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RECOMMENDED OVERFISHING DEFINITIONS AND CONTROL RULES FOR THE WESTERN PACIFIC REGIONAL FISHERY MANAGEMENT COUNCIL'S PELAGIC FISHERY MANAGEMENT PLAN

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SUMMARY

Control rules and status determination reference points are recommended for management unit species in the Western Pacific Regional Fishery Management Council's Pelagic Fishery Management Plan. The fisheries and stocks for western Pacific skipjack and yellowfin tuna, North and South Pacific albacore, swordfish, and blue marlin are in good condition. For stocks of bigeye tuna and eastern Pacific yellowfin tuna, fishing mortality appears to be marginally above the levels that would support maximum sustainable yield (MSY) on a continuing basis. Overfishing must be reported for these stocks, and international management arrangements are needed to reduce fishing mortality. The biomass of these stocks is nearly at the level which supports MSY, and well above the level at which the stocks would be defined as overfished.

OVERFISHING DEFINITIONS AND CONTROL RULES

The goal of the Magnuson-Stevens Fisheries Conservation and Management Act (MSFCMA) is to ensure the long-term sustainability of fish catches by halting or preventing overfishing and by rebuilding any overfished stocks. Overfishing is defined to occur when fishing mortality (F) is higher than the level at which fishing produces the maximum sustainable yield (MSY). The MSY is the maximum long-term average yield that can be produced by a stock on a continuing basis. A stock is overfished when stock biomass (B) has fallen to a level below that which can produce MSY. So there are two aspects that managers must monitor to determine the status of a fishery: the level of F in relation to F at MSY (F_{MSY}) and the level of B in relation to B at MSY (B_{MSY}).

The Technical Guidance (Restrepo et al., 1998) for National Standard 1 requires the development of control rules identifying "good" versus "bad" conditions in the fishery and the stock and describing management action that will influence a control variable (e.g. F) as a function of some stock size variable (e.g. B) to achieve good conditions. Each control rule must define reference points called status determination criteria: one for F that defines when overfishing is occurring, and one for B that defines when the stock is overfished. The status determination criterion for F is the maximum fishing mortality threshold (MFMT) and the status determination criterion for B is the minimum stock size threshold (MSST). When F/F_{MSY} exceeds the MFMT overfishing is occurring. When B/B_{MSY} falls below MSST the stock is overfished. When either of these two conditions occurs, NMFS must notify Congress that the stock is overfished, and fishery managers must take action to halt overfishing, or rebuild the stock. A reasonable MSY control rule template for Western Pacific Region pelagics may be derived from the default MSY control rule suggested by Restrepo et al. (1998) and also adopted for the Atlantic tunas, billfishes and sharks (Fig. 1).

The y-axis labeled F/F_{MSY} (Fig. 1) indicates the variable over which managers must exert some control as a function of B/B_{MSY} on the x-axis. The default MFMT recommended by the Technical Guidelines (Restrepo et al., 1998) has an upper limit set at F_{MSY}, shown as a horizontal line at $1 = F/F_{MSY}$. In applying the MSY control rule, F (or rather the ratio F/F_{MSY}) must not be allowed to exceed the MFMT, although a stock with a B level well above B_{MSY} can support larger F values for a limited time while B declines towards B_{MSY}. Other types of control rules would allow higher F levels under specified conditions, but such rules would require reliable measures of B and a very good understanding of stock dynamics.

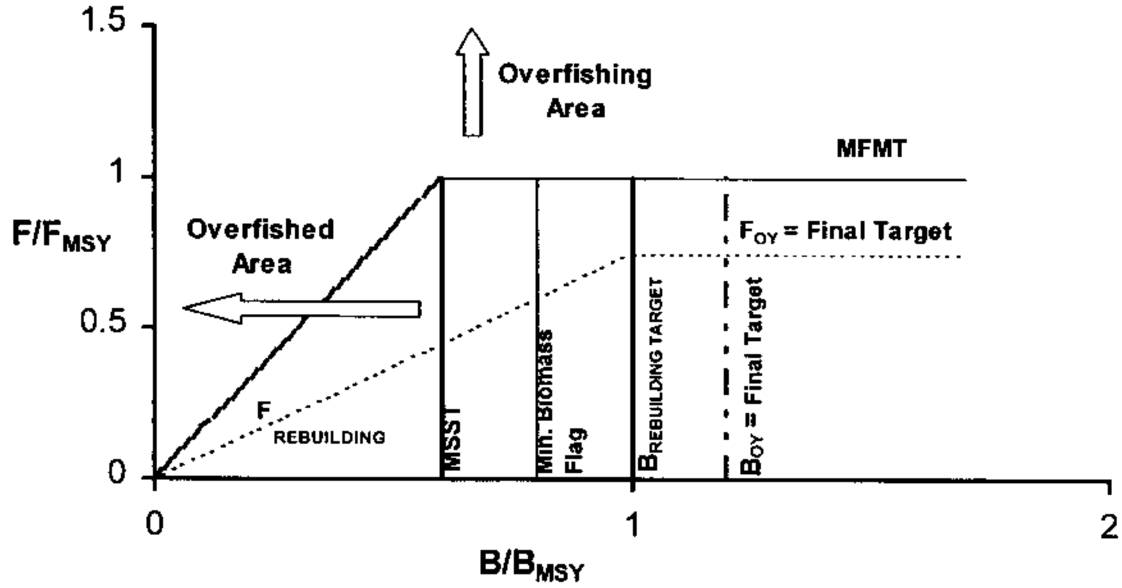

Figure 1. MSY control rule and reference points

The MSST is shown in Figure 1 as a vertical line at a B level below B_{MSY}. This allows for some degree of natural fluctuation of biomass around B_{MSY} under an MSY harvest policy. When B falls below MSST, however, the stock is considered to be overfished and F must be reduced below the MFMT by an amount that depends on the severity of the stock depletion, the stock's capacity to rebuild, and the desired recovery time for the stock. A minimum biomass flag (Fig.1) should also be defined so that if B drops below it managers are prompted to implement remedial action before biomass reaches the MSST.

Rebuilding plans are required when stock biomass falls below MSST. Different control rules may be used in rebuilding plans. For example, in a constant catch scenario, F would start out at a safe level not exceeding the MFMT and decline further to an optimum target level as the stock recovers. This type of control rule is used for some overfished pelagic species in the Atlantic. A more precautionary rebuilding strategy that may satisfy SFA requirements for many pelagic species is to follow the optimum yield (OY) control rule as illustrated by the dashed line labeled $F_{REBUILDING}$ in Figure 1. OY is MSY as reduced by relevant socioeconomic factors, ecological considerations, and fishery biological constraints to provide the greatest long-term benefits to the Nation. Under the suggested OY control rule (adapted from the Restrepo et al. 1998 default guidelines), when B is below B_{MSY}, F is controlled as a linear function of B, until a rebuilding target of B_{MSY} is reached at F_{OY}. A final OY target (B_{OY}) somewhat greater than B_{MSY} is achieved by keeping fishing mortality at F_{OY} (Fig.1).

In assessing species status in relation to the status determination criteria for the FMP the best information available about stock status was used. This was derived primarily from analyses and reports issued by NMFS and fishery research organizations such as the Secretariat of the Pacific Community (SPC), the Inter-American Tropical Tuna Commission (IATTC), and the National Research Institute for Far Seas Fisheries (NRIFSF). These are also the primary sources of status of stock evaluations in the WPRFMC Pelagics Annual Report which has been designated as the Stock Assessment and Fishery Evaluation (SAFE) report for the FMP. The SAFE report will include annual updates on the status of the stocks (i.e., most recent assessments) and fisheries in relation to the status determination criteria. Stocks of highly migratory species should be managed throughout the range of the stocks, involving fisheries of many nations. Multilateral management authority over international fisheries in the western Pacific is anticipated but not yet operational. The NMFS and WPRFMC should continue to actively participate in the nascent process of establishing international management over pelagic species in the western Pacific and to continue to promote management measures across the Pacific consistent with the control rules parameterized herein or evolving from multilateral deliberations.

Despite the existence of stock assessment analyses for several of the key species, most of the pelagic management unit species are considered to be "data poor." Where possible, the defaults described in the Technical Guidelines for data moderate species have been used to parameterize control rules. As NMFS and other organizations produce improved stock assessments and as the timely completion and scientific review of these assessments become part of a formal international management process, the status determination criteria and control rules will be altered and improved. The framework procedure should be followed to change management measures in the Pelagic FMP.

MAXIMUM FISHING MORTALITY THRESHOLDS

The National Standard and Technical Guidelines require the specification of a maximum fishing mortality threshold (MFMT) which must not exceed the fishing mortality rate associated with the MSY Control Rule. In this FMP, the upper limit for fishing mortality should be F_{MSY}, as called for in the default:

i.e.,

$$MFMT < F_{limit} = F_{MSY,} \tag{1}$$

and at biomass levels below MSST the MFMT declines linearly toward zero fishing mortality . According to precautionary principles, MFMT should represent the upper boundary, and management should target a lower F level not to exceed F_{OY}. The International Commission for the Conservation of Atlantic Tunas (ICCAT) and the IATTC in the eastern Pacific treat F_{MSY} as a target level of fishing mortality, rather than a limit. If such an approach were adopted by an international management organization in the western and central Pacific, then the WPRFMC would be compelled to consider the same plan. A more precautionary approach by the U.S. in managing its own fisheries might conflict with MSFMCA provisions (e.g. § 304(e)) intended to protect traditional levels of U.S. participation in internationally managed fisheries on highly migratory fish stocks. Also unilateral reduction of fishing effort by fleets under WPRFMC jurisdiction would have very little effect on fishing mortality for most stocks because these fleets catch such a small fraction of the total harvest.

Various proxies for F_{MSY} are recommended by the Technical Guidelines when F_{MSY} can not be reliably estimated (Restrepo et al., 1998). For some data moderate stocks (e.g. bigeye tuna, North Pacific albacore, and blue marlin) the information on F/F_{MSY} needed for current stock status determination is directly available (Table 1) from published and unpublished studies. However, gaps in the available information for other species require the use of proxies. When necessary the proxy for F_{MSY} used here is:

$$F_{MSY} = 0.8\ M. \tag{2}$$

Other proxies may be used as stock assessment studies are conducted on more species, such as sharks. As new information is reviewed in the SAFE report, the WPRFMC should select appropriate reference points and implement new or improved control rules via the framework process. For example, an assessment of blue shark is currently being conducted by NMFS in collaboration with the NRIFSF. On future occasions, management reference points may be re-estimated because of technological progress or changes in fishery operations, on the basis of best available data and following the logic presented here.

The tabulation of relative fishing mortality rates (Table 1) indicates that overfishing is taking place on two stocks, bigeye tuna and eastern Pacific yellowfin tuna. The uncertainty surrounding most of the status determination criteria for data moderate species could be about one-half to double the tabled estimates. For the data poor management unit species (MUS) stocks, the recent level of F in relation to the status determination criteria is often unknown (Table 1). No reliable stock assessments have been conducted for these stocks. In some cases (e.g., eastern Pacific skipjack tuna, other billfishes) production model assessments have been attempted but fits to the data were too poor to provide a useful indication of stock status (IATTC, 1999a; Suzuki, 1989; Skillman, 1989a). For other MUS stocks, data collection procedures for the largest (non-U.S.) pelagic fisheries have not even mandated basic catch reporting (e.g. mahimahi, wahoo, moonfish, oilfishes, oceanic pomfrets, and most pelagic sharks).

Table 1. Fishing mortality rates of Pacific pelagic MUS relative to the maximum fishing mortality threshold of F_{MSY}.

Stock	Relative fishing mortality rate (F_{year}/F_{MSY})	Is overfishing occurring? (i.e., is $F > F_{MSY}$)
Bigeye tuna	$F_{94}/F_{MSY} = 1.09$	Yes
N. Pacific albacore	$F_{95}/F_{MSY} = 0.9$	No
S. Pacific albacore	$F_{93}/F_{MSY} = 0.62$	No
E. Pacific yellowfin tuna	$F_{97}/F_{MSY} = 1.08$	Yes
W. Pacific yellowfin tuna	$F_{98}/F_{MSY} = 0.11$ to 0.22	No
E. Pacific skipjack tuna	Unknown	Unknown, very unlikely
W. Pacific skipjack tuna	$F/F_{MSY} = 0.25$	No
Other tunas	Unknown	Unknown
N. Pacific swordfish	$F_{97}/F_{MSY} = 0.1$	No
Blue marlin	$E_{97}/E_{MSY} = 0.46$ to 0.88	No
Other billfishes	Unknown	Unknown
Pelagic sharks	Unknown	Unknown
Other MUS	Unknown	Unknown

Some of the least-studied MUS stocks (e.g., mahimahi, wahoo, moonfish, oilfishes, oceanic pomfrets) may need to be managed as part of a mixed stock complex with targets and limits set for better known tuna and billfish stocks. The National Standard Guidelines allow overfishing of "other" components in a mixed stock complex if (1) long-term benefits to the Nation are obtained, (2) similar benefits cannot be obtained by modification of the fishery to prevent overfishing of the these components, and (3) the results will not cause any component or ecologically significant unit to require protection under the Endangered Species Act (ESA). Domestic fishery monitoring provides some indication of the status of some of these components in the form of catch-per-unit-effort (CPUE) time series. The domestic CPUE time series are reviewed in the annual SAFE report and would indicate any severe, sustained declines in apparent relative abundance that would be relevant to ESA concerns. Other MUS (e.g., oilfishes, some oceanic shark species) are primarily bycatch. The FMP should be altered so that such species are managed as bycatch rather than as MUS.

MINIMUM STOCK SIZE THRESHOLDS

The defaults for the minimum stock size threshold (Table 2) should be those recommended in the Technical Guidelines for data-moderate situations (Restrepo et al. 1998) where:

$$MSST = B_{limit} = (1\text{-}M)\ B_{MSY} \text{ when } M < 0.5, \text{ and} \tag{3}$$

$$MSST = B_{limit} = 0.5\ B_{MSY} \text{ when } M >= 0.5. \tag{4}$$

The second equation was applied to yellowfin and skipjack tunas whose natural mortality rates exceed 0.5; otherwise, the first equation was used. Estimates of B_{year}/B_{MSY} were available from published and unpublished studies for some stocks (e.g. bigeye tuna, North Pacific albacore, and blue marlin). For eastern Pacific yellowfin tuna, one of the best assessed tuna stocks in the Pacific, the published stock assessments did not provide any estimates of B_{MSY} or F_{MSY}. Therefore, for this stock we calculated B_{MSY} as MSY/0.8 M Stock assessment studies in the Pacific usually have not directly provided estimates of the status determination criteria required by the MSFCMA. U.S. delegates to the developing international fishery management bodies in the Pacific will need to promote the establishment of standard stock status reference points, targets, and limits amenable to MSFCMA requirements.

For some stocks with relatively high fecundity a proxy for B_{MSY} was calculated as suggested by the National Standard Guidelines for data poor situations

$$B_{MSY} = 0.4\ B_0\,, \tag{5}$$

where B_0 is the initial biomass or carrying capacity. For these stocks $CPUE_{year}/CPUE_0$ was also used as a proxy for B_{year}/B_0 as described in the Technical Guidelines for data poor situations so that standardized CPUE time series extending back to the earliest ($CPUE_0$) years of the fishery could be used to estimate B_{year}/B_{MSY}.

$$B_{year}/B_{MSY} = (CPUE_{year}/CPUE_0) * (B_0/B_{MSY}) \tag{6}$$

Such estimates based on CPUE time series may have to be recalculated periodically to account for technological developments or changes in fishing modes.

The estimates of relative biomass compared with the status determination criteria for assessed stocks of the Pacific pelagic MUS (Table 2) indicate that none of these stocks are overfished even though F/F_{MSY} indicates overfishing is occurring in bigeye tuna and eastern Pacific yellowfin tuna (Table 1). The overfishing determinations for these two tuna stocks were based on the F_{MSY} being only slightly exceeded, with substantial uncertainty about the true situation.

The default limit control rule for data poor situations is to set a catch limit based on a multiplier of the average annual catch from some time period when there is no qualitative or quantitative evidence of declining biomass. At most, the catch limit multiplier is 1.00 for situations when B is suspected to be above B_{MSY}. For situations where the biomass is suspected to be between B_{MSY} and the MSST, the multiplier is 0.67. When B is believed to be below the MSST, the multiplier is 0.33. The FMP should implement the default control rules for data moderate stocks such as bigeye and yellowfin tunas, albacore, blue marlin, and swordfish. For cases which are currently very data poor, the SAFE report may provide the information needed to implement recommended defaults using the framework process.

Table 2. Stock biomass of Pacific pelagic MUS relative to the minimum stock size threshold.

Stock	Relative biomass (B_{year}/B_{MSY})	MSST	Is the stock overfished? (is B_{year}/B_{MSY} < MSST)
Bigeye tuna	$B_{94}/B_{MSY} = 0.99$	0.6 B_{MSY}	No
N. Pacific albacore	$B_{95}/B_{MSY} = 1.1$	0.7 B_{MSY}	No
S. Pacific albacore	$B_{93}/B_{MSY} = 2.5$	0.7 B_{MSY}	No
E. Pacific yellowfin tuna	$B_{97}/B_{MSY} = 0.95$	0.5 B_{MSY}	No
W. Pacific yellowfin	$B_{98}/B_{MSY} = 1.65$	0.5 B_{MSY}	No
E. Pacific skipjack tuna	$B_{97}/B_{MSY} = 2.5$	0.5 B_{MSY}	No
W. Pacific skipjack tuna	$B/B_{MSY} = 2.5$	0.5 B_{MSY}	No
Other tunas	Unknown	Unknown	Unknown
N. Pacific swordfish	$B_{year}/B_{MSY} = 2.47$	0.7 B_{MSY}	No
Blue marlin	$B_{97}/B_{MSY} = 1.1$ to 1.7	0.8 B_{MSY}	No
Other billfishes	Unknown	Unknown	Unknown
Pelagic sharks	Unknown	Unknown	Unknown
Other MUS	Unknown	Unknown	Unknown

MANAGING FOR OPTIMUM YIELD

In 1991, Amendment 1 to the Pelagics Fishery Management Plan (FMP) made OY a management goal for pelagic fisheries inside the EEZ. Consistent with the broader definition of OY, the FMP defines OY for the WPRFMC EEZs as the number of pelagic fish that can be harvested by domestic and foreign vessels in the EEZ of each island area without causing "local overfishing" or "economic overfishing" and without significantly contributing to "growth overfishing" or "recruitment overfishing" on a stockwide basis. Stockwide MSY and OY control rules are intended to prevent overfishing on a stockwide basis. Local overfishing occurs when fish are removed from local waters at a faster rate than they can be replaced by new recruits entering from more distant areas (Skillman et al., 1993; Boggs, 1994; He and Boggs, 1996, 1997). The maximum economic yield (MEY, analogous to OY) that can be obtained from a local fishery on a pelagic species is much smaller than the MEY for the stock throughout its range (Skillman et al., 1993). The EEZ-specific definition of MEY or OY should be given a unique designation in the FMP (e.g., (MEY_{EEZ} or OY_{EEZ}) to distinguish it from the broader, stockwide MSFMCA definition.

Stocks of highly migratory species should be managed throughout their range by an effective international management authority with active NMFS and WPRFMC participation to promote precautionary management measures including stockwide MSY and OY control rules. For pelagic MUS, the stockwide OY target level of fishing mortality and biomass should be set at the defaults of 75% of F_{MSY} and 75% of B_{MSY}, respectively, as recommended in the Technical Guidelines. Meanwhile, the WPRFMC should continue to manage pelagic fisheries under its jurisdiction via its limited entry program to achieve OY_{EEZ} as currently defined in the Pelagic FMP.

A minimum biomass flag is established in relation to OY as a precautionary signal of the need for management action to prevent further stock decline to the MSST level and avoid the need for a rebuilding plan . Minimum biomass flags should be set at the default value of

$$(1 - M)\, B_{OY} \quad \text{for } M < 0.5 \text{ and} \tag{7}$$

$$(1 - 0.5)\, B_{OY} \quad \text{for } M >= 0.5 \tag{8}$$

where B_{OY} is approximately 125% of B_{MSY}, as indicated in the Technical Guidelines. The second equation applies to yellowfin and skipjack tunas. Although fishing mortality is higher than F_{OY} for North Pacific albacore and perhaps blue marlin (Table 1), none of the precautionary minimum biomass flags signal a need for management action (Table 3).

Table 3. Biomass of Pacific pelagic MUS relative to the precautionary minimum biomass flag.

Stock	Relative biomass (B_{year}/B_{MSY})	Minimum biomass flag	Does the flag signal a need for action
Bigeye tuna	$B_{94}/B_{MSY} = 0.99$	$0.6\ B_{OY} = 0.75\ B_{MSY}$	No
N. Pacific albacore	$B_{95}/B_{MSY} = 1.1$	$0.7\ B_{OY} = 0.88\ B_{MSY}$	No
S. Pacific albacore	$B_{93}/B_{MSY} = 2.5$	$0.7\ B_{OY} = 0.88\ B_{MSY}$	No
E. Pacific yellowfin	$B_{97}/B_{MSY} = 0.95$	$0.5\ B_{OY} = 0.63\ B_{MSY}$	No
W. Pacific yellowfin	$B_{98}/B_{MSY} = 2.5$	$0.5\ B_{OY} = 0.63\ B_{MSY}$	No
E. Pacific skipjack	$B_{97}/B_{MSY} = 2.5$	$0.5\ B_{OY} = 0.63\ B_{MSY}$	No
W. Pacific skipjack	$B/B_{MSY} = 2.5$	$0.5\ B_{OY} = 0.63\ B_{MSY}$	No
Other tunas	Unknown	Unknown	Unknown
N. Pacific swordfish	$B_{year}/B_{MSY} = 2?$	$0.8\ B_{OY} = 1.00\ B_{MSY}$	No
Blue marlin	$B_{97}/B_{MSY} = 1.1$ to 1.7	$0.8\ B_{OY} = 1.00\ B_{MSY}$	No
Other billfishes	Unknown	Unknown	Unknown
Pelagic sharks	Unknown	Unknown	Unknown
Other MUS	Unknown	Unknown	Unknown

MUS STATUS AND WPRFMC MANAGEMENT

This section discusses the best available information used for the status determination criteria tabulated above, as well as recommended WPRFMC management actions to limit directed fisheries on these stocks. An important context for these deliberations is the relative fishing mortality rate due to catches by fisheries under WPRFMC jurisdiction (F_{jur}/F_{MSY} ;Table 4). Catches by WPRFMC fisheries (C_{jur}) expressed as a fraction of the stockwide catch (C) can be used to calculate the relative WPRFMC fishing mortality rate as:

$$F_{jur}/F_{MSY} = (C_{jur}/C) * (F/F_{MSY}). \qquad (9)$$

This relative fishing mortality rate (F_{jur}/F_{MSY}) represents the maximum possible reduction in relative fishing mortality that could be achieved through the closure of all pelagic fisheries under WPRFMC jurisdiction. For the two stocks where overfishing is occurring (bigeye tuna and eastern Pacific yellowfin tuna), reduction of fishing effort by fisheries managed under the FMP would have no effect on the stock status relative to the determination criteria. Unless fishing effort outside of WPRFMC jurisdiction is reduced, overfishing will continue on these stocks.

Table 4. Relative fishing mortality rate under the jurisdiction of the Western Pacific Regional Fishery Managment Council (F_{jur}/F_{MSY}).

Stock	Percentage of stockwide catch taken by WPRFMC fisheries (100 C_{jur}/C)	Relative fishing mortality rate from Table 1 (F/F_{MSY})	Relative WPRFMC fishing mortality rate (F_{jur}/F_{MSY})
Bigeye tuna	1.5%	1.09	0.016
N. Pacific albacore	2.4%	0.9	0.022
S. Pacific albacore	0.7%	0.62	0.0043
E. Pacific yellowfin tuna	0.07%	1.08	0.0008
W. Pacific yellowfin	0.4%	0.11 to 0.22	0.0004 to 0.0008
E. Pacific skipjack tuna	0.01%	Unknown	Unknown
W. Pacific skipjack tuna	0.1%	0.25	0.00025
Other tunas	Unknown	Unknown	Unknown
N. Pacific swordfish	23%	0.3	0.069
Blue marlin	3.7%	0.46 to 0.88	0.017 to 0.033
Other billfishes	Unknown	Unknown	Unknown
Pelagic sharks	Unknown	Unknown	Unknown
Other MUS	Unknown	Unknown	Unknown

Bigeye Tuna

For this report, bigeye tuna is treated as a single basin-wide stock, although some assessments have assumed separate eastern and western stocks. This report relies on the stock assessment conducted for bigeye tuna throughout the Pacific by the NRIFSF (Miyabe, 1995). Estimates of F_{94}/F_{MSY}, B_{94}/B_{MSY}, C_{94}, and MSY are provided but a value for M (used in Tables 2 and 3) is not. We conservatively chose M = 0.4 from a range of values (0.4 to 0.8) used in recent bigeye stock assessment modeling (Miyabe and Bayliff, 1998). The latter reference reviews a number of bigeye tuna stock assessments, including the one used here (Miyabe1995). The best source of stockwide catch totals for bigeye and several other species (used in Table 4) are those published by the Secretariat of the Pacific Community Oceanic Fisheries Program (SPC-OFP) because they are the most current, including data through 1998 (Lawson, 1999).

A large degree of uncertainty in some of the estimates employed in the case of bigeye is evident from these studies, but the bigeye stock biomass appears to be at or around MSY. The basin-wide stock assessment using data through 1994 included only longline catches and is now outdated due to the recent increase in purse-seine bigeye catches. Most production models on bigeye tuna are based on longline catch data with a predominant selectivity for relatively large fish. These models do not account for a recent change in selectivity due to increased catches of juvenile bigeye tuna by purse-seiners. Therefore, using the current total bigeye catch for purposes of comparison to MSY values from older studies (including Miyabe, 1995) is probably not valid. An updated stockwide assessment that considers the recent change in selectivity is needed.

Current estimates of bigeye stock biomass indicate that it is well above the MSST (Table 2), so the stock is not overfished. However, current estimates of fishing mortality suggest that overfishing of bigeye is occurring (Table 1). Therefore some action must be taken to stop overfishing. The only effective option available to the WPRFMC and NMFS will be to promote the establishment of an effective Pacific-wide fishery management authority and to petition that authority to reduce stockwide fishing effort by at least 9% to conform with the MSY control rule, or by 31% to conform with the OY control rule. Unilaterally reducing the harvest of bigeye tuna by WPRFMC-managed fisheries would be ineffectual in reducing overfishing, and it would conflict with the MSFCMA objective to obtain optimum yield for U.S. fisheries. Unilateral action to deprive U.S. fishermen of access to the bigeye tuna resource would not reflect traditional participation by U.S. fishermen relative to foreign competitors, and thus would be contrary to § 304(e) of the MSFMCA. The harvest by fisheries managed in the pelagic FMP is too small ($F_{jur}/F_{MSY} = 0.016$, Table 4) for even its total elimination to have any impact on stock status in relation to the status determination criteria.

Studies have attempted to determine evidence of declining catch rates in the Hawaii EEZ fisheries as a function of the magnitude of local fishing in the EEZ around Hawaii with the goal of determining whether local overfishing of bigeye tuna was occurring (Boggs, 1991; He and Boggs, 1996). These studies found no evidence that local fishing had increased to a level above OY_{EEZ}, or any indication that fishing in the EEZ was having a negative effect on local catch rates. In 1994 the WPRFMC established a limited-entry program for the Hawaii-based longline fishery (Amendment 7) which accounts for almost all of the bigeye tuna catch in all WPRFMC EEZs. An important objective of the limited entry program was to prevent economic overfishing and achieve OY_{EEZ}. The number of longline vessels registered with Federal limited-entry permits is restricted to a total of 164.

Albacore Tuna

Albacore have an anti-equatorial distribution in the Pacific, due to their preference for subtropical and temperate waters. There is consensus for treating North and South Pacific populations as separate stocks. Information on North Pacific albacore for Tables

1-4 came from the Report of the 15th North Pacific Albacore Workshop (Shaw and Bartoo, 1998) and two working papers (Bartoo et al., 1997; Au,1997). The status determination criteria indicate that the stock is not overfished, nor does the minimum biomass flag indicate any need for stock rebuilding action. However, the suggested OY control rule would require limiting fishing mortality to 0.75 F_{MSY}. An international agreement to employ an OY control rule in the management of this stock would be required to effectively reduce fishing mortality since the mortality due to fisheries under WPRFMC jurisdiction accounts for only 2.4% of total F (Table 4).

Estimates of current F for the South Pacific albacore stock are from Fournier et al. (1998). Since that study did not address F_{MSY}, this parameter was estimated as 0.8 M. An M value of 0.3 was taken as the middle of a range of values given by Hampton et al. (1999). A time series of standardized CPUE given by Fournier et al. (1998) indicates that current CPUE is about the same as initial CPUE which was the basis for the relative biomass estimate of 2.5 (Table 2). South Pacific albacore catch data used in Table 4 are from the most current source (Lawson, 1999). The stock is in healthy shape, and WPRFMC fisheries take a tiny fraction of the harvest (Table 4).

Yellowfin Tuna

Stock assessment studies on yellowfin and skipjack tuna generally focus on either the eastern or the western Pacific, coinciding with the distribution of the major surface fisheries. There is no scientific consensus or strong evidence for separate eastern and western Pacific stocks. Since these assessments are the most current and include both surface and longline fishery statistics, we have used them in conducting this status determination. Catch data for both stocks used in Table 4 are from the SPC-OFP (Lawson, 1999).

The IATTC regularly assesses the eastern Pacific yellowfin tuna stock (IATTC, 1999) although their reports do not provide the parameter values needed for Tables 1 and 2. Therefore F was calculated from the current catch divided by current biomass. Current biomass was found by multiplying an estimate of abundance (from cohort analysis) by mass-at-age data. Then, F_{MSY} was calculated as 0.8M, with M = 0.8, to get F/F_{MSY} for Table 1. Current fishing mortality is just above that needed to produce MSY, and the stock biomass appears to be very close to the B_{MSY} level and well above MSST. Technically, overfishing is occurring on this stock but the stock is not overfished. The IATTC estimates MSY at 270,000 metric tons (t) and institutes an annual quota to try to keep harvest at about the MSY level. In 1997 the quota was 220,000 t plus 3 discretionary increments of 15,000 mt, or a total quota of 265,000 mt. Although fisheries under WPRFMC jurisdiction do operate in the eastern Pacific (defined as east of 150 degrees west longitude), their catch of yellowfin tuna in that region is minuscule and irrelevant to the management of fishing mortality on this stock (Table 4).

WPRFMC fisheries in the Hawaii EEZ do not harvest enough yellowfin tuna to have a negative influence on local CPUE for yellowfin tuna (Boggs, 1994; He and Boggs, 1996, 1997). Therefore, it appears that local fishing mortality directed at yellowfin is below the level that would produced OY_{EEZ}, and no reduction of WPRFMC-managed yellowfin fishing mortality is required at this time.

Hampton et al. (1999) provide an estimate of current F for the western Pacific stock based on tagging data analyses. This assessment derived an M value of 1.6, twice as high as the M = 0.8 value more commonly assumed for yellowfin tuna (IATTC, 1999). Relative fishing mortality calculated using 0.8M as F_{MSY} varies from 0.11 to 0.22 depending on M (Table 1). The Hampton (1999) study also found that biomass was about 66% of B_0, from which a relative biomass of 1.65 is calculated by assuming that $B_{MSY} = 0.4\ B_0$ (Table 2). Neither of the status determination criteria indicates a need for management action .

Skipjack Tuna

As with yellowfin tuna, skipjack tuna stock assessment, generally focuses on either the EPO or the WPO instead of the entire Pacific basin. The IATTC has not been able to conduct reliable production model analyses or cohort analyses on skipjack tuna, in part perhaps because much of the skipjack biomass may enter the eastern Pacific fishery via immigration. In any case there are no estimates of relative fishing mortality for the eastern Pacific. Recent CPUE data do not appear to show any decline relative to CPUE in the earliest years of the fishery, although in the 1960s CPUE was at a generally higher level than in the preceding or following decades (IATTC, 1999a). Thus, the CPUE data indicate a current relative biomass ratio of 2.5 based on the assumption that $B_{MSY} = 0.4\ B_0$ (Table 2). The stock seems very healthy. The catch of skipjack tuna by WPRFMC fisheries in the eastern Pacific is even more insignificant than the catch of yellowfin tuna, and the much greater natural productivity of skipjack tuna generally precludes any concerns about the impact of WPRFMC-managed fisheries on the skipjack stock.

Tagging research on skipjack tuna in the western Pacific (Hampton et al., 1999) provides estimates of fishing mortality and total mortality in the 1990s that are used to estimate the relative fishing mortality rate of 0.25 (Table 1). Again standardized CPUE indices show no decrease in CPUE from the earliest times of the fishery, and thus the relative biomass is assumed to be about 2.5 (Table 2). This stock appears to be in very good condition.

Swordfish

Swordfish is the non-tuna species of major commercial importance in the Pacific, and harvests by WPRFMC fisheries comprise an important fraction of the total swordfish harvest. Yet by contrast to several tuna species, relatively little is known about swordfish in the North Pacific, and the associated catch and effort statistics are characterized by a substantial level of uncertainty and incompleteness. Recent attempts to determine the status of the North Pacific swordfish stock were inconclusive (ISC, 1999). To address limitations of these assessments, an operational model was designed at the NMFS Honolulu Laboratory during 1998-99 to evaluate the performance of stock assessment and fishery management procedures in this data poor context (M. Labelle, unpublished manuscript NMFS, Honolulu Laboratory). This type of simulation model is basically an amalgamation of data, parameter estimates, and hypotheses from various sources. When information was missing on some components, information from other pelagic species and from the ecological literature was used to complete the model. The model incorporates key features of age-structured and length-based models and accounts for growth, reproduction, mortality, recruitment, exploitation, and movement. When supplied with the existing time series of fishing effort for all major tuna and swordfish fisheries in the North Pacific, the model predicts catch trends that conform very well to the observed patterns over 1952-96. In the absence of more suitable alternatives, this model was used to provide preliminary estimates of the biological reference points required for this review of stock status.

At the MSY level, the predicted overall fishing mortality rate (F_{msy}) was about 0.26, which corresponds roughly to the average natural mortality rate ($M = 0.3$) for males and females used in the simulation. Statistical results for comparisons of predicted and observed catch patterns were almost identical for predictions of MSY ranging from 27,000 t to over 100,000 t, although the best hypothesis was for MSY at about 57,000 t with a fishing mortality rate in 1996 (F_{96}) predicted to be about 0.0254. The corresponding F_{96}/F_{msy} is estimated at 0.1 (Table 1) and B_{96}/B_{MSY} is estimated at 2.47 (Table 2). Since B_{96} exceeds MSST, and F_{96}/F_{msy} is less than 1.0, this analysis indicates that the North Pacific swordfish stock is not overfished. However, the level of uncertainty surrounding these estimates is very high.

Blue Marlin

Blue marlin are believed to comprise a single Pacific-wide stock (Skillman, 1989b). Status determination criteria are based on IATTC assessment work (IATTC, 1999b), assuming that the relative fishing effort (E/E_{msy}) from that assessment is an acceptable proxy for F/F_{MSY}. M is assumed to be about 0.2. The blue marlin stock in the Pacific appears to be healthy, with the current levels of biomass and fishing mortality near the levels required to maintain MSY (Hinton, 1999). If the uppermost estimate of relative fishing effort given in Table 1 is a reasonable estimate of F/F_{MSY}, then the suggested OY control rule would require some reduction in fishing mortality for blue marlin. An effective OY control rule would require establishment of an effective Pacific-wide fishery management authority that would reduce stockwide fishing mortality by about 15% (assuming that the relative fishing mortality ratio is 0.88). It would be futile to require such reductions unilaterally in the domestic fishery because the mortality due to fisheries under WPRFMC jurisdiction accounts for only 3.7% of total F (Table 4). Furthermore, a unilateral mortality reduction would conflict with the MFCMA's objective to obtain optimal yield for U.S. fisheries.

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