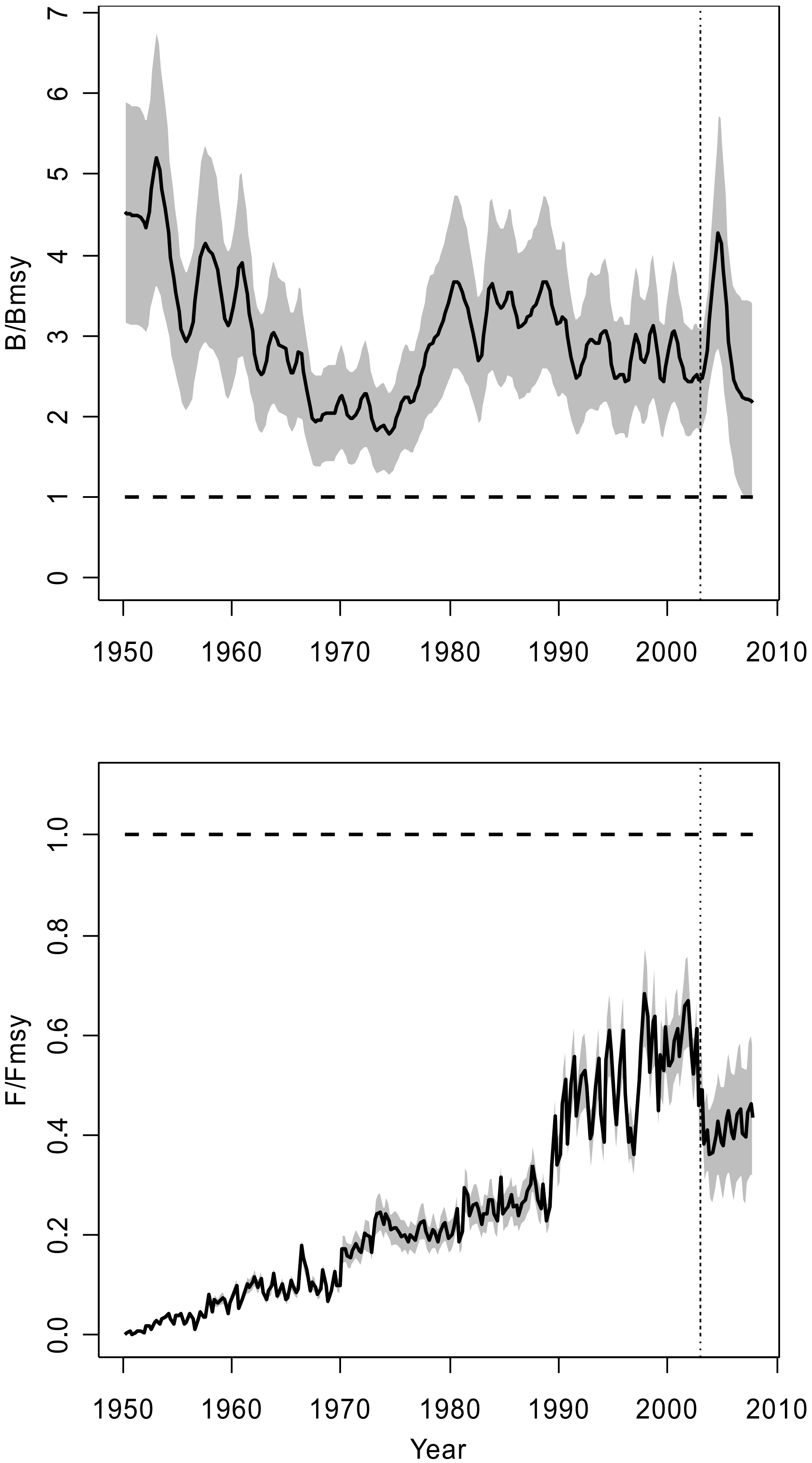


Figure 35. Trends in the biological reference points for the WCPO yellowfin stock: spawning biomass relative to the spawning biomass at MSY (top) and fishing mortality relative to the fishing mortality at MSY (bottom). **The solid dashed line represents the reference level (MSY). The dotted vertical line indicates the beginning of population projections based on the most recent year's fishing effort.**

3.3 *Bigeye Tuna*

3.3.1 Catch

Bigeye tuna are an important component of tuna fisheries throughout the Pacific Ocean. Bigeye are taken by purse-seine and pole-and-line (surface) gears, mostly as juveniles, and by longline gear, as valuable adult fish. They are a principal target species of both the large distant-water longliners from Japan, Korea and more recently Taiwan, and of 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 WCPO 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 115,000 and 220,000 mt (Figure 36), with Japanese longline vessels generally contributing over 80% of the catch until the early 1990s. The total WCPO bigeye catch (103,833 mt) for 2003 was the seventh consecutive year that catches exceeded 100,000 mt. However, the Pacific-wide bigeye catch (189,719 mt) for 2003 was the lowest for five years, primarily due to significant decreases in the EPO catches.

The longline catch in the EPO, the area east of 150°W and historically the primary bigeye longline fishing area, has varied in the range 50,000–102,000 mt since 1980, surpassing 100,000 mt once in 1991, but has fallen to below 50,000 mt in recent years, with an historical low in 1999 (33,526 mt). The WCPO longline catch has ranged between 40,000–77,000 mt for the past thirty years (Figure 36). The WCPO and EPO bigeye longline catches for 2003 (64,051 mt and 44,582 mt, respectively) were much lower than catches taken in 2002 (the WCPO bigeye longline catch for 2002 was the highest ever).

Purse-seine catch in the EPO (40,720 mt in 2003) continues to account for a significant proportion (48% in 2003) of the total EPO bigeye catch. The WCPO purse-seine bigeye catch for 2003 was estimated to be 20,684 mt, declining over the four consecutive years since the record level of catch in 1999 (35,920 mt) due to the corresponding reduction in drifting FAD sets. The WCPO pole-and-line fishery has accounted for between 2,000–4,000 mt of bigeye catch annually over the past decade, and the "other" category, representing various gears in the Philippine, Indonesian and Japanese domestic fisheries, has accounted for about 12,000–17,000 mt in recent years (Figure 37).

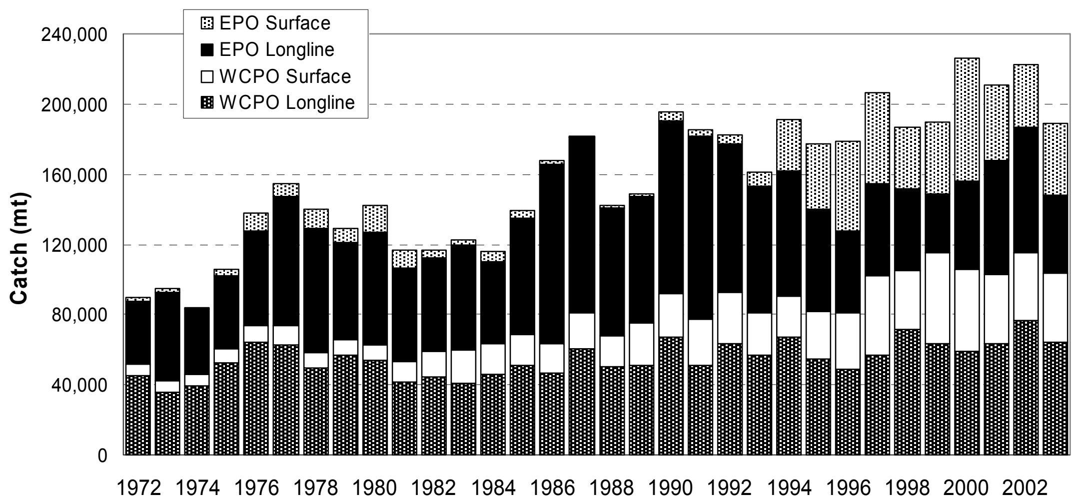


Figure 36. Bigeye tuna catch in the Pacific Ocean.

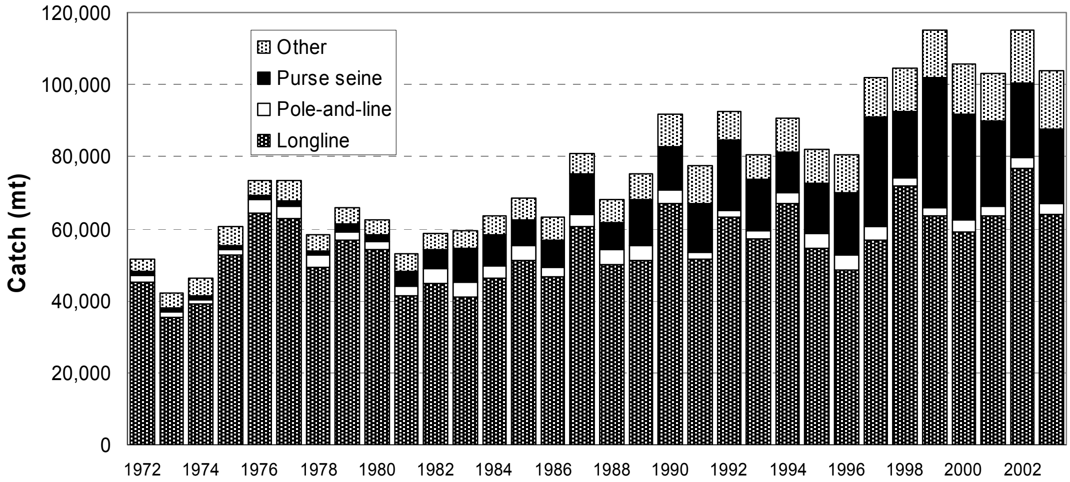


Figure 37. WCPO Bigeye tuna catch, by gear.

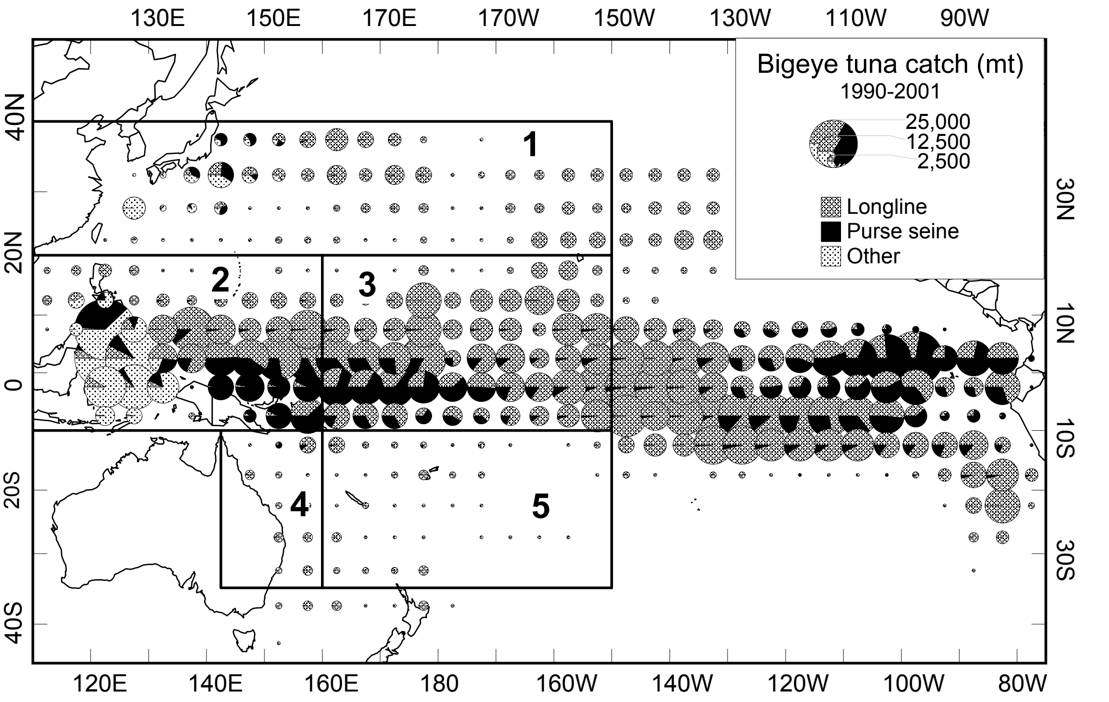


Figure 38. Distribution of bigeye tuna catch, 1990–2001. **The five-region spatial stratification used in stock assessment for the WCPO is shown.**

Figure 38 shows the spatial distribution of bigeye catch in the Pacific for the period 1990–2001 (2002 and 2003 longline data for all fleets are not yet available). Most of the WCPO catch is taken in equatorial areas, both by purse-seine and longline, but with significant longline catch in some sub-tropical areas (east of Japan, east coast of Australia). In the equatorial areas, much of the longline catch is taken in the central Pacific, continuous with the important traditional bigeye longline area in the eastern tropical Pacific.

3.3.2 Catch per Unit of Effort

The longline fishery provides the most potentially useful information on bigeye tuna relative abundance in the Pacific. In the years prior to 1980, yellowfin was the preferred target species in the WCPO longline fishery, in contrast to years after 1980, when bigeye targeting became progressively more important; such changes need to be accounted for if the CPUE time series are to be interpreted as indices of relative abundance.

Two approaches (GLM and SHBS) were applied to account for these changes in the operation of the fishery and derive standardised indices of bigeye CPUE from the Japanese longline fishery (see Langley 2003b and Bigelow et al. 2004 for details). These indices were derived for the five regions used to define the bigeye fishery operating in the WCPO (see Figure 41) and incorporated in the 2004 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.

The two approaches for standardising the CPUE data yielded similar trends in relative abundance for each of the five regions, although there were considerable differences in the CPUE trends are evident among regions (Figure 39). The equatorial area of the fishery (regions 2 and 3) accounts 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 deviate over the subsequent period, with a general increase in CPUE in region 2, while CPUE in region 3 either remained relatively constant (GLM) or declined slightly (SHBS) (Figure 39).

Trends in the CPUE indices differed for the other regions of the WCPO fishery. For regions 1 and 4, CPUE declined sharply during the first 10–20 years of the fishery and remained relatively stable, at a lower level, from 1970 to present (Figure 39). For region 5, CPUE remained relatively constant from the mid 1950s to the mid 1970s, increased sharply in the late 1970s, and returned to lower levels in the 1990s (Figure 39).

3.3.3 Size of Fish Caught

Average annual catch-at-size of bigeye tuna in the WCPO is shown in Figure 40. The longline fishery has clearly accounted for most of the catch of large bigeye in the WCPO. 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 Philippines handline fishery. Large bigeye are very rarely taken in the WCPO purse-seine fishery and only a relatively small amount comes from the handline fishery in the Philippines. Bigeye sampled in 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 take small bigeye (20–60 cm FL). Associated sets account for nearly all the bigeye catch in the WCPO purse-seine fishery with considerable variation in the sizes from year to year. As with yellowfin (Figure 29), 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 gears.

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).

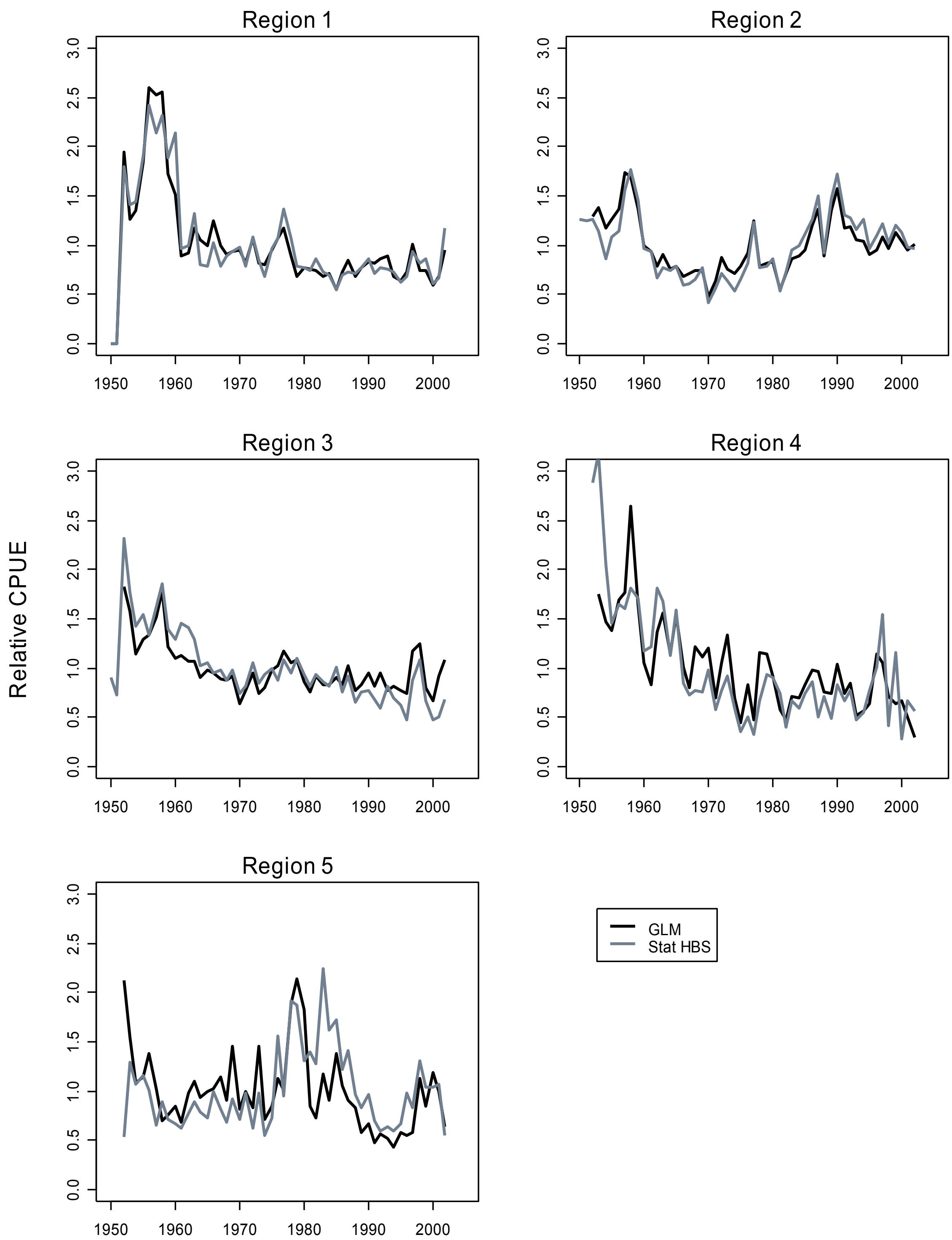


Figure 39. Annual trends in bigeye standardised CPUE indices (GLM and SHBS) for the Japanese longline fleet by MFCL region. For comparison, all indices have been scaled by the average of the series.

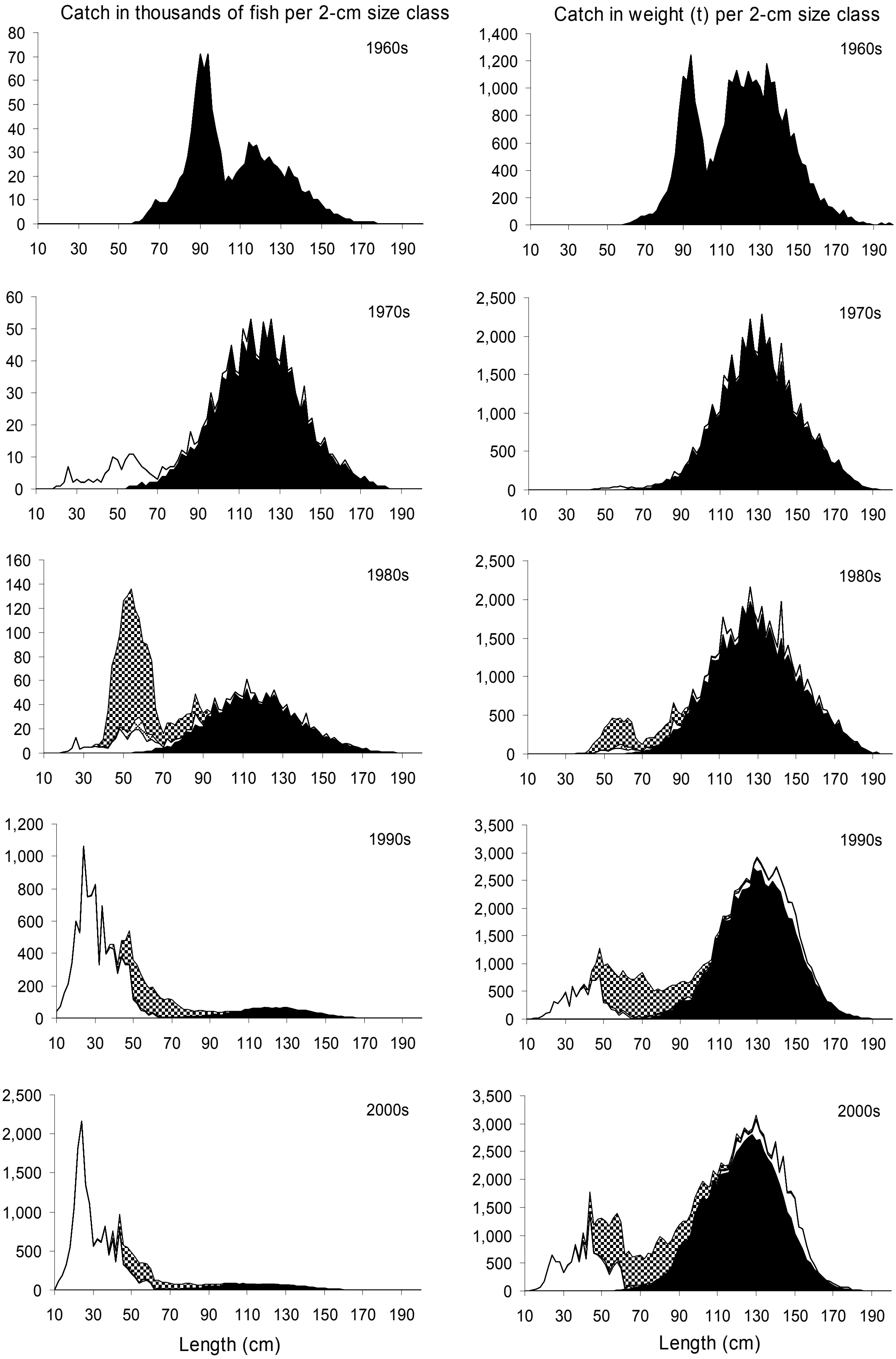


Figure 40. Average annual catches of bigeye tuna in the WCPO by size and gear type during decadal periods **(black–Longline; white–Phil-Indo fisheries; grey–purse-seine associated; hatching–purse-seine unassociated, catches negligible).**

3.3.4 Stock Assessment

Previous reports have presented the results of a MULTIFAN-CL analysis of bigeye tuna on a Pacific-wide basis. This work is ongoing and will be reported separately in due course. The analysis described here is restricted to the WCPO (i.e. west of 150°W) assuming that movement between the WCPO and the EPO is minimal. Catch, effort (standardised and unstandardised) and size composition data covering the period 1950–2003 using a quarterly time stratification have been assembled. The spatial coverage of the model is the WCPO, within which a five-region spatial stratification (see Figure 38) has been adopted. Catch, effort and size data for 17 fisheries (8 longline, 2 Philippine domestic, 1 Indonesian domestic and 6 western Pacific purse-seine fisheries) were used in the analysis. Several different model options were investigated using the different standardised effort series from the longline fisheries (Bigelow et al. 2004; Langley 2003b).

The limited amount of tagging data available from SPC's Regional Tuna Tagging Project was incorporated into the analysis. The model structure adopted thus far includes: quarterly recruitment, 40 quarterly age classes, independent mean lengths for the first 8 age classes with von Bertalanffy growth constraining the mean lengths for the remaining age classes, structural time-series variation in catchability for non-longline fisheries, age-specific natural mortality and age-specific movement among the model regions. The model period was extended to include a four-year projection period (2004–07). A detailed description of the data, model structure and results is available in Hampton et al. (2004b) (http://www.spc.int/OceanFish/Html/SCTB/SCTB17/SA-2.pdf).

The stock assessment results presented in this report are from the analysis using the statistical habitat-based standardised (SHBS) CPUE time-series. The details of this assessment may differ from the other analyses depending on the respective longline effort series included in the model; however, the overall conclusions of the separate assessments are comparable. The stock projections for 2004–07 assume future recruitment is at the level of the long-term average and future method/area fishing effort is comparable to the level of recent years. Consequently, the stock projections are highly uncertain.

Annual average **fishing mortality rates** for juvenile (less than 100 cm) and adult bigeye tuna for the WCPO as a whole are shown in Figure 41. Fishing mortality for adults increased steadily over the model period, while juvenile fishing mortality was low prior to 1980 and increased rapidly during the 1990s. A major factor in this increase has been the increase in assumed catches in Indonesia, which are based on yellowfin tuna catches reported by the Indonesian national authorities and an assumption (in the absence of sampling data) that these catches contain a fixed proportion of bigeye tuna. Increased purse-seine catches, mainly using FAD sets, have also contributed to increased juvenile fishing mortality.

Annual **recruitment** estimates are presented in Figure 42. Recruitment was relatively high in the early model period and generally declined in the 1950s and 1960s. Since the 1970s, there has been a strong increasing trend in recruitment and recent recruitment is the highest for the model period. The trend is mainly driven by the very strong increase in recruitment in the western equatorial area (region 2) and, to a lesser extent, the recent recruitment estimates from the eastern equatorial area (region3). This pattern may be an artefact related to the development of the Indonesia/Philippines and purse-seine fisheries and/or the limited size data from the early period. This issue requires further investigation. The model also predicts above average recruitment in the mid 1950s to account for the high CPUE observed in regions 1–3 during the early period. There is high uncertainty for recruitment estimates from the 1950s and early 1960s due to the limited amount of size composition data from this period.

The time series of estimated **biomass** is shown in Figure 43. Total estimated biomass of bigeye tuna declined by about 40% during the 1950s and 1960s, mainly due to the decline in estimated recruitment in regions 1 and 3. 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 3) revealing a steady decline in biomass since the 1970s.

The ***impact of fishing*** on the total biomass has increased over time as catches and fishing mortality have increased, particularly since the 1970s (Figure 44). The current level of catch, in particularly from the longline fishery and more recently the Indonesian fishery, is having a large impact on the biomass level (Figure 45). The impact of fishing is highest in the equatorial area (regions 2 and 3) and the north-western Pacific (region 1), reducing biomass in these regions by 50–80%. However, despite the high fishery impact (increasing fishing mortality), the model predicts total biomass has remained relatively stable due to the steady increase in annual recruitment over the last two decades and the relatively low fishery impacts in the south-western Pacific (regions 4 and 5).

Conclusion

The current bigeye assessment indicates the stock is not in an overfished state ($B_{CURRENT} > B_{MSY}$) although current fishing mortality rates are approaching or exceeding the level of F_{MSY} ($F_{CURRENT} \approx F_{MSY}$) and over-fishing may be occurring (Figure 46). The current level of exploitation appears not to be sustainable in the long term, unless the high recent recruitment is maintained in the future. Lower future recruitment is a possibility if the recruitment trends for bigeye in the EPO are mirrored in the WCPO. On this basis, the SCTB recommended that, as a minimum measure, there be no further increase in the fishing mortality rate for bigeye tuna from the recent level ($F_{CURRENT}$). If future evidence supports a shift to a lower productivity regime, a decrease in total catch would be anticipated in order to maintain the stock at sustainable levels.

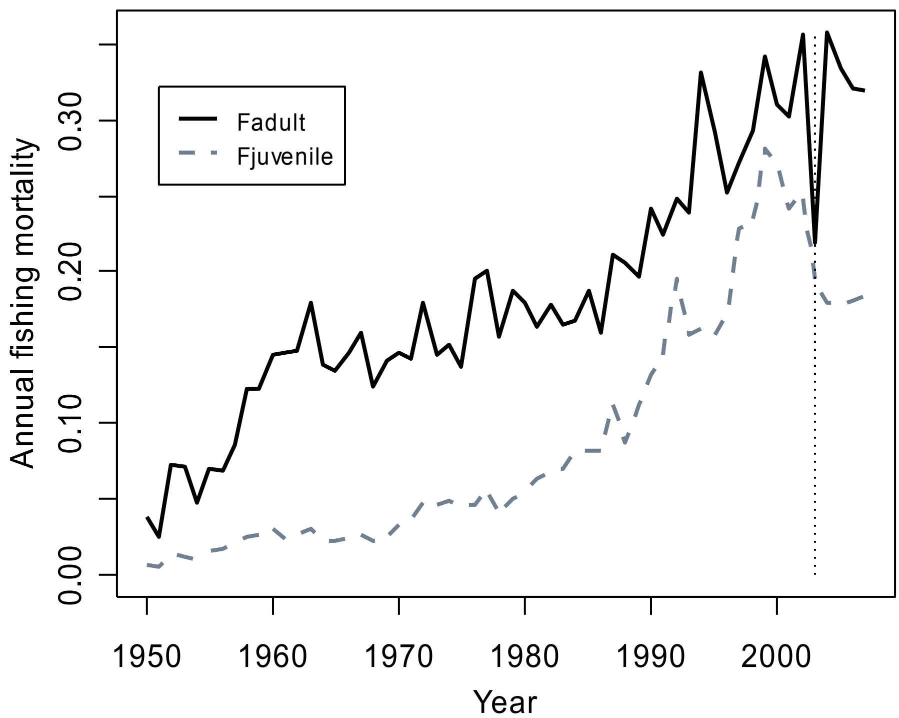


Figure 41. Estimated average annual fishing mortality rates for juvenile (less than 100 cm) and adult bigeye tuna. The dotted vertical line indicates the beginning of population projections based on the most recent year's fishing effort.

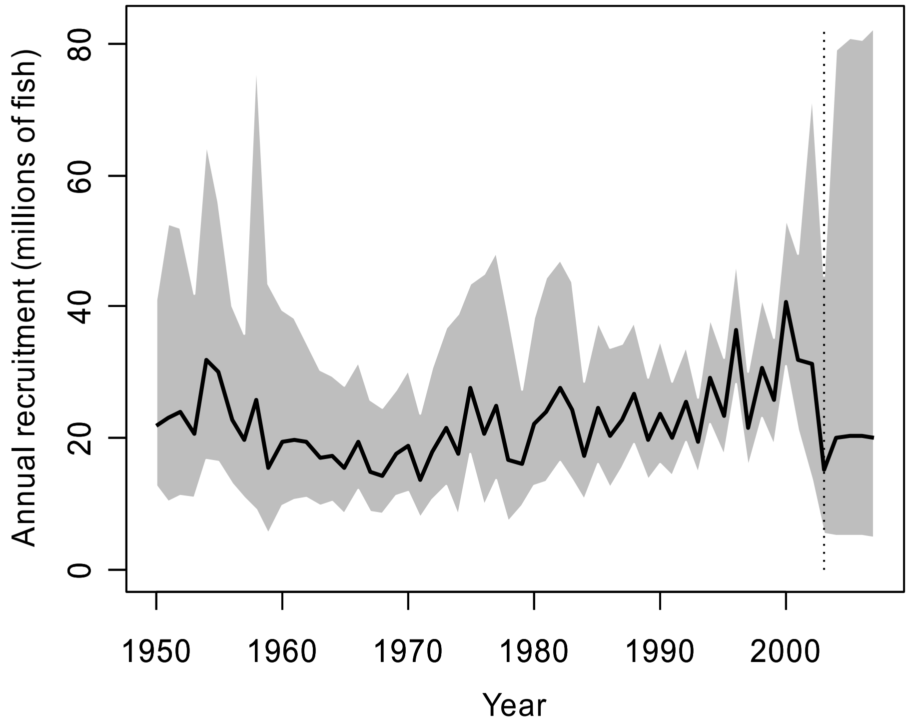


Figure 42. Estimated annual bigeye tuna recruitment (millions) for the WCPO. **The shaded area indicates the approximate 95% confidence intervals. The dotted vertical line indicates the beginning of population projections based on the most recent year's fishing effort.**

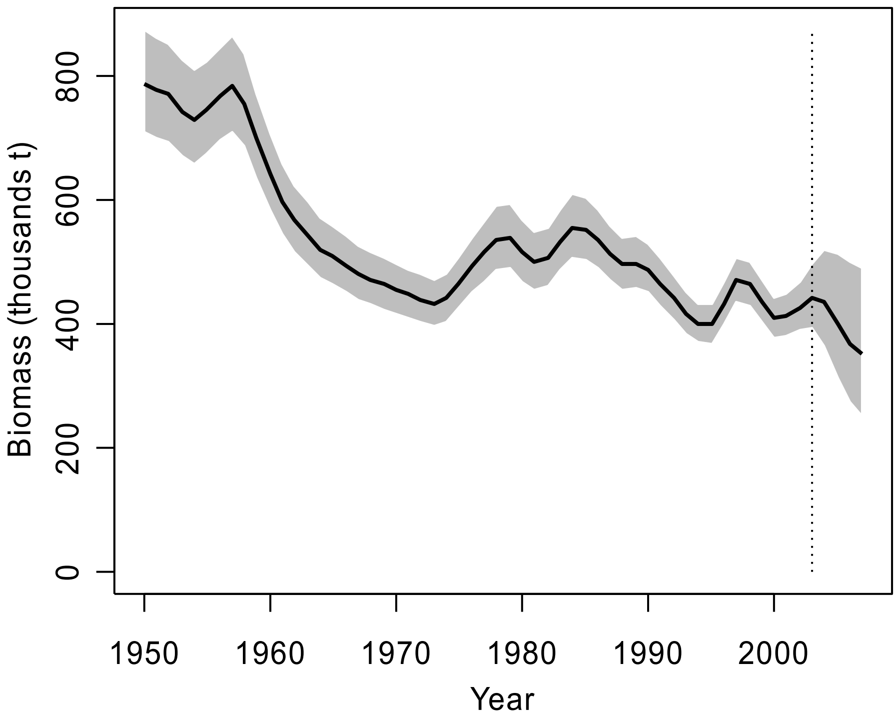


Figure 43. Estimated annual average total bigeye tuna biomass (thousand t) for the WCPO for the base-case analysis (SHBS longline effort). **The shaded areas indicate the approximate 95% confidence intervals. The dotted vertical line indicates the beginning of population projections based on the most recent year's fishing effort.**

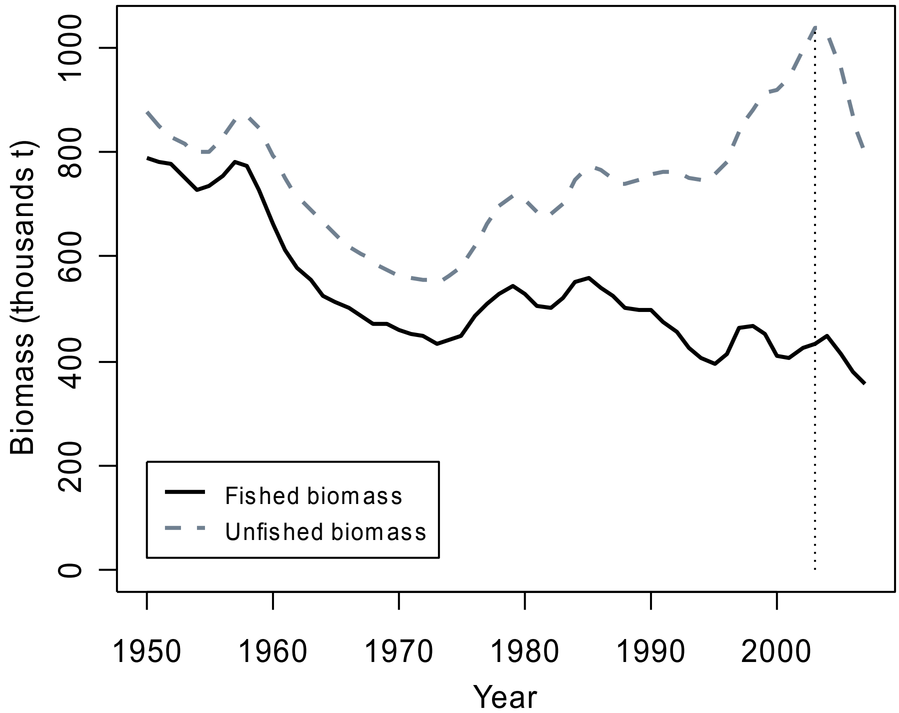


Figure 44. The estimated impact of fishing on bigeye tuna biomass in the WCPO. **The lower biomass trajectory (darkest line) represents the model estimates of total biomass in each area. The upper trajectory is the estimated biomass that would have occurred in the absence of fishing assuming that recruitment was unaffected by fishing. The dotted vertical line indicates the beginning of population projections based on the most recent year's fishing effort.**

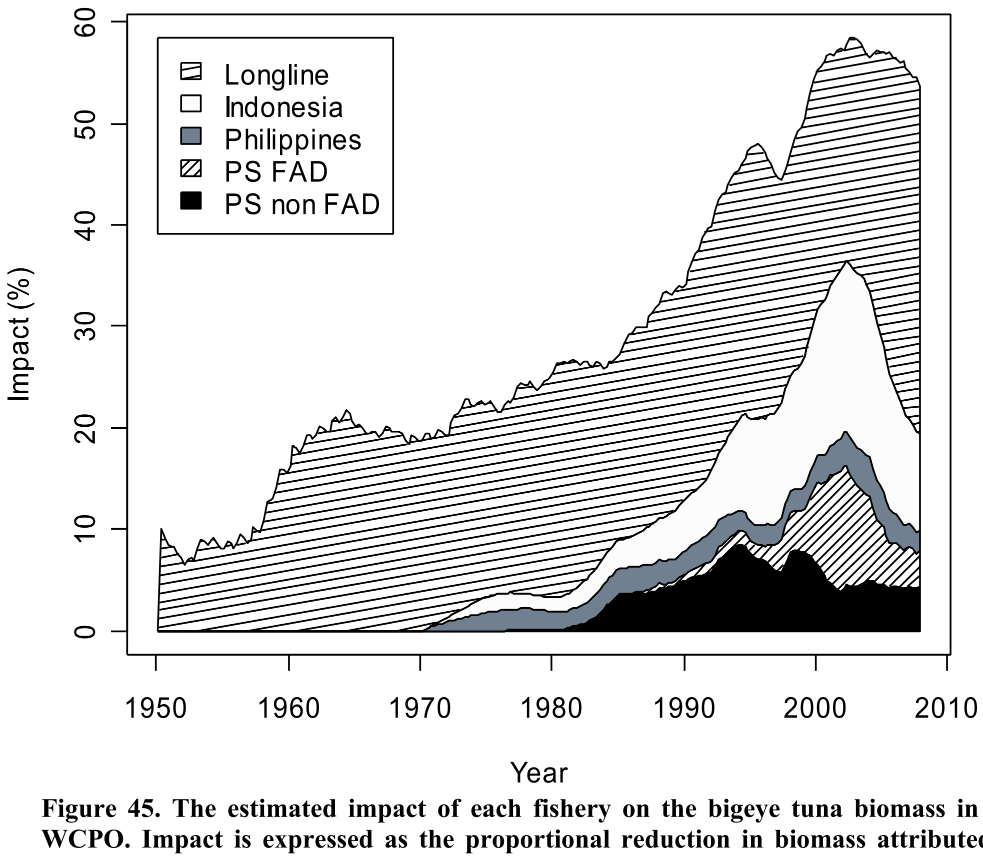


Figure 45. The estimated impact of each fishery on the bigeye tuna biomass in the WCPO. Impact is expressed as the proportional reduction in biomass attributed to fishing.

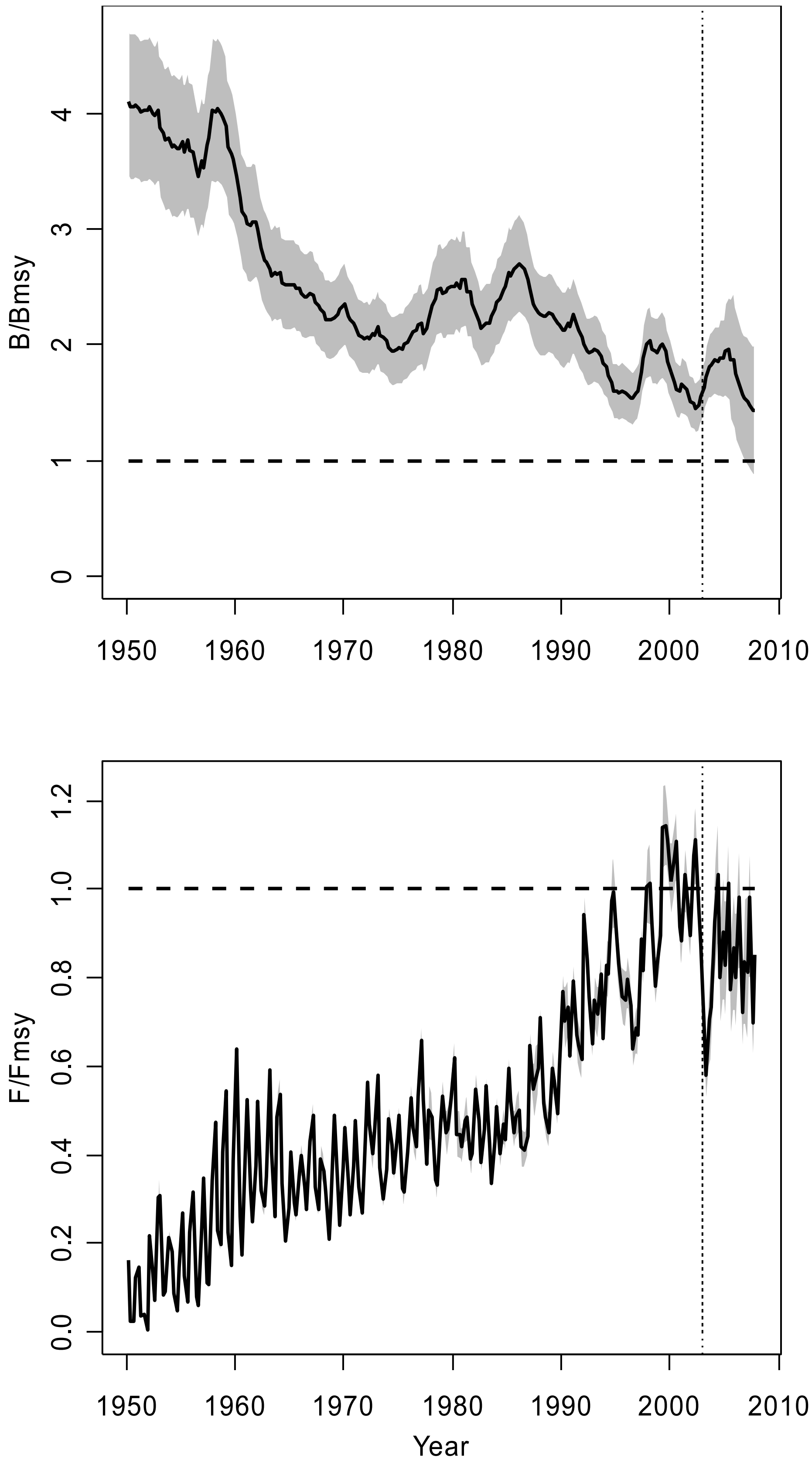


Figure 46. Trends in the biological reference points for the WCPO bigeye stock: spawning biomass relative to the spawning biomass at MSY (top) and fishing mortality relative to the fishing mortality at MSY (bottom). **The solid dashed line represents the reference level (MSY). The dotted vertical line indicates the beginning of population projections based on the most recent year's fishing effort.**

3.4 South Pacific Albacore Tuna

3.4.1 Catch

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

Historically, annual South Pacific albacore catches have generally been within 25,000–40,000 mt, although a peak was attained in 1989 (52,575 mt), when a significant driftnet fishing was operating (Figure 47; "Other" is essentially the driftnet catch). The highest catch on record (55,709 mt) was attained during 2002, while the total catch in 2003 was at a comparable level (54,531 mt).

Since the mid-1990s, the longline catch has steadily increased and has been the main contributor of the fisheries exploiting South Pacific albacore. During this period, the longline catch has been in the range of 24,000–50,000 mt, while the troll catch, for a season spanning November–April, has been within the 3,000–8,000 mt range (Figure 47). The Taiwanese distant-water longline fleet has been the dominant fleet in this fishery for more than two decades, but there have been recent changes in the species and areas targeted by this fleet (more vessels are now targeting bigeye in the eastern equatorial waters of the WCPO), which has resulted in a reduced contribution to the overall albacore catch in recent years (Figure 48). In contrast, annual longline albacore catches by Pacific Island countries increased significantly in the past 4–5 years (Figure 48) with increased fleet sizes in all countries participating in the fishery. The catch by Pacific-island countries in the last three years represented around 50% of the total south Pacific albacore longline catch. Poor catch rates experienced by the Pacific Islands fleets in 2003 resulted in a reduced catch level compared to 2002 (Figure 47; Langley 2004b).

The distant-water longline catch is widely distributed in the South Pacific (Figure 49), but with catches concentrated in the western part of the region. Troll catches are distributed in New Zealand's coastal waters, mainly off the South Island, and along the SCTZ**.** Less than 15% of the overall South Pacific albacore catch is usually taken east of 150°W.

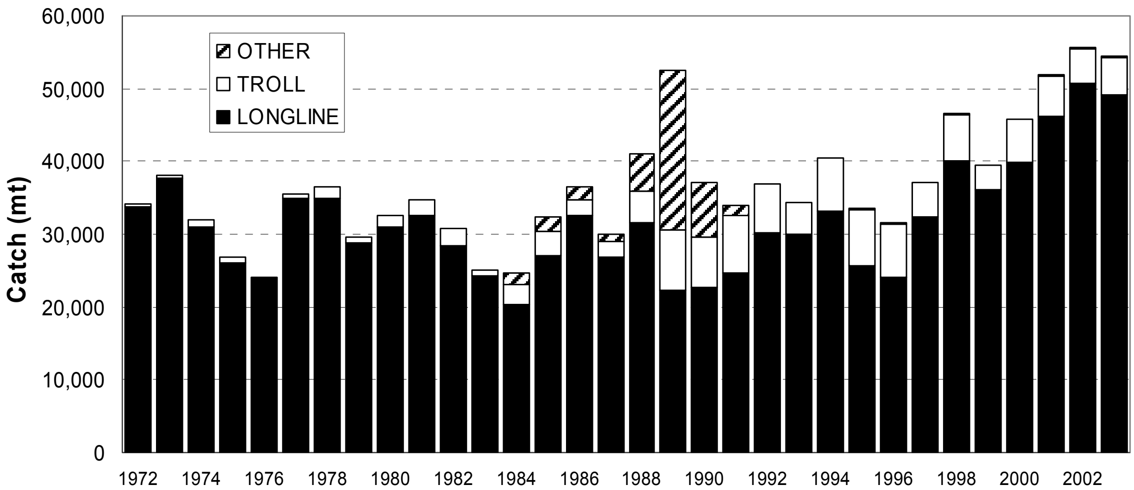


Figure 47. South Pacific albacore tuna catch, by gear **('Other' is primarily catch by the driftnet fishery).**

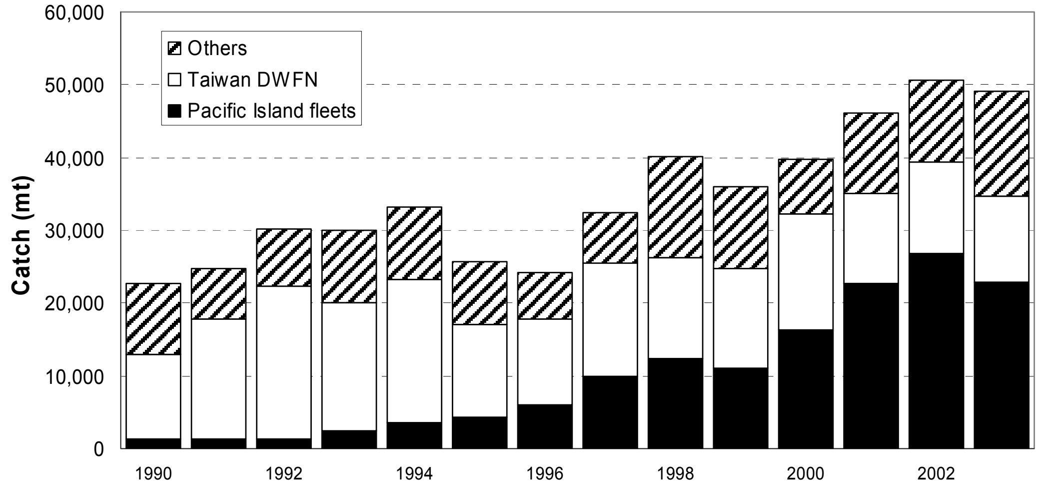


Figure 48. South Pacific albacore longline catch (mt) by fleet category.

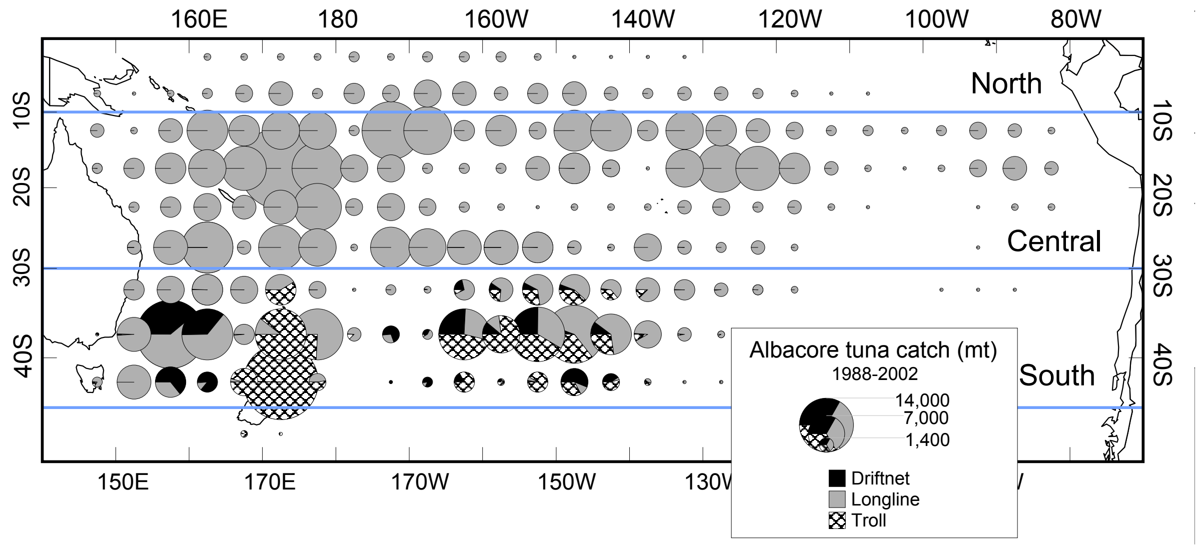


Figure 49. Distribution of South Pacific albacore tuna catch, 1988–2002. **The three-region spatial stratification used in the analysis of CPUE data is also presented.**

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 Taiwanese distant-water fleet are generally used as this fleet has consistently targeted albacore tuna over a long period of time. Longline CPUE (numbers of fish per hundred hooks) is typically highest in the higher latitudes (STCZ and 30–50°S), moderate in the tropics and subtropics (10–30°S) and low near the equator (0–10°S). Time series of CPUE for these latitudinal bands are plotted in Figure 50. Taiwanese longline CPUE declined from the late 1960s to the late 1980s in all areas then steadily increased in the early-mid 1990s after a low point in 1990. Since 1999, nominal CPUE has been relatively stable in the central and southern areas. The drop in CPUE in the northern area during recent years is probably related 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 Taiwanese longline fleet (Langley 2003a). For each of the main fishery areas, the standardised indices were very similar to the nominal CPUE.

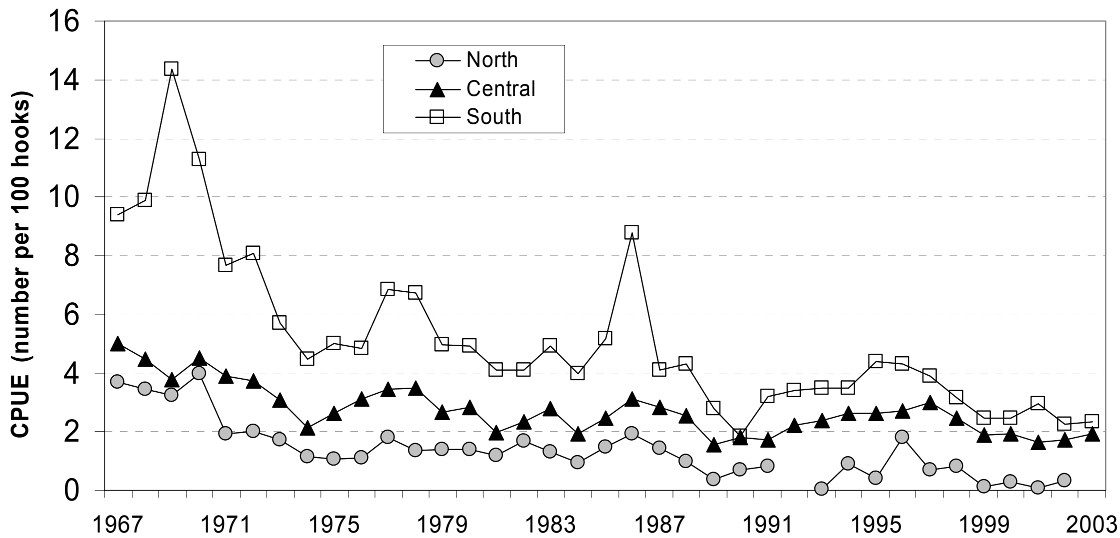


Figure 50. Nominal South Pacific albacore tuna CPUE for Taiwanese longliners (2003 data are provisional). South = 30–50°S, central = 10–30°S, north = 0–10°S.

Recent trends in the catch rate of albacore from the Pacific Islands domestic longline fisheries were summarised in Langley (2004b). The analysis noted recent declines in the catch rate of albacore in a number of fisheries, in particular Vanuatu, Fiji, Tonga, Samoa, the Cook Islands and French Polynesia, although the extent of the decline varied (Figure 51).

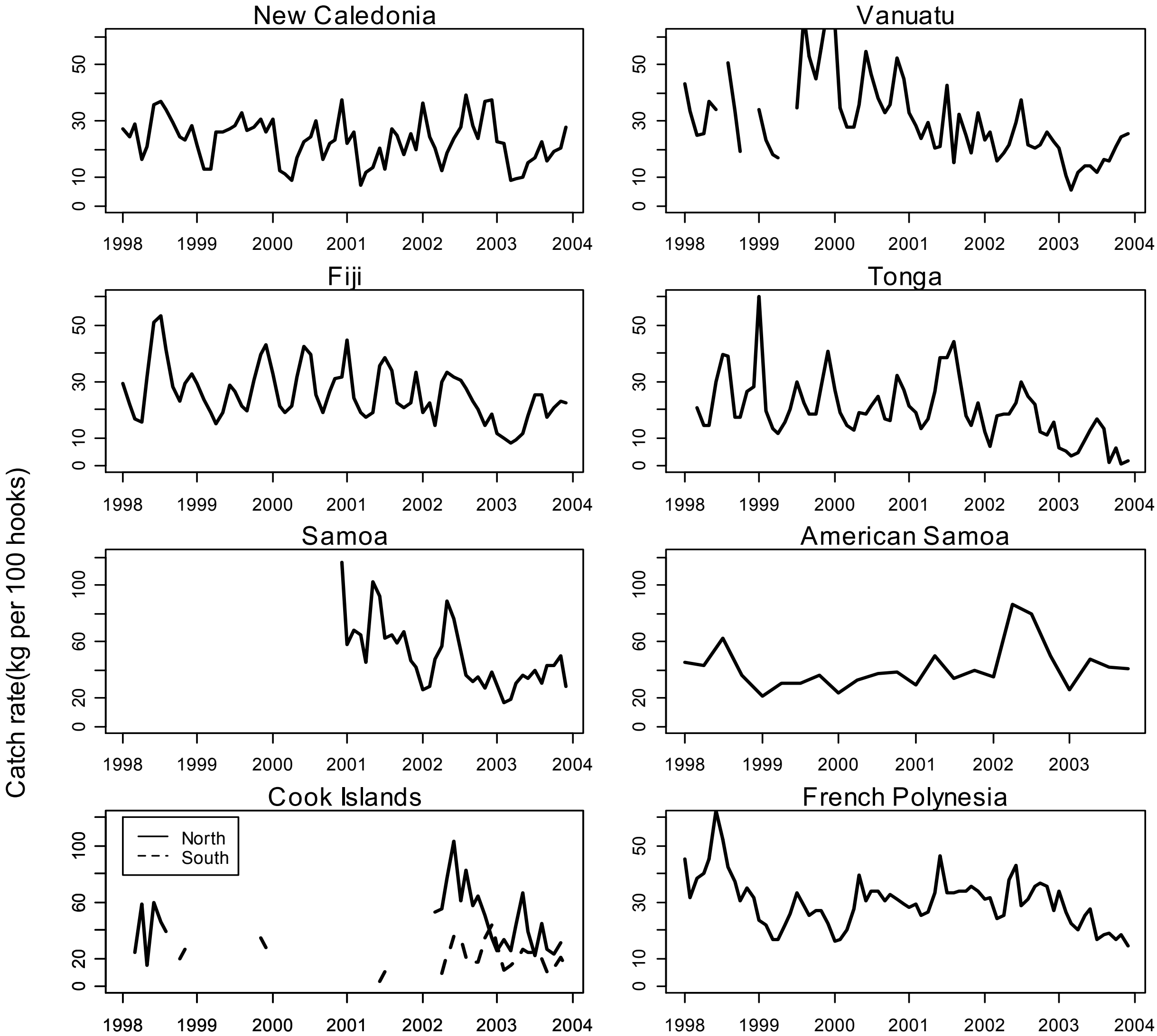


Figure 51. Albacore catch rates (kg per 100 hooks) of the Pacific Island domestic longline fleets by EEZ from 1998 to 2003.

The troll fishery CPUE for the New Zealand domestic fleet tended to increase during the 1980s, but has been relatively stable during the 1990s (Figure 52). 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. There has been some convergence in the CPUE of these fleets in recent years, regardless of the areas fished. Catch rates of juvenile albacore in the troll fishery during 2003 were the highest for a number of years.

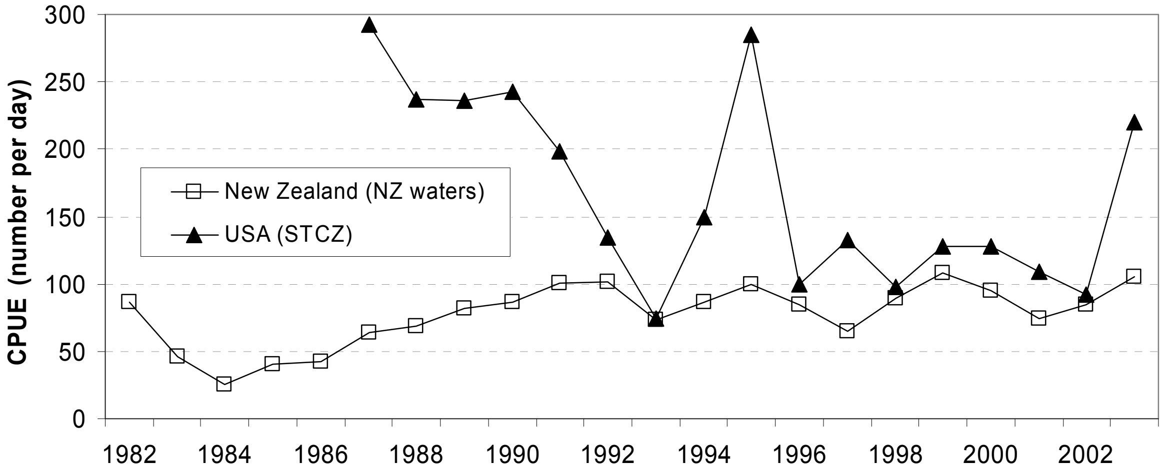


Figure 52. South Pacific albacore tuna CPUE for the New Zealand domestic troll fleet and the USA troll fleet operating east of 180° along the STCZ.

3.4.3 Size of Fish Caught

Average annual catch-at-size of albacore tuna is shown in Figure 53. There are no noteworthy changes in the size distributions for the longline fishery over time; this fishery tends to catch adult fish with a distinct mode around 95cm fork length. The troll fishery and the surface driftnet fishery (when it was operating) account for 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 49).

3.4.4 Stock Assessment

The last formal stock assessment of South Pacific albacore was presented to the SCTB in 2003 (Labelle & Hampton 2003). Based on the results of this assessment, the 17^{th} meeting of the SCTB concluded that is was unlikely that the stock is being overfished or is in an overfished state. However, the assessment is considered highly uncertain due to the lack of informative data concerning stock size.

Since 2003, the assessment has been updated and many of the underlying structural assumptions of the previous model have been investigated. The results of the new assessment differ from the previous analysis in terms of the magnitude of the total stock biomass and current exploitation rates, although the overall conclusion of the assessment remains unchanged, i.e., that current levels of catch are sustainable and current stock biomass is substantially higher than all accepted biological reference points. However, the results of the new assessment have yet to be formally reviewed and, consequently, are not documented in this report. The new assessment will be presented to the Scientific Committee of the WCPFC in August 2005.

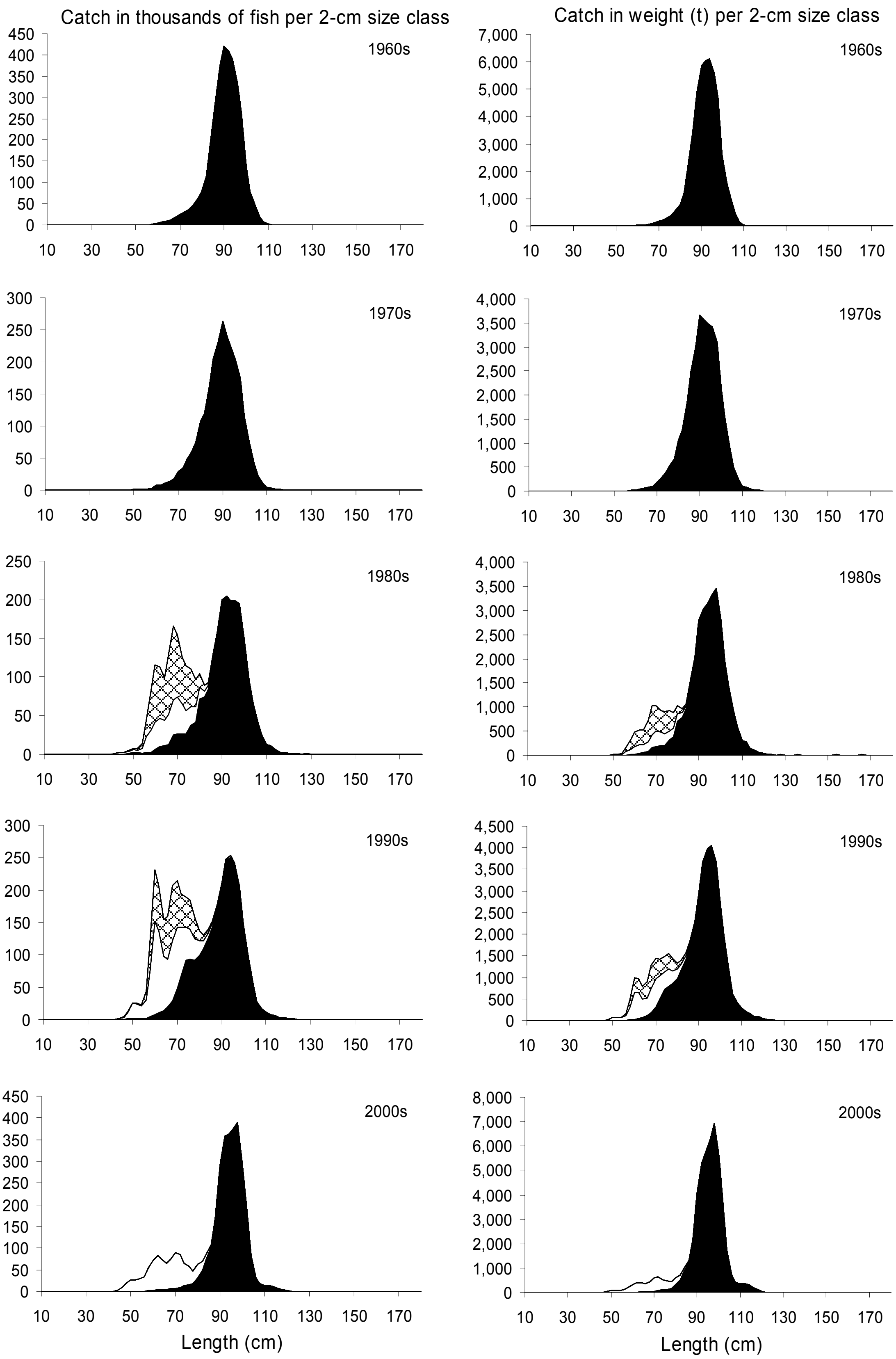


Figure 53. Average annual catches of albacore in the south Pacific by size and gear type during decadal periods **(black–Longline; white–Troll; hatching–surface driftnet).**

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 conservsation and management of the tuna resource in the WCPO. 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 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. However, 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 WCPO 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 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 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 sharks (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 WCPO, with the probable exception of the Indonesian and Philippines fisheries. Annual catch estimates have also been derived for the four main billfish species caught (blue marlin, black marlin, striped marlin, and swordfish) (Williams 2004). However, limited data exist regarding the magnitude of the catch of the many other associated species caught in the WCPO 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 WCPO 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 WCPO: the western tropical Pacific (WTP) shallow-setting longline fishery, the WTP deep-setting longline fishery, and the western south Pacific (WSP) albacore fishery (Figure 54). 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%, 74%, and 62% of the catch from the WTP shallow, WTP deep, and WSP albacore fisheries, respectively (Figure 54). The relative proportion of the main tuna species varied in accordance with the targeting practices.
- Blue shark (*Prionace glauca*) was the third ranked species in the catch composition of all three fisheries.
- The WTP shallow fishery has the highest proportion of associated species in the catch, principally shark and billfish species (Figure 54).
- Opah (moonfish, *Lampris guttatus*) represents a significant component of the WSP albacore longline catch.
- 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 54).

4.2.2 Purse-seine

Fishery observer data from the equatorial purse-seine fishery for 1999–2003 represent an overall coverage rate of about 6%[2] (of sets) and were analysed to determine the species composition of catches (by weight) from unassociated (free-school) and associated (log and FAD) sets. Both set types were dominated by catches of skipjack and yellowfin, with the two species accounting for 99% and 90% of the catch from unassociated and associated sets, respectively (Figure 55). Bigeye tuna represented 1% of the catch from unassociated sets and 8–10% of the catch from associated sets, principally comprised of juvenile fish (see Figure 40). 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 29).

Other species represent a trivial component of the catch from unassociated sets and only 1% and 2% of the catch of drifting FAD and log sets, of which rainbow runner (*Elagatis bipinnulata*) is the most significant component (Figure 55). 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 trigger fish (Balistidae), silky shark, and oceanic whitetip shark) (Figure 55).

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[2] 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 (>20%). The coverage rates of the other main fleets (Taiwan, Korea and Japan) is currently <5%.

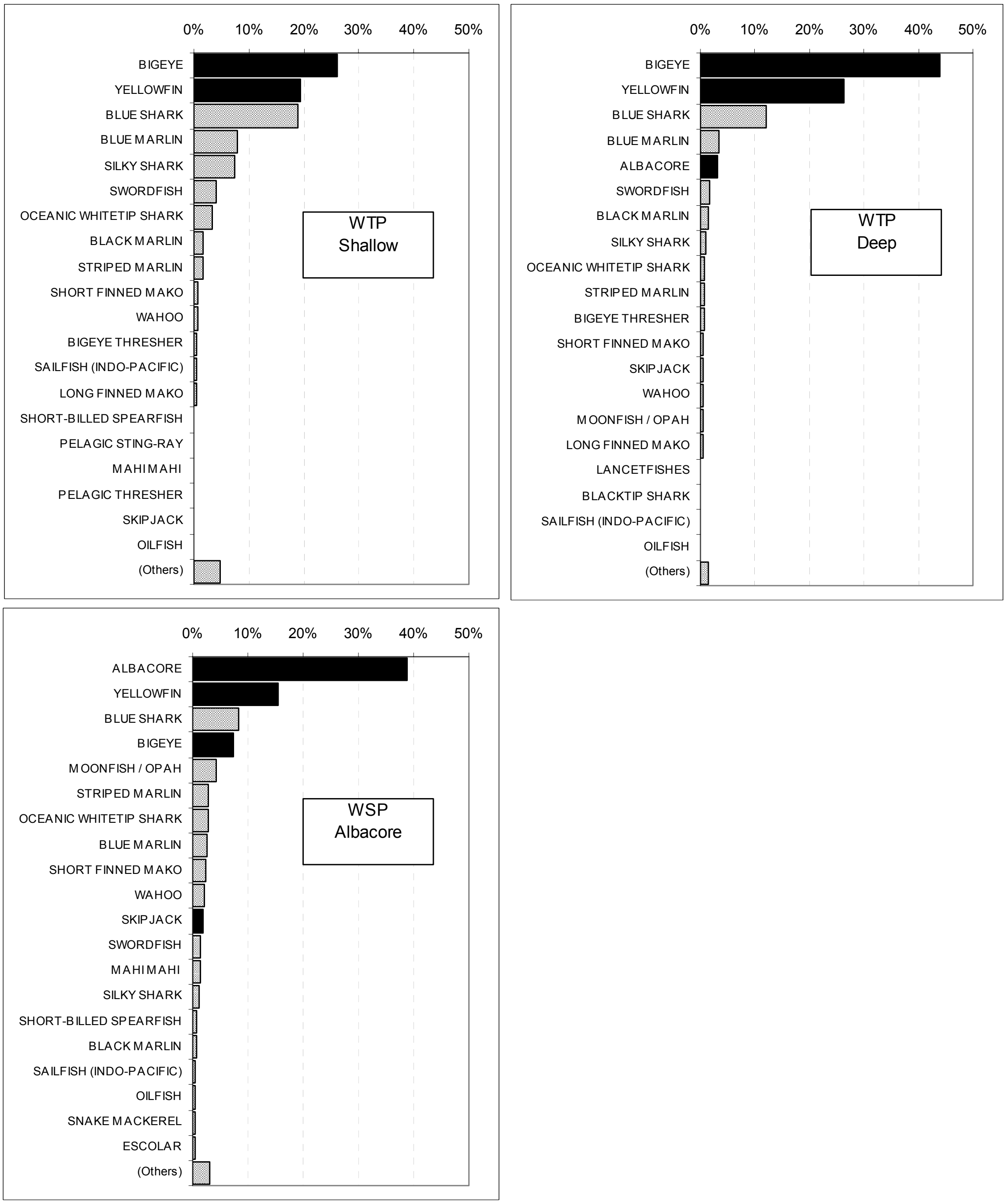

Figure 54. Percentage composition of the 20 main species caught by longline (by weight) for the three main fisheries in the WCPO determined from recent observer data (1999–2003). **Fishery codes: WTP shallow/deep, western tropical Pacific shallow/deep longline sets; WSP Albacore, western south Pacific albacore target fishery. Number of sets sampled is 797, 760, and 1,202, respectively.**

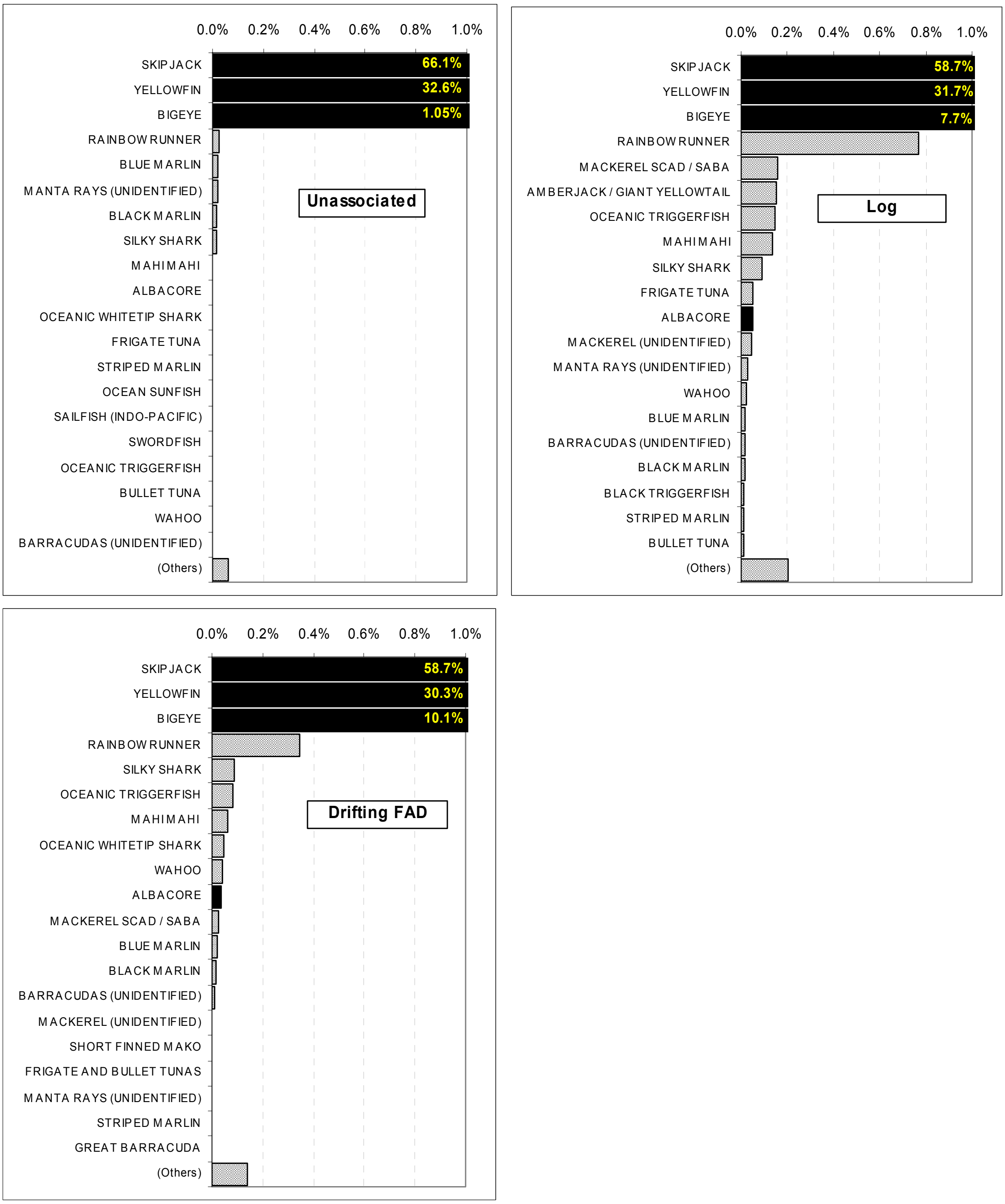

Figure 55. Percentage composition of the 20 main species caught by unassociated, log and drifting FAD purse-seine sets (by weight) in the WCPO determined from recent observer data (1999–2003). Number of sets sampled is 3,676, 785, and 2,469, respectively.

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 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 limitations of available resources and, more critically, insufficient data to undertake such an assessment. 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.

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 WCPO varies considerably over 3–5 year periods, fluctuating around the overall average level of stock biomass during the last three decades. The percentage reduction in stock biomass attributable to the fishery has been 20% in recent years, although there has been greater impact (30–35%) in the main area of operation of the purse-seine fishery. Recent catch levels are easily sustainable under current stock productivity conditions.

4.3.2 Yellowfin

The assessment reaffirms the result of the previous assessment that the yellowfin stock in the WCPO is presently not being overfished (i.e. $F_{CURRENT} < F_{MSY}$) and that it is not in an overfished state ($B_{CURRENT} > B_{MSY}$). The assessment indicates that the equatorial regions are likely to be fully exploited, with the greatest fishery impacts attributable to the Indonesian fishery and the equatorial purse-seine fishery.

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 approaching or exceeding the level of F_{MSY} ($F_{CURRENT} \approx F_{MSY}$) and over-fishing may be occurring. The current level of exploitation appears not to be sustainable in the long term, unless the high recent recruitment is maintained in the future.

4.3.4 Albacore

The assessment of the South Pacific albacore tuna stock is highly uncertain due to a lack of informative data concerning stock size. Nevertheless, it is concluded that that current levels of catch are sustainable and current stock biomass is substantially higher than all accepted biological reference points.

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 WCPO. Annual estimated catches from the WCPO have steadily increased from the mid 1970s and have approached 15,000 mt in recent years (Williams 2004) (Figure 56).

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. Since the 1960s, annual catches of black marlin from the WCPO have remained relatively stable at about 1,000–2,000 mt (Figure 56). 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 south-western 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 WCPO declined sharply in the 1960s and early 1970s and remained at less than 5,000 mt per annum over the subsequent years (Figure 56). 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.

There has been no stock assessment of the striped marlin resource in the WCPO, although an assessment of the south-western Pacific stock is proposed for 2005.

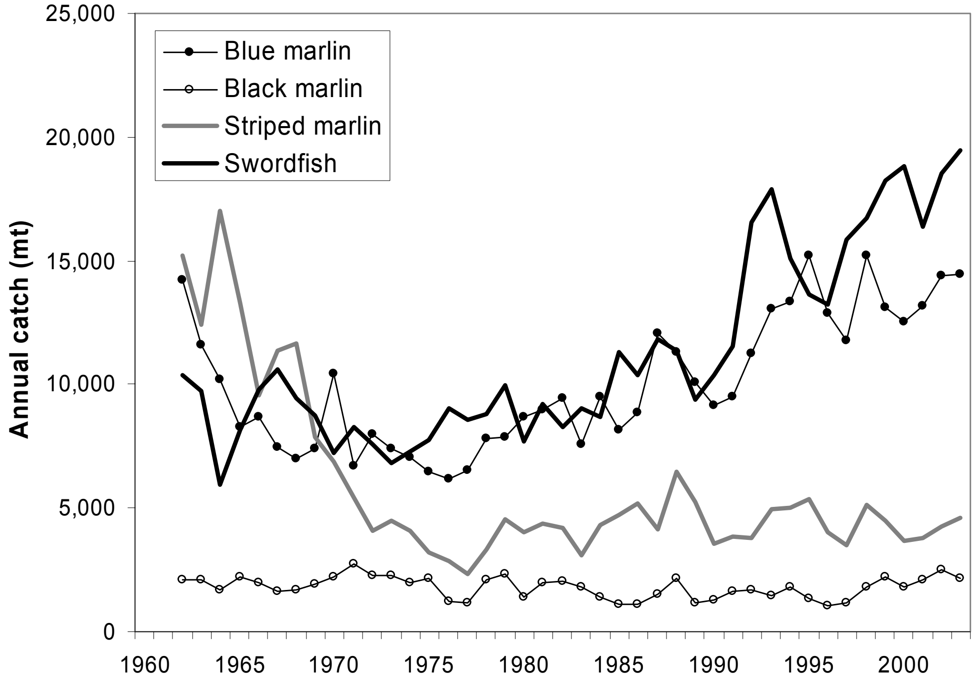

Figure 56. Total annual catches of the four main billfish species from the WCPO (see Williams 2004 for details).

4.3.8 Swordfish

Swordfish are distributed throughout the Pacific Ocean. It has been generally concluded that swordfish is comprised of four semi-independent stock of swordfish within the Pacific; a northern stock, a southwestern stock, and two eastern Pacific stocks. Catches of swordfish from the WCPO, principally encompassing the two former stock units, steadily increased from the early 1970s and have approached 20,000 mt in recent years (Figure 56).

The results of preliminary modeling (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).

There has been no assessment of the swordfish resource in the southwestern Pacific, although a preliminary assessment is likely to be available in 2005/06. A recent analysis of swordfish catch rates from the longline fishery operating off the east coast of Australia has revealed a sequential spatial depletion of swordfish in the area (Campbell & Hobday 2003). However, this phenomenon has occurred in a small area relative to the spatial extent of the distribution of the southwestern stock.

4.3.9 Marine Mammals

For the WCPO, 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 23,593 sets observed in the last 10 years. 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). It may be presumed that a large proportion of these individuals escaped from the purse-seine net and were alive on release. 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.

4.3.10 Marine Turtles

The WCPO is home to five species of widely distributed sea turtles. All species are long-lived and slow growing and therefore vulnerable to over-exploitation. 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.

A small number of marine turtles were observed captured by purse-seine (Table 1). Many of the turtles were not identified by species. Of the five species recorded, loggerhead turtles (*Caretta caretta*) were the most numerous and all individuals were dead. The fate of a significant proportion of the turtles released from purse-seine sets was unknown.

Olive Ridley turtle (*Lepidochelys olivacea*), green turtle (*Chelonia mydas*), and hawkesbill turtle (*Eretmochelys imbricata*) 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 turtles, principally leatherback turtles (*Dermochelys coriacea*), 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.

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 WCPO for 1995 to 2004 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 = 23,593	Marine mammals	Bottlenose dolphin	0	0	4	4
		Dolphin (unidentified)	3	4	51	58
		Marine mammal (unidentified)	33	43	575	651
		Total	36	47	630	713
	Marine turtles	Green turtle	1	0	4	5
		Hawkesbill turtle	6	0	2	8
		Leatherback turtle	0	0	1	1
		Loggerhead turtle	0	50	0	50
		Olive ridley turtle	3	4	3	10
		Marine turtle (unidentified)	15	0	62	77
		Total	25	54	72	151
Longline, WTP N = 3,674	Marine mammals	Dolphin (unidentified)	1	1	0	2
		Whale (unidentified)	1	1	0	2
		Marine mammal (unidentified)	4	1	0	5
		Total	6	3	0	9
	Marine turtles	Green turtle	18	3	0	21
		Hawkesbill turtle	10	1	0	11
		Leatherback turtle	4	0	0	4
		Loggerhead turtle	3	1	0	4
		Olive ridley turtle	22	8	0	30
		Marine turtle (unidentified)	27	18	2	47
		Total	84	31	2	117
	Seabirds	Bird (unidentified)	1	7	0	8
Longline, WSP N = 1,496	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	0	0	1
		Leatherback turtle	1	1	1	3
		Marine turtle (unidentified)	0	1	0	1
		Total	2	2	1	5
	Seabirds	Total	0	0	0	0

Research into modified fishing methods, specifically the use of deep-setting gear and "circle" rather than "J"-hooks, show 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 WCPO 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 WCPO. Data from observer programmes operating in the Australia, 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 the scope of this report.

4.3.12 Other Protected Species

Within the WCPO, 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 WCPO 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 57). 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 the 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 lower productivity of the north and south subtropical gyres and the western equatorial warm pool.

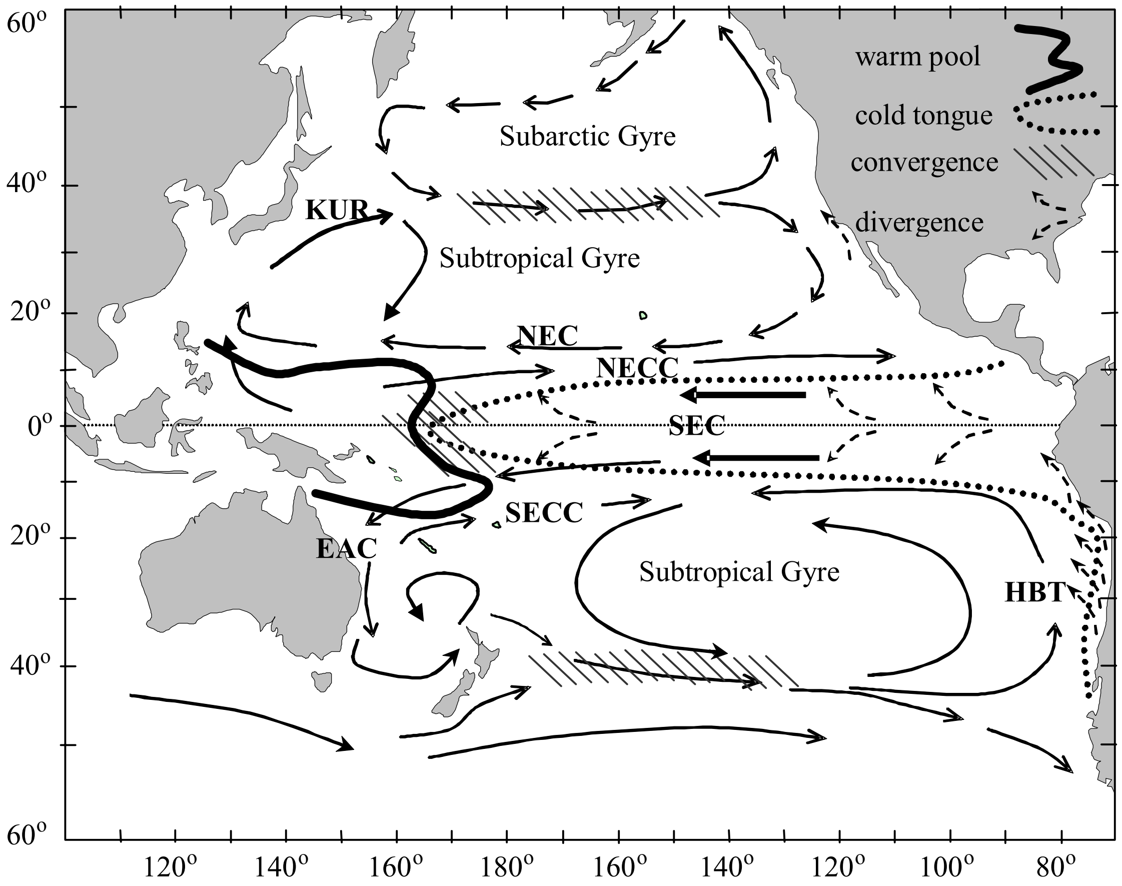

Figure 57. The main oceanographic features of the Pacific Ocean. **SEC, South Equatorial Current; NEC: North Equatorial Current; SECC, South Equatorial Counter-Current; NECC, North Equatorial Counter-Current; KUR, Kuroshio Current; EAC, East-Australian Current; HBT, Humboldt Current.**

The general east-west water transport is counter-balanced 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 twenty years, powerful El Niño events 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 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 58). Positive PDO indices (warm phases) correspond to warm SST anomalies along the northeastern Pacific Coast, cool sea surface 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 to 30 years have been identified. The cool phase prevailed 1890–1924 and 1947–1976, and 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.

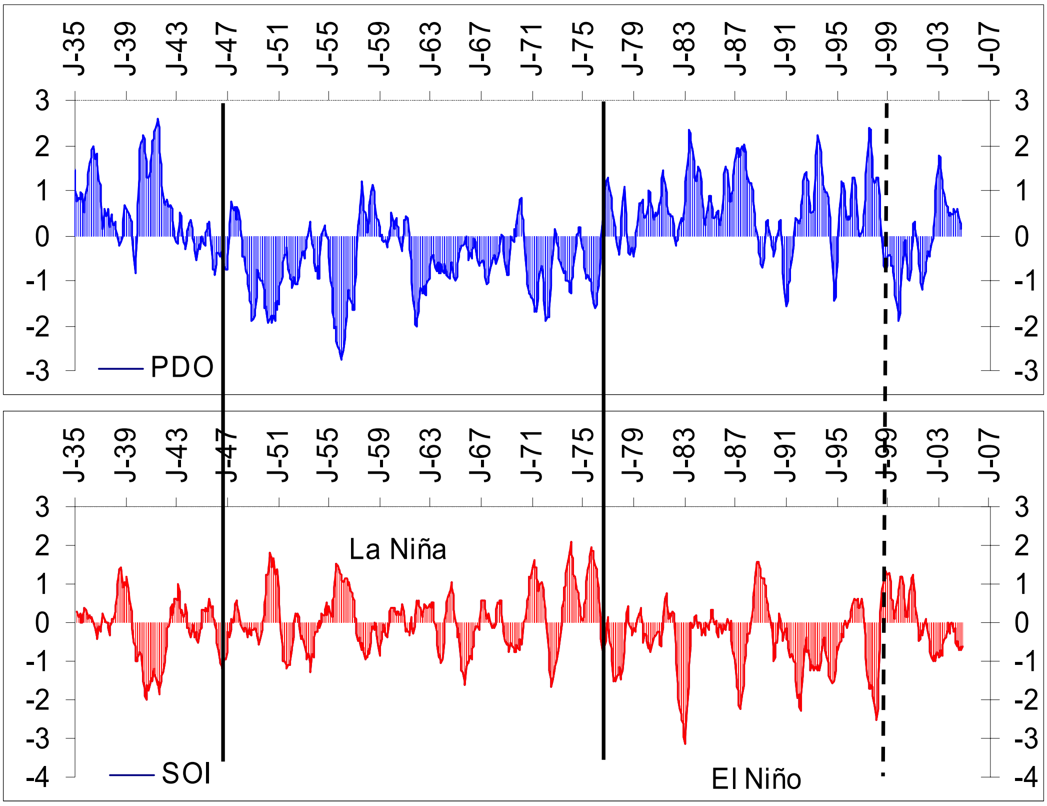

Figure 58. Monthly trends in the Southern Oscillation Index (SOI) and Pacific Decadal Oscillation (PDO).

A correlation between both ENSO and PDO signals is evident for the last fifty years (Figure 58). 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 warm phase of PDO, or conversely La Niña events during 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.

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 on 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 gears (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 are 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 (Figures 31 and 42) and the PDO (Figure 58).

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 that is characterised by slower growth and long life spans (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 to 12 months) experienced by the purse-seine fisheries, while for albacore the impact will occur after 5–6 years, on 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. As the main interactive processes existing between the species groups are the trophic relationships, it is crucial to understand the trophic structure of the pelagic ecosystem.

A collaborative study on the trophic structure and tuna movement in the cold tongue – warm pool pelagic ecosystem of the equatorial Pacific, funded by the Pelagic Fisheries Research Program of the University of Hawaii, was initiated in 2003. Scientists from SPC, IATTC, CICIMAR and the University of Hawaii are conducting similar studies in the western, central and eastern Pacific to compare the pelagic food webs of the different areas. The main objectives of the study are: (1) to define the trophic structure of the pelagic ecosystems in the western, central and eastern parts of the tropical Pacific Ocean, (2) to establish an isotope-derived biogeography of the pelagic tropical Pacific ecosystems, and (3) to characterise large-scale tuna movements related to upwelling regions along the equator. Results of this study should help define ecosystem linkages leading to tuna production and the effect of climate variability on the systems, information important for both fisheries production and ecosystem modelling.

The programme includes a large sampling programme in the WCPO, augmenting sampling conducted in previous years. Stomach, liver and muscle samples of tuna, billfish, shark and other fish are collected onboard fishing vessels (longline, purse-seine, pole-and-line) throughout the region. The fish stomachs are examined to determine the diet of the main predator species. Stable isotope analysis of muscle and liver samples is conducted (by the University of Hawaii) to determine the trophic level (TL) (phytoplankton has a TL = 1, top predators such as sharks have a TL around 5).

A preliminary analysis has been conducted on the diet of four species. The diet 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; lancetfish feeds at the surface and in deeper waters on fish and molluscs but also on small quantities of crustacea 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.

The isotope data have yielded two types of information. It appears that for the same species isotope values of nitrogen and carbon can be very different between areas, suggesting regional differences in the isotope values of the base of the food chain. This observation may allow isotope values to be used as internal markers to determine the origin of the fish and to infer information regarding direction and rates of migration. The other information provided by isotope analysis is that the fish examined probably eat some species of prey that are not observed in the stomachs. Indeed, by applying a simple model, the isotope value of a predator can be predicted from the calculated value of its diet. A mismatch between the predicted and observed values may indicate the rapid digestion of certain prey items that are not observed in the stomach, but are still important for the diet and need to be taken into account.

Diet data from stomach examination will be analysed for all the species and summarised into a diet matrix that is the basis of the ecosystem model Ecopath with Ecosim, a mass-balanced model that allows testing of different scenarios of environmental forcing and the impacts of fishing (http://www.ecopath.org/). A preliminary Ecopath/Ecosim model has been developed for the WCPO (Godinot & Allain 2003). The three species of tropical tuna (skipjack, yellowfin, and bigeye) were considered as different groups and 17 other functional groups were included in the model: detritus, phytoplankton, zooplankton, crustacea, cephalopods, epipelagic and mesopelagic fish, small top predators and adult top predators.

Data inputs for each group were biomass, production, consumption, ecotrophic efficiency, catch and diet matrices. By modifying some of the parameters, the model was balanced and was used to simulate increasing catch using Ecosim. The major weakness of the Ecopath model was the large uncertainty regarding most model parameters, including diets. Most of the input parameters were derived from studies outside of the WCPO. This leads to large uncertainty in the estimation of the data input values, as biological factors and abundance can vary strongly with area. Moreover, many of the functional groups were either not included in the model or overaggregated due to a lack of available data. It is planned to update the model with the inclusion of the more recent information available concerning the diet of some key species.

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, 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 are provided by a coupled 3D physical-NPZD (nutrients-phyto-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 59). 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^{o}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/).

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 59). 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.

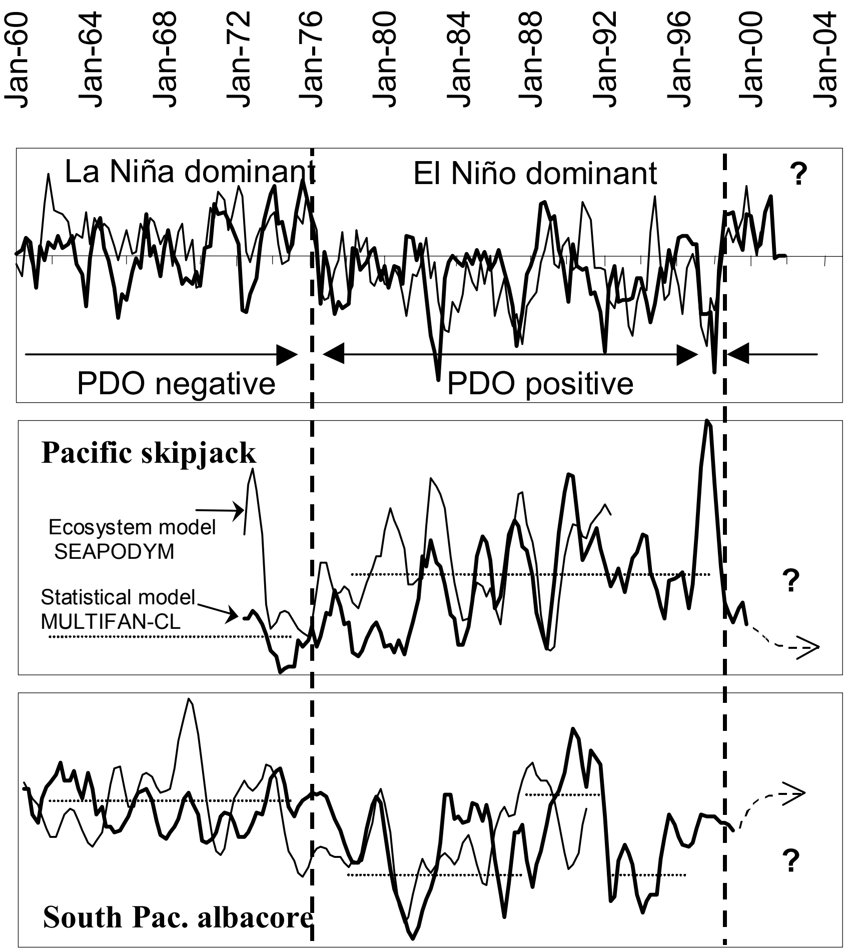

Figure 59. **Climate oscillations and tuna recruitment in the Pacific. Fluctuation of the Southern Oscillation Index (thick curve) and Pacific Decadal Oscillation (thin curve) (top). Recruitment series of skipjack from the statistical model MULTIFAN-CL and the spatial ecosystem model SEAPODYM for skipjack (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.**

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