Seafood Watch

Seafood Report

MONTEREY BAY AQUARIUM®

Yellowfin tuna

Thunnus albacares

All Regions

Original Report Published July 9, 2007
Stock Status Update and Bycatch Addendum
October 7, 2010

Jesse Marsh
Senior Fisheries Research Analyst (Former)
Monterey Bay Aquarium

About Seafood Watch® and the Seafood Reports

Monterey Bay Aquarium's Seafood Watch® program evaluates the ecological sustainability of wild-caught and farmed seafood commonly found in the United States marketplace. Seafood Watch® defines sustainable seafood as originating from sources, whether wild-caught or farmed, which can maintain or increase production in the long-term without jeopardizing the structure or function of affected ecosystems. Seafood Watch® makes its science-based recommendations available to the public in the form of regional pocket guides that can be downloaded from the Internet (seafoodwatch.org) or obtained from the Seafood Watch® program by emailing seafoodwatch@mbayaq.org. The program's goals are to raise awareness of important ocean conservation issues and empower seafood consumers and businesses to make choices for healthy oceans.

Each sustainability recommendation on the regional pocket guides is supported by a Seafood Report. Each report synthesizes and analyzes the most current ecological, fisheries and ecosystem science on a species, then evaluates this information against the program's conservation ethic to arrive at a recommendation of "Best Choices", "Good Alternatives" or "Avoid." The detailed evaluation methodology is available upon request. In producing the Seafood Reports, Seafood Watch® seeks out research published in academic, peer-reviewed journals whenever possible. Other sources of information include government technical publications, fishery management plans and supporting documents, and other scientific reviews of ecological sustainability. Seafood Watch® Fisheries Research Analysts also communicate regularly with ecologists, fisheries and aquaculture scientists, and members of industry and conservation organizations when evaluating fisheries and aquaculture practices. Capture fisheries and aquaculture practices are highly dynamic; as the scientific information on each species changes, Seafood Watch's sustainability recommendations and the underlying Seafood Reports will be updated to reflect these changes.

Parties interested in capture fisheries, aquaculture practices and the sustainability of ocean ecosystems are welcome to use Seafood Reports in any way they find useful. For more information about Seafood Watch® and Seafood Reports, please contact the Seafood Watch® program at Monterey Bay Aquarium by calling 1-877-229-9990.

Disclaimer

Seafood Watch® strives to have all Seafood Reports reviewed for accuracy and completeness by external scientists with expertise in ecology, fisheries science and aquaculture. Scientific review, however, does not constitute an endorsement of the Seafood Watch® program or its recommendations on the part of the reviewing scientists. Seafood Watch® is solely responsible for the conclusions reached in this report.

Seafood Watch® and Seafood Reports are made possible through a grant from the David and Lucile Packard Foundation.

Table of Contents

I. Executive Summary

As a global commodity, yellowfin tuna is found in the market as canned light tuna, but is also frequently sold fresh and frozen. While some yellowfin tuna is caught by U.S. fisheries, the majority of the tuna in the marketplace is imported. In this report, the worldwide fleets catching yellowfin other than the U.S. fishery are referred to as "international." In the U.S., the main sources of imported canned tuna vary from year to year, but include Thailand, Ecuador, Indonesia, the Philippines, Vietnam, and Mexico. Yellowfin is caught in the Atlantic, Pacific, and Indian Oceans, and is mixed when is processed; for this reason, in most cases the fishing country or fishing gear cannot be identified. Fresh tuna sold as sashimi or ahi is likely caught with longlines or pole and line gear.

Yellowfin tuna, *Thunnus albacares*, is a wide-ranging pelagic species caught in commercial, recreational, and subsistence fisheries throughout the world's oceans. Yellowfin matures at an early age, has a moderate lifespan, is highly fecund, and is widely distributed, making it inherently resilient to fishing pressure. The four stocks of yellowfin comprise the western and central Pacific (WCPO), eastern Pacific (EPO), Atlantic, and Indian Ocean (IO)stocks. The stock status of Pacific yellowfin stocks appears to have improved since the last assessments. The EPO yellowfin stock is not subject to overfishing, and has recovered from the overfished condition it has been in since the mid-2000s, but there is moderate uncertainty in the latest stock assessment with current biomass either slightly above or slightly below target levels, depending on assumptions used in the model. As a result, the stock is considered a moderate conservation concern. The WCPO stock is also not being overfished and overfishing is not occurring, and biomass is above target levels, making this stock a low conservation concern. Most assessment results indicate that the Atlantic yellowfin stock is not currently overfished or undergoing overfishing. However, there is moderate uncertainty, and some results suggest the stock may be overfished or undergoing overfishing when the moderate uncertainty is taken into account. Stock status is thus considered a moderate conservation concern. Uncertainty over the status of the IO stock is high, overfishing appears to have been occurring for some years, and biomass levels have declined steeply to a point around the MSY level. There is therefore a high conservation concern associated with the stock status of yellowfin in the Indian Ocean.

Yellowfin is caught with purse seines, troll, handline, and pole and line gear, and pelagic longlines. The level of bycatch varies according to the gear type. Troll, handline, and pole and line gear result in little bycatch and are a low conservation concern. Purse seine sets on dolphins (used only in the EPO) and unassociated schools are considered to have moderate bycatch (dolphin mortalities have declined dramatically in the dolphin set fishery), while purse seine sets on floating objects or fish aggregating devices (FADs) are deemed a critical conservation concern due to the bycatch of juvenile tuna (in particular bigeye and yellowfin), other pelagic fishes, sharks, and sea turtles. The uncontrolled growth of the floating object fishery is cause for concern. Pelagic longlines also catch a number of incidental species, including endangered and threatened sea turtles, seabirds, marine mammals, and billfish. Those fisheries with observer data demonstrating declining bycatch trends or evidence that bycatch levels are not contributing to the decline of a species – the U.S. Atlantic and Hawaii-based longline fisheries – are considered to be of high conservation concern according to Seafood Watch® criteria. All international pelagic longline fisheries are considered by Seafood Watch® to have critical bycatch levels.

Troll/pole, purse seine and pelagic longline gear have negligible habitat effects on the seafloor, though the ecosystem effects of removing large predators such as tuna are not understood. Longlines may have effects on the food web by removing large predators (including many species caught as bycatch, such as sharks), and floating objects or FADs used with purse seines can have ecological impacts by altering fish behavior. This combined with the benign habitat effects of purse seine, troll/pole and pelagic longline gear results in a moderate conservation concern for floating object purse seines and pelagic longlines and a low concern for troll/pole and unassociated or dolphin-set purse seine gear for habitat and ecosystem impacts of the fishery.

International management bodies manage fish stocks, while U.S. federal management bodies manage U.S. fisheries. International management bodies for yellowfin include the International Commission for the Conservation of Atlantic Tunas (ICCAT) in the Atlantic Ocean, the Inter-American Tropical Tuna Commission (IATTC) in the eastern Pacific Ocean, the Western and Central Pacific Fisheries Commission (WCPFC) in the western and central Pacific Ocean, and the Indian Ocean Tuna Commission (IOTC) in the Indian Ocean. Regulations are generally based on recommendations by IATTC staff or scientific committees of the ICCAT and IOTC, and implemented by the member and cooperating countries. In the Atlantic, the U.S. fishery is managed under the Fishery Management Plan (FMP) for Atlantic Tunas, Swordfish, and Sharks by the Highly Migratory Species (HMS) division of the National Marine Fisheries Service (NMFS). In the U.S. exclusive economic zone (EEZ) around Hawaii and the U.S. Pacific Islands, yellowfin is managed by the Western Pacific Fishery Management Council (WPFMC) under the Pelagics Fishery Ecosystem Plan. Yellowfin in the U.S. EEZ off California, Oregon, and Washington are managed by the Pacific Fishery Management Council (PFMC) under the Highly Migratory Species Fishery Management Plan. Management of the yellowfin tuna resource is complicated by the fact that individual countries may have less or more stringent regulations than those of the international management bodies. As there are numerous countries landing yellowfin, generalizations were made in this report concerning the effectiveness of the management regime. In those cases where information is available to differentiate individual country management practices, Seafood Watch® has attempted to include this in the overall recommendation. Management is ranked highly effective for the U.S. eastern Pacific troll/pole fishery, the Hawaii-based and U.S. Atlantic longline and troll/pole fleets, and the U.S. pole and line fishery in the WCPO. Management is deemed moderately effective for the international troll/pole fisheries in the Pacific, Atlantic, and Indian Oceans; the purse seine fisheries in the Pacific and Atlantic; the unassociated purse seine fishery in the Indian ocean; and the international longline fleets in the Pacific and the Atlantic. Management is deemed ineffective in the Indian Ocean floating object and longline fisheries.

Overall, troll/pole-caught yellowfin from the U.S-based EPO, WCPO and Atlantic fisheries is considered a **Best Choice** due to the minimal impacts of this gear, the healthy/moderate status of the stock in this region, and highly effective management. The international troll/pole and unassociated purse seine fisheries for yellowfin tuna in the WCPO are also a **Best Choice** due to minimal to moderate bycatch, minimal impacts of the fishing gear, healthy stocks and moderately effective management. Troll/pole-caught yellowfin from the Indian Ocean, the international EPO and international Atlantic is a **Good Alternative**. Longline-caught yellowfin in the U.S. fishery in the Atlantic and Hawaii is also ranked as a **Good Alternative** due to a reduced bycatch concern in this fishery resulting from mitigation measures. Purse seine-caught yellowfin from unassociated and dolphin sets is also considered a **Good Alternative** due to the reduced bycatch levels in these fisheries compared to floating object purse seine and longline fisheries. While dolphin sets do continue to result in dolphin mortality, the population consequences of this bycatch are uncertain. Yellowfin caught in unassociated sets is a more environmentally friendly option, although it falls in the same category as dolphin sets. Yellowfin caught in the floating object/FAD purse seine fishery is recommended as **Avoid** regardless of which ocean it is from due to the bycatch and ecosystem concerns associated with this fishery. Various bycatch, management, and stock concerns throughout these oceans results in a ranking of **Avoid** for longline-caught yellowfin in international fisheries.

Pocket Guide Recommendations
More detailed recommendations are included in this report than are reflected in the general recommendations that appear on the Seafood Watch® pocket guides. Due to space limitations, generalizations must be made when communicating this information via the pocket guide. Troll/pole-caught yellowfin is recommended as a **Good Alternative**, as 75% of troll/pole-caught yellowfin is a **Good Alternative**, while only 25% is a **Best Choice.** Longline-caught yellowfin from the U.S. fleets (U.S. Atlantic and Hawaii) is a **Good Alternative**, while longline-caught yellowfin from all other fleets is recommended as **Avoid**. Canned light tuna that is troll/pole-caught is recommended as a **Best Choice** because most troll/pole-caught skipjack (the species that composes the majority of "light" tuna) is a **Best Choice**. All other canned light tuna is recommended as **Avoid** because the majority is caught with gear types that have critical bycatch concerns.

This report has been updated at frequent intervals, most recently on October 7, 2010. Please see Appendices III through VI for summaries of the changes made.

Table of Sustainability Ranks

	Conservation Concern			
Sustainability Criteria	**Low**	**Moderate**	**High**	**Critical**
Inherent Vulnerability	√			
Status of Stocks	√ WCPO	√ EPO, Atlantic	√ Indian	
Nature of Bycatch	√ Troll/pole	√ Dolphin and unassociated purse seine	√ Hawaii longline; U.S. Atlantic longline	√ All other longline; FAD purse seine
Habitat Effects	√ Troll/pole; unassociated and dolphin set purse seine	√ Purse seine (FAD), longline		
Management Effectiveness	√ U.S. troll/pole; Hawaii longline; U.S. Atlantic	√ Int'l Troll/pole; Int'l LL (Pacific and Atlantic); Int'l	√ Indian Ocean (longline, FAD	

	longline	purse seine (Pacific, Atlantic, and Indian unassociated sets)	sets)	

About the Overall Seafood Recommendation:

- A seafood product is ranked **Best Choice** if three or more criteria are of Low Conservation Concern (green) and the remaining criteria are not of High or Critical Conservation Concern.
- A seafood product is ranked **Good Alternative** if the five criteria "average" to yellow (Moderate Conservation Concern) OR if the "Status of Stocks" and "Management Effectiveness" criteria are both of Moderate Conservation Concern.
- A seafood product is ranked **Avoid** if two or more criteria are of High Conservation Concern (red) OR if one or more criteria are of Critical Conservation Concern (black) in the table above.

Overall Seafood Recommendation:

Seafood Watch® Recommendation	Where Caught and Gear Used
Best Choice	U.S. Atlantic Ocean troll/pole
	U.S. Eastern Pacific troll/pole
	Western Pacific troll/pole
	Western Pacific unassociated purse seine
Good Alternative	U.S. Atlantic longline
	Hawaii-based longline
	Atlantic Ocean troll/pole (international)
	Indian Ocean troll/pole
	Eastern Pacific Ocean troll/pole (international)
	Eastern Pacific Ocean unassociated and dolphin purse seine
	Atlantic unassociated purse seine
	Western and central Pacific and Indian Ocean unassociated purse seine
Avoid	Eastern Pacific floating object purse seine
	Atlantic floating object purse seine
	Western and central Pacific and Indian Ocean floating object purse seine
	Pacific, Atlantic, and Indian Ocean longline (international)

Common acronyms and terms

CPUE	Catch Per Unit Effort
EEZ	Exclusive Economic Zone
EPO	Eastern Pacific Ocean
FAD	Fish Aggregating Device
FFA	Forum Fisheries Agency
FMP	Fishery Management Plan
FR	Federal Rule
HMS	Highly Migratory Species
IATTC	Inter-American Tropical Tuna Commission
ICCAT	International Commission for the Conservation of Atlantic Tunas
IOTC	Indian Ocean Tuna Commission
IUU	Illegal, Unreported, and Unregulated
MSY	Maximum Sustainable Yield
NEI	Nowhere Else Included. These landings are mostly flag of convenience landings.
NMFS	National Marine Fisheries Service
PFMC	Pacific Fishery Management Council
SCRS	Standing Committee on Research and Statistics
SPC	Secretariat of the Pacific Community
SBR	Spawning Biomass Ratio
WCPFC	Western and Central Pacific Fisheries Commission
WCPO	Western and Central Pacific Ocean
WIO	Western Indian Ocean
WPFMC	Western Pacific Fishery Management Council

Baitboat: Fishers use a pole with fixed length line that has a barbless hook with either an artificial lure or live bait. In this way, fish are caught one at a time, and fishers can immediately throw back any unwanted catch. Pole and line-caught is another term for baitboat-caught; throughout this report the term pole and line will be used.

Longline: Longlines consist of a main horizontal fishing line that can be 50 – 65 nautical miles long. Smaller vertical lines with baited hooks are spaced intermittently along the main line, and can be rigged to fish at various depths depending on the target species and fishing conditions. The longlines used to target tuna are pelagic longlines, and are fished in the upper water column.

Purse seine: Purse seining involves encircling a school of tuna with a long net (typically 200 m deep and 1.6 kilometers long). The net is weighted at the bottom and the top is kept at the surface of the water by a series of floats. One end of the net is pulled out from the main vessel by a skiff, which encircles the school of tuna, and the bottom of the net is then closed by a purse line run through the leadline by a series of rings. The net is then hauled in, and most of the net is broad onboard, leaving a small volume of water in the net and allowing the catch to be brought onboard using a large dip net (NRC 1992). There are several types of purse seine sets: those set on dolphins (dolphin sets); those set on floating objects or FADs (floating object sets); and those set on a school of tuna that is not associated with either dolphins or a floating object (unassociated sets).

Trolling: Trolling consists of towing artificial lures with barbless hooks behind the fishing vessel (Childers 2003). Troll gear is also called jig gear; the term trolling will be used in this report.

II. Introduction

Yellowfin tuna, *Thunnus albacares*, is found in the subtropical and tropical waters of the Atlantic, Pacific, and Indian Oceans (ICCAT 2004; Froese and Pauly 2005). It is exploited throughout its range, and supports a number of both large and small-scale fisheries. Worldwide, yellowfin is caught primarily in the Pacific Ocean (63%), followed by the Indian Ocean (27%), and the Atlantic Ocean (10%). Yellowfin is caught both commercially and recreationally. Tunas such as yellowfin are highly migratory, thus their physiology is different from that of most other bony fishes. Tunas have a high metabolic rate, with a standing metabolic rate that is 2 – 10 times higher than most other active fishes (Korsmeyer and Dewar 2001). Tunas are also endothermic, and maintain internal body temperatures warmer than the surrounding seawater (Graham and Dickson 2001). Yellowfin is an opportunistic feeder, consuming crustaceans, cephalopods, and mesopelagic fish (IOTC 2003).

Yellowfin aggregate with floating objects and school primarily by body size (Froese and Pauly 2005). Smaller yellowfin (< 10 kg) form mixed schools with skipjack tuna (*Katsuwonus pelamis*) and bigeye tuna (*Thunnus obesus*), primarily in surface waters. Larger yellowfin are found in both surface and sub-surface waters, and are also known to school with dolphins in the eastern Pacific Ocean (EPO) (IATTC 2004a; ICCAT 2004; Froese and Pauly 2005). When yellowfin associate with marine mammals, they concentrate below the marine mammals, rather than with them at the surface.

After skipjack, yellowfin is the most commonly caught tuna species worldwide (Table 1) (Lawson 2004a). The types of gear used to capture yellowfin generally vary according to the region, and include purse seines, longlines, pole and line gear, gillnets, handlines, and other gears. Overall, purse seines catch the largest quantity of yellowfin worldwide. There are several types of purse seine fisheries, including those set on floating objects, those set on unassociated schools (unassociated or school sets), and those set on tuna associated with dolphins (dolphin sets). Floating objects used by the purse seine fishery include flotsam (e.g., logs, dead animals, lost fishing gear) and man-made FADs (fish aggregating devices).[1] Logs are increasingly being equipped with radio range beacons or satellite radio (Gaertner et al. 1998). Man-made FADs are either moored or allowed to drift, and include objects such as buoys and metal or bamboo frameworks; in most oceans buoys have been moored in coastal areas to stimulate local fisheries (Girard et al. 2004). FAD fishing operations vary considerably by ocean basin and fishing vessel. For instance, anchored FADs are commonly used in the Philippines, Solomon Islands, and Indonesia (Fonteneau et al. 2000). Spanish purse seiners commonly use supply vessels, which are used to deploy and maintain FADs as well as monitor the quantity of tuna under FADs (Fonteneau et al. 2000). Some FADs are deployed with buoys equipped with sonar that provide real-time estimates of tuna aggregations beneath them (Bromhead et al. undated).

FADs both attract and aggregate tuna, in that tuna within 10 kilometers (km) of a FAD with orient toward the FAD but do not necessarily remain in its vicinity (Girard et al. 2004). Several hypotheses have been suggested to explain tuna behavior around floating objects; the most likely

[1] FADs are also used in non-purse seine fisheries, such as troll/pole fisheries (e.g., Holland et al. 2000; Kakuma 2000); however, for the purposes of this report, FAD fisheries/sets refer only to purse seine fisheries unless otherwise stated.

is that floating objects provide a focal point in an optically void environment (Hunter and Mitchell 1966). FADs may also provide a place for tuna to rest after foraging, and may provide information to the tuna on the diversity of the area (Freon and Dagorn 2000). There are limited data on drifting FADs, which provide more than 50% of global tuna catch (Girard et al. 2004). FAD fisheries have historically been more prominent in the Pacific and Indian Oceans, and are generally used in the eastern, but not the western, Atlantic (Fonteneau et al. 2000).

In an area such as the EPO where yellowfin associate with dolphins, fishers can easily find a school of tuna by locating a group of dolphins. The most common dolphin species that fishers follow include spotted (*Stenella attenuata*) and spinner dolphins (*Stenella longirostris*) (Hall 1997). When the net is set to encircle the tuna, however, dolphins are also encircled by the net. Purse seines targeting yellowfin are set on dolphins only in the EPO. An estimated six million dolphins have been killed in this fishery since it began; dolphin mortality was at its highest from 1959 – 1971 (Hall 1998; Reilly et al. 2005). The Marine Mammal Protection Act (MMPA) requires mandatory observer coverage of tuna fisheries, and the IATTC has worked with fishers to modify their fishing practices in such as way as to reduce dolphin mortality (Hall 1997). The International Dolphin Conservation Program (IDCP) has also set annual mortality rates for dolphins in purse seine fisheries. During the 1990s, the U.S. began to restrict imports of canned tuna caught by dolphin sets (Gerrodette and Forcada 2005). Currently, only "Dolphin-Safe" tuna may be imported into the U.S., which is defined as tuna caught in purse seine trips where there are no sets on dolphins (Gerrodette and Forcada 2005). However, a reduction in dolphin sets has resulted in increased sets on floating objects, resulting in higher bycatch (Vaca-Rodríguez and Enríquez-Andrade 2002).

In the U.S. in 2003, yellowfin was landed in a number of states, including Hawaii (1,549 mt; 38% of total catch), Louisiana (1,367 mt; 33%), California (465 mt; 11%), North Carolina (229 mt; 6%), Florida (west coast—217 mt; 5%), Texas (125 mt; 3%), and New Jersey (44 mt; 1%), as well as Massachusetts, Florida (east coast), New York, Maryland, South Carolina, Delaware, and Virginia (< 1% each) (NMFS 2005a).

Pacific

There are two stocks of yellowfin in the Pacific, one in the EPO and one in the western and central Pacific Ocean (WCPO) (Figure 1), although genetic evidence and tagging suggest there is some mixing between these two stocks (Ward et al. 1994; Hampton et al. 2004). Fisheries operating in the EPO catch varying sizes of yellowfin, with the floating object and unassociated purse seine and pole and line fisheries catching younger, and therefore smaller, yellowfin. The dolphin-associated purse seine and longline fisheries tend to catch larger yellowfin (Maunder and Harley 2005). In the EPO, the catch of yellowfin from floating object sets has increased since 1993 (Maunder and Harley 2005). There are both regional and seasonal differences in the types of purse seine sets in the EPO. For instance, dolphin sets are more common north of 5ºN latitude, while unassociated sets are more common off Mexico, Colombia, and Ecuador (Lennert-Cody and Hall 2000). The Mexican fleet sets very few log-associated sets (Vaca-Rodríguez and Enríquez-Andrade 2002). Overall, in the EPO yellowfin are predominantly caught in dolphin sets (Lennert-Cody and Hall 2000). Catch of yellowfin in purse seines in the EPO generally increased from 1975 – 2003, while longline catches were more variable (Figure 2) (A. Fonteneau, pers. comm.).

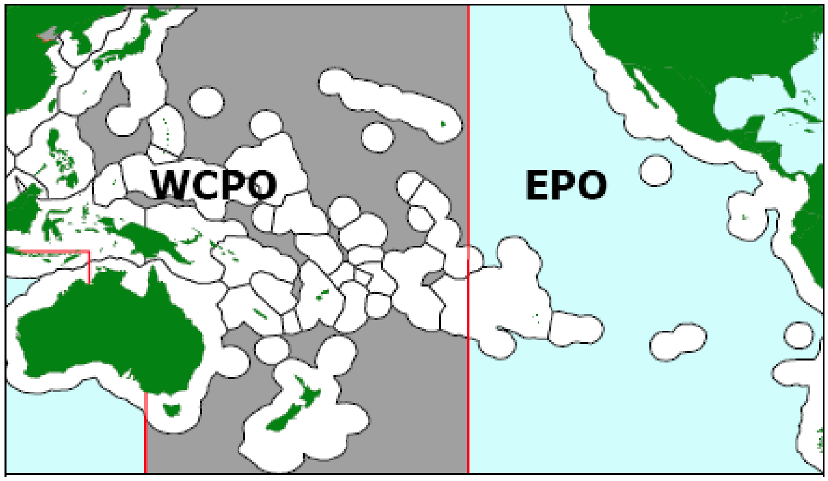

Figure 1. The WCPO and EPO, delineated at 150°W longitude (Figure from PFMC 2006).

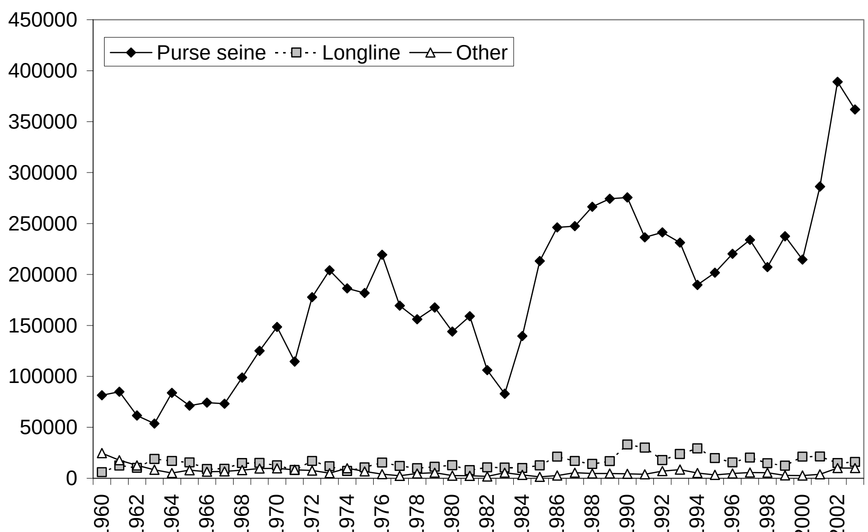

Figure 2. Yellowfin catch in the EPO, 1960 – 2003 (Data from A. Fonteneau pers. comm.).

Overall, yellowfin landings in the WCPO have increased steadily since the 1950s. Several different gear types are used to catch yellowfin in the WCPO, the majority being purse seines (Figure 3) (Hampton et al. 2004), which primarily target skipjack (65% in 2003), but also catch yellowfin (23% in 2003), albacore (7% in 2003), and bigeye (5% in 2003) (Williams and Reid 2004). Japan, Korea, Taiwan, and the U.S. are the four main purse seine fleets operating in the WCPO (Williams and Reid 2004). In addition, catches by vessels flagged by Papua New Guinea have increased steadily since 1999. In 2003, the Japanese, Korean, and Taiwanese fleets set most commonly on unassociated schools, the U.S. fleet set most commonly on unassociated schools and logs, and the Papua New Guinea fleet set most commonly on anchored FADs and unassociated schools (Figure 4) (Williams and Reid 2004).

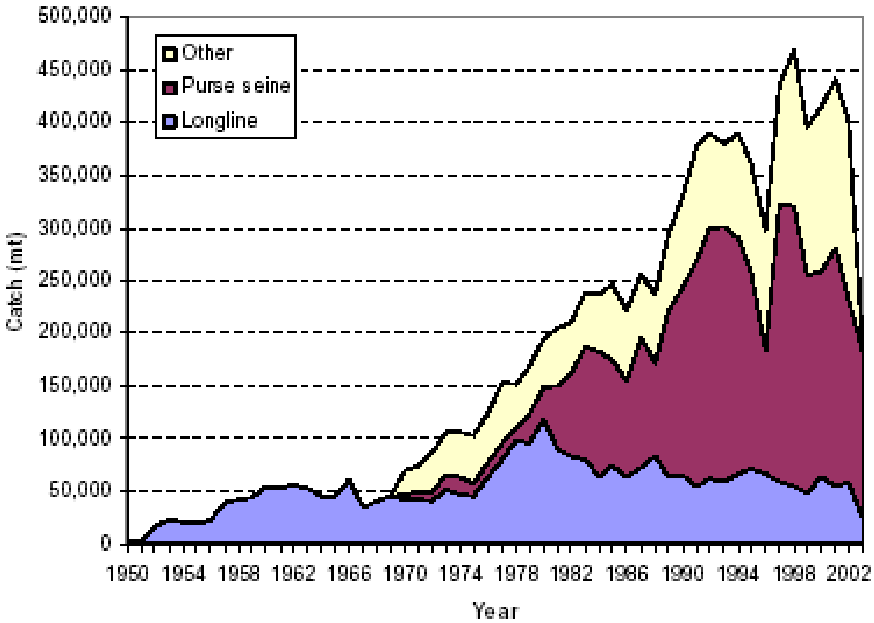

Figure 3. Yellowfin catch in the WCPO by gear, 1950 – 2003. Purse seines are the dominant gear type used to catch yellowfin in the WCPO (Figure from Hampton et al. 2004).

While approximately 60% of the yellowfin catch in the WCPO is from purse seines, yellowfin is also caught with longlines (17%), as well as gillnets, trolls, and handline gear (20%) (Hampton and Fournier 2001). Tuna from the industrial purse seine and pole and line fisheries in the WCPO is mostly frozen and used for canned tuna (Désurmont and Chapman 2000). In Hawaii, there is an offshore handline fishery that targets tuna associated with weather buoys and seamounts, and an inshore fishery that targets tuna associated with moored FADs (Itano and Holland 2000); yellowfin have been shown to travel between these FADs repeatedly (Brill et al. 1999). Adult yellowfin spend between 60 – 80% of their time above 100 m depth in Hawaiian waters (Brill et al. 1999), as well as just above the top of the thermocline in California waters (Block et al. 1997). The majority of yellowfin caught by U.S. vessels in the South Pacific is landed in American Samoa, with less than 1% landed in the U.S. (Coan et al. 1999).

In the Philippines, tuna are caught in small-scale fisheries with handlines and gillnets, as well as large-scale purse seine and ringnet gear; overall there are over 10 gear types used in this fishery in association with FADs, called payaos (Dickson and Natividad 2000). In 2005, much of the bigeye and yellowfin landed in the Philippines was caught with handline gear (Barut and Garvilles 2006). Whereas in the past, most of this product was exported to Japan for sashimi, much of it is now frozen and smoked—Philippines handline-caught and foreign longline-caught tuna are mixed at the processing stages (Barut and Garvilles 2006). This FAD-associated yellowfin is caught in large quantities and at a very small average size (< 1 kg) (SPC data). Purse seine-caught tuna is used for canneries, processing plants, and other related industries, while handline caught tuna is used for sashimi (Dickson and Natividad 2000).

The international management agencies responsible for yellowfin in the Pacific Ocean include the Inter-American Tropical Tuna Commission (IATTC) and the Western and Central Pacific Fisheries Commission (WCPFC). The Pacific Islands Forum Fisheries Agency (FFA) is a management coordination body for Pacific Island nations, while the Secretariat of the Pacific

Community (SPC) provides research and technical assistance. Individual countries may be managed by additional bodies; U.S. fisheries are also managed by the National Marine Fisheries Service (NMFS), the Pacific Fishery Management Council (PFMC), and the West Pacific Fishery Management Council (WPFMC). Regulations are based on recommendations by the staff or scientific committees of the IATTC and WCPFC, and implemented by the member and cooperating countries.

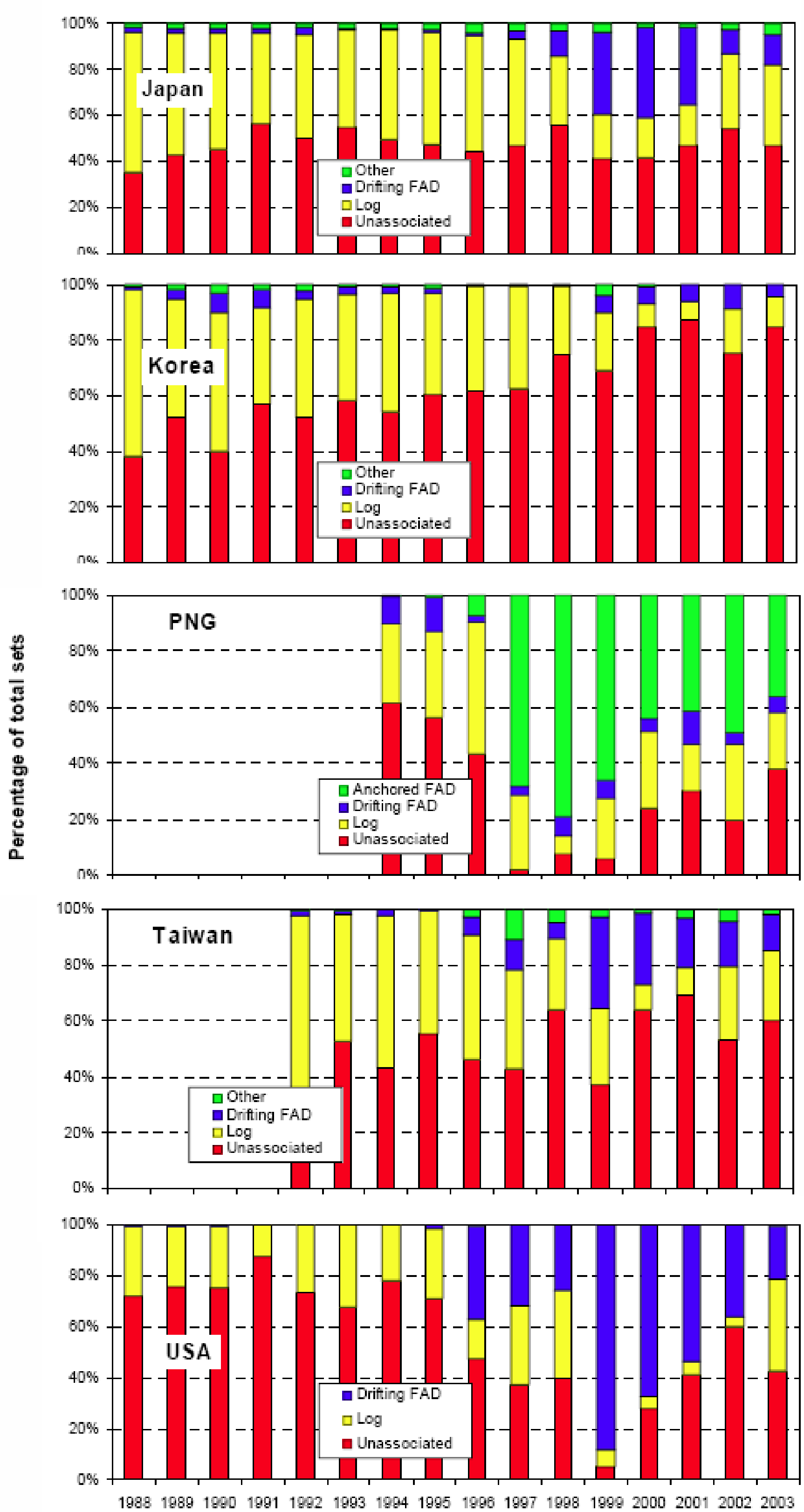

Figure 4. The percentage of total sets by school type for the major purse seine fleets in the WCPO. For the Asian fleets, unassociated school sets accounted for at least 50% of the total purse seine sets in 2003 (Figure from Williams and Reid 2004).

Atlantic

There is one stock of yellowfin in the Atlantic, with its main spawning ground in the equatorial zone of the Gulf of Guinea (ICCAT 2004). In the eastern Atlantic, there are numerous pole and line fisheries operating along the African coast (Figure A1 in Appendix I); the average size of yellowfin caught ranges from 2.5 kg in Tema to 30 kg around the Azores, Canary Islands, and Cape Verde (ICCAT 2004). Purse seiners target spawning yellowfin in the equatorial region of the Atlantic, as well as smaller yellowfin (4 kg) that associate with floating objects along with skipjack and bigeye. Purse seines are the most commonly-used gear in the Atlantic (Figure 5). In the eastern equatorial Atlantic, purse seines are used to target skipjack, bigeye, and yellowfin (Fonteneau et al. 2000b). The equatorial region is considered a nursery and recruitment area for these small tuna (Fonteneau et al. 2000b). Larger yellowfin (34 kg) are caught in free schools (ICCAT 2004). In the western Atlantic, longlines are the primary gear used (catching 27 – 51 kg yellowfin); however, purse seine catches have increased since the early 1980s and are now more common than in the past. From 1998 – 2002 there was no yellowfin landed in the U.S. domestic purse seine fishery in the Atlantic, although international landings of yellowfin in the purse seine fishery averaged 90,941 mt annually over the same time period (NMFS 2004a). Domestic longline catch of yellowfin averaged 2,693 mt annually from 1998 – 2002 (NMFS 2004a). Both U.S. and Mexican longline fleets target yellowfin in the Gulf of Mexico. Although gear configurations and bait-use have varied since the early to mid-1980s, when the fishery began, the Mexican fleet is currently using U.S.-style monofilament gear and live bait, while the U.S. fleet has been prohibited from using live bait since September 1, 2000, due to concerns of billfish bycatch (50 CFR 635, August 1, 2000; Brown et al. 2004).

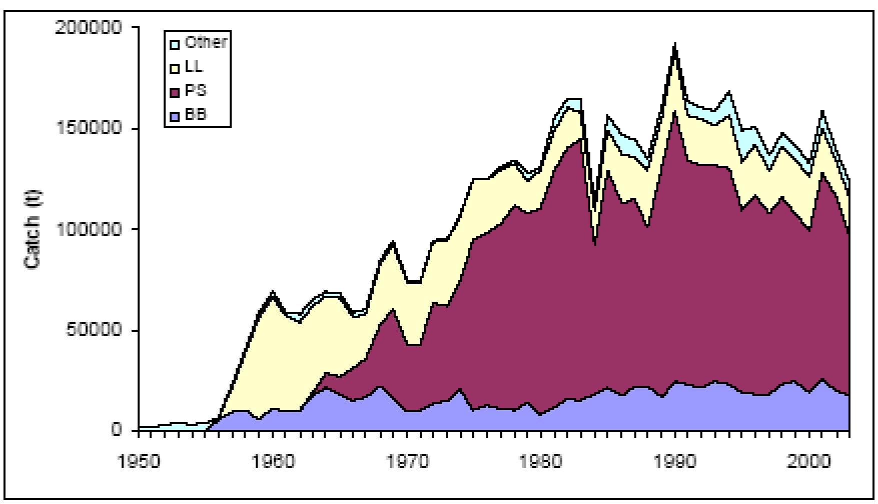

Figure 5. Catch of yellowfin tuna in the Atlantic by gear type, 1950 – 2003. Purse seines are the most common gear type used. LL = longline, PS = purse seine, BB = baitboat (i.e., pole and line) (Figure from ICCAT 2004).

The international management agency responsible for yellowfin in the Atlantic Ocean is the International Commission for the Conservation of Atlantic Tunas (ICCAT), and U.S. fisheries operating in the Atlantic are managed by the Highly Migratory Species (HMS) Division of NMFS. Regulations are based on recommendations by the staff or scientific committees of ICCAT, and implemented by the member and cooperating countries.

Indian Ocean

There is one stock of yellowfin in the Indian Ocean, although there is some uncertainty with its structure (IOTC 2003). Unlike the fisheries for yellowfin in the Atlantic and Pacific Oceans, artisanal fisheries in the Indian Ocean are responsible for 20 – 25% of the total catch (IOTC

2003). Small-scale longliners operate in the Indian Ocean, and the catch is often consumed locally (Miyake 2005). There is also a purse seine fishery that sets on both FADs and unassociated schools, and both industrial and artisanal longline fisheries (Figure 6) (IOTC 2004). In the eastern Indian Ocean, fleets from China, Taiwan, and Indonesia land their catch in Thailand; bigeye is the main target of the Chinese fleet (Nootmorn et al. 2002), while yellowfin is the primary target of the Taiwanese and Indonesian fleets (Nootmorn et al. 2002). Effort in the longline and purse seine fisheries has been increasing since the 1980s, with maximum catch levels reached in 2003 at nearly 500,000 mt (Figure 7) (IOTC 2004). The increased catch level observed in 2003 may be a result of concentrations of yellowfin, as well as increased efficiency in both the longline and purse seine fisheries (IOTC 2004). Increased FAD use and monitoring are also likely contributing to the increased catch levels and efficiency of the fishery (D. Itano, pers. comm.). If this increased catch was indeed due to increased catchability, rather than increased biomass of yellowfin, these fishing mortality results would lead to the yellowfin stock in the Indian Ocean being overexploited (IOTC 2004). In general, most of the yellowfin catch is taken in the western Indian Ocean, with 45% of the total yellowfin catch from the purse seine fishery (Figure A2 in Appendix I) (IOTC 2003). From 1995 – 2003, FAD sets accounted for 59 – 76% of the total purse seine yellowfin catch (IOTC 2005). Yellowfin in the Indian Ocean is managed by the Indian Ocean Tuna Commission (IOTC). Regulations are based on recommendation by the staff or scientific committees of the IOTC, and implemented by the member and cooperating countries.

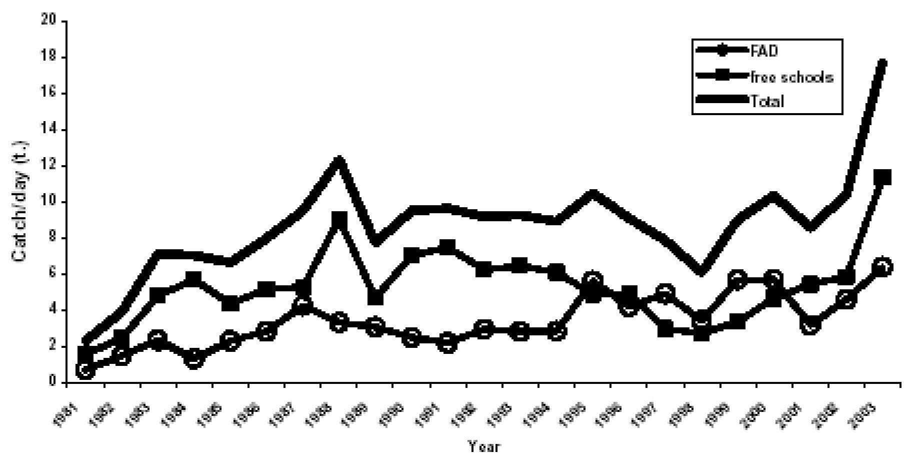

Figure 6. Catch rates (catch/day in mt) for yellowfin caught in the purse seine fisheries in the Indian Ocean, which has been dominated by sets on free schools (i.e., unassociated schools) in recent years (Figure from IOTC 2004).

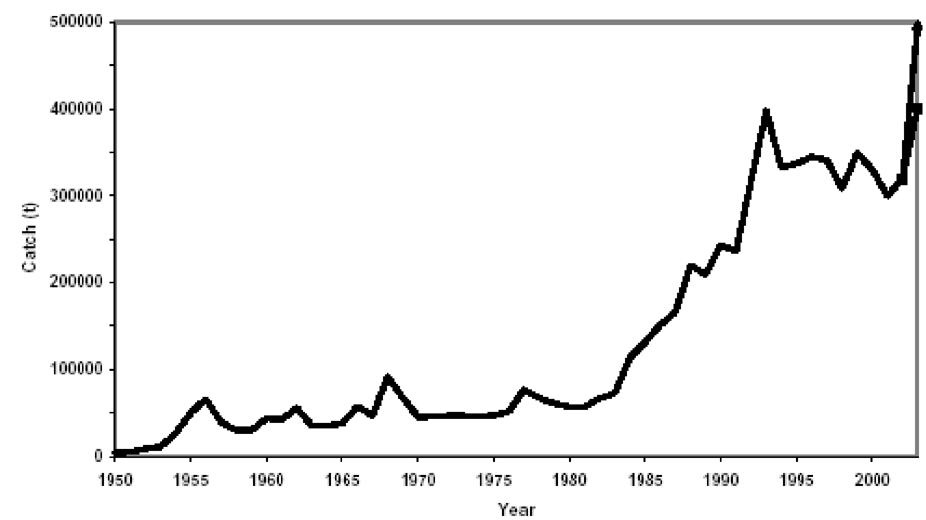

Figure 7. Yellowfin catch in the Indian Ocean, 1950 – 2003 (Figure from IOTC 2003).

Table 1. Yellowfin catch by region, country, and gear.

Region	Catch[2]	Fishing Countries	Gears Used	Sources
East Atlantic	98,125 mt (8%)	France (33%); Spain (25%); Ghana (19%); Netherlands / Antilles (7%); NEI (5%); Taiwan (5%); Japan (2%); Cape Verde (2%); China P.R. (1%); Latvia, South Africa, Senegal, Namibia, Maroc, Gabon, Angola, Philippines, Portugal (<1% each)	Purse seine (77%); pole and line (14%); longline (8%); other surface gears (2%)	ICCAT 2004
West Atlantic	24,978 mt (2%)	U.S. (31%); Venezuela (30%); Brazil (14%); Taiwan (7%); Mexico (5%); Grenada (3%); Japan (3%); St. Vincent / Grenadines (2%); Dominican Republic, Trinidad & Tobago, Philippines, Sta. Lucia, Dominica, Barbados, Canada, Cuba, Bermuda, Colombia, China PR (< 1% each)	Longline (41%); other surface gears (26%); purse seine (18%); pole and line (15%)	ICCAT 2004
Western and central Pacific	464,150 mt (40%)	Philippines (26%); Indonesia (22%); Japan (11%); Taiwan (10%); Republic of Korea (10%); Papua New Guinea (8%); U.S. (5%); Solomon Islands (1%); China (1%); Federate States of Micronesia (1%); other countries[3] (< 1%)	Purse seine (61%); longline (16%); pole and line (3%); troll (1%); other gear (19%)	Lawson 2004b; WCPFC 2010
Eastern Pacific	273,743 mt (23%)	Mexico (33%); Venezuela (21%); Bolivia, Colombia, Guatemala, Honduras, Nicaragua, El Salvador, Unknown (17%); Ecuador (15%); Panama (12%); Spain, U.S., Taiwan, Vanuatu, Costa Rica, Belize (≤ 1% each)	Purse seine (98%), longline, pole and line (< 1%)	IATTC 2005
Indian Ocean	312,000 mt (27%)	Spain (17%); France (12%); Indonesia (10%); Taiwan (9%); Iran (8%); Maldives (7%); NEI (6%); Sri Lanka (6%); Seychelles (5%); Japan, Oman, NEI (excluding Russia), Comoros, NEI-fresh tuna, Other, NEI-deep freezing, India , Pakistan, China, Yemen, Tanzania, Korea, Mauritius (<5%)	Purse seine (45%); longline (27%); gillnet (17%); pole and line (7%); line (2%); other (1%)	IOTC 2003

[2] Catch data for the Atlantic Ocean are from 2003, data for the Indian Ocean are from 2002, data for the EPO are from 2004, and data for the WCPO are from 2003.
[3] Other countries include New Zealand, Australia, Fiji, Kiribati, Marshall Islands, French Polynesia, New Caledonia, American Samoa, Samoa, Tonga, Cook Islands, Vanuatu, Guam, Palau, Northern Marianas, and Nauru.

Scope of the analysis and the ensuing recommendation:
This analysis encompasses yellowfin tuna caught by domestic and foreign vessels in the Atlantic, Pacific, and Indian Oceans. Due to the limited data available for some criteria, particularly bycatch, generalizations by both country and ocean basin have been made concerning the severity of bycatch in the pelagic longline and purse seine fisheries.

Availability of Science

There is a need for increased catch, effort, and size data for Indonesian and Philippine fisheries in the WCPO (Hampton et al. 2004). There is also a considerable lack of data in the Indian Ocean, including poor knowledge of catches, efforts, and size-frequency for the fresh tuna longline fleets and deep freezing longlines fleets since the mid-1980s, a lack of accurate data from the Indonesian fishery before 2002, and poor knowledge of the catch composition from Russian Federation purse seiners operating under flags of convenience (IOTC 2004). There are no international data on the bycatch levels and trends in pelagic longline and purse seine fisheries, and observer coverage and data varies by ocean. Although individual countries or commissions may have bycatch mitigation regulations or observer programs, much of these data are not available to the public and therefore cannot be evaluated. IUU fishing creates the additional problem of lack of data collection and reporting. Observer data from the WCPO has high confidence intervals due to low rates of observer coverage, with an overall coverage rate of less than 0.1% (Molony 2005).

Due to the complexity of the global tuna fisheries, more detailed recommendations are included in this report than will be reflected in the general recommendation that appears on the Seafood Watch® pocket guides.

Market Availability

Common and market names:
The Hawaiian name for yellowfin is ahi, a term which has become common in the mainland U.S. as well. Yellowfin imported from countries such as the Philippines and Indonesia is also sold as ahi. When used for sushi or sashimi, yellowfin is commonly sold as *maguro* or *toro.*

Seasonal availability:
Yellowfin is available year-round.

Product forms:
Yellowfin is sold as light canned tuna, which may be a mixture of the following species: yellowfin, bigeye, skipjack, longtail, and bluefin (NMFS 2004b,c). Yellowfin caught in purse seines is primarily used for canning, while yellowfin caught with longlines is used for sashimi (Hall 1998; Beverly 2002). Yellowfin is also sold fresh, frozen, or smoked. Imported, non-canned yellowfin may be treated with tasteless smoke to maintain the appearance of red flesh; the primary ingredient in tasteless smoke is carbon monoxide. Although the use of carbon monoxide is not thought to cause any health concerns, seafood treated with carbon monoxide has been banned in Canada and many European countries so that spoiled fish may not be sold as

fresh fish. U.S. sources of yellowfin do not need to be treated with carbon monoxide, as there is less time from when the fish is caught until it gets to the market.

Import and export sources and statistics:
In 2004, 21,457 mt of fresh and frozen yellowfin was imported from 54 countries, the vast majority of which (approximately 78%) came from Indonesia, the Philippines, Vietnam, Trinidad and Tobago, Brazil, Costa Rica, Mexico, and Panama (Figure 8) (NMFS 2005a). Other sources of fresh and frozen yellowfin tuna in 2004 included Fiji, Venezuela, Thailand, Ecuador, Singapore, Canada, Grenada, Western Samoa, Taiwan, Malaysia, Maldive Islands, Barbados, South Africa, Sri Lanka, Marshall Islands, El Salvador, French Polynesia, Uruguay, China, Papua New Guinea, Federated States of Micronesia, Tonga, Australia, Japan, Cook Islands, Oman, South Korea, Portugal, Chile, Turkey, Guatemala, Italy, Solomon Islands, New Zealand, India, Spain, Colombia, Dominican Republic, Guinea, Honduras, Iceland, Peru, Israel, Tunisia, France, and Senegal.

Both canned yellowfin and canned skipjack tuna are sold as light tuna, and these two species (amongst the others mentioned above) are often mixed in the canning process. In 2004, a total of 172,093 mt of non-albacore canned tuna[4] was imported to the U.S., 98% of which came from six countries: Thailand (45%), the Philippines (25%), Ecuador (17%), Indonesia (7%), Vietnam (4%), and Mexico (1%). The remaining countries that imported non-albacore canned tuna in 2004 were China, South Korea, Costa Rica, Malaysia, Guinea, Spain, Portugal, Colombia, Papua New Guinea, Iran, Italy, Taiwan, Singapore, Brazil, India, Peru, Croatia, Japan, Canada, Cape Verde, Turkey, and Argentina (NMFS 2005a).

The U.S. and Europe are the two main markets for canned tuna, and the U.S. did not export any canned tuna in 2004. In addition, Mexico consumes much of their purse seine catch domestically as canned tuna. In 2004, Fiji and Trinidad & Tobago dominated as the primary source of tuna loins for the U.S. (Eurofish 2005). Some of the tuna imported into the U.S. is then canned in California, American Samoa, or Puerto Rico canneries (Eurofish 2005). Tuna canneries in Thailand process tuna from the Indian Ocean and western Pacific (Sharp 2001). The U.S. has been the largest importer of canned tuna globally almost every year from 1979 – 2001 (FAO 2003). Canned tuna imports in 2004 were 201,078 mt, 14% of which was canned albacore (NMFS 2005a). The total dollar amount of non-albacore canned tuna imported in 2004 was US$365 million (NMFS 2005a). However, overall tuna consumption in the U.S. is declining (Eurofish 2005), possibly due to increased concerns about mercury in canned tuna and increased prices due to lower world tuna supply (Johnson 2004).

In 2004, 97% of "other" (yellowfin, bigeye, bluefin, and longtail) canned tuna from domestic canneries was from the western Pacific, and 3% was from the eastern Pacific (NMFS 2004c). Imports of "other" canned tuna were from the eastern Pacific (25%), western Pacific (75%), and the Indian Ocean (<1%) (NMFS 2004c).

In 2003, the most recent year for which both U.S. landings data and foreign trade data are available, U.S. landings were 9.6% of the fresh and frozen yellowfin tuna available in the U.S.

[4] This tuna was listed as "not specifically provided for", and is likely a mix of yellowfin, skipjack, and tongol tuna.

market. Thus, approximately 90% of the fresh and frozen yellowfin consumed in the U.S. is imported.

It should be noted that yellowfin imported from a particular country does not necessarily mean that the yellowfin was caught by the importing country's fishing fleet. For instance, vessels from many countries land their tuna catch at various ports around the world; Taiwan alone has 73 foreign ports where they transship and land their tuna catch (Fisheries Agency undated). Taiwanese vessels land yellowfin tuna in both Indonesian and Philippines ports; thus yellowfin imported from these two countries may not be caught by the domestic Indonesian and Philippines fleets (Yamashita 2000).

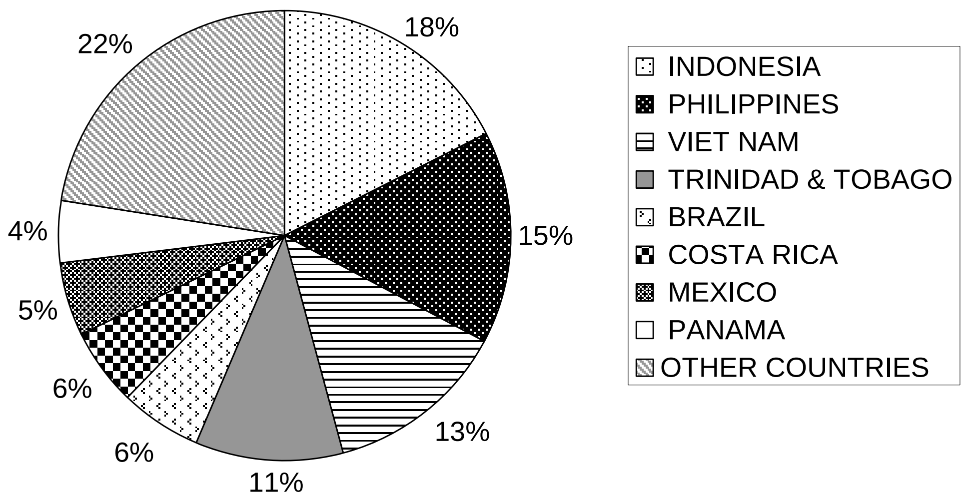

Figure 8. Imports of fresh and frozen yellowfin tuna in 2004 (NMFS 2005a).

III. Analysis of Seafood Watch® Sustainability Criteria for Wild-caught Species

Criterion 1: Inherent Vulnerability to Fishing Pressure

Yellowfin has a broad species range, being found in the Pacific, Atlantic, and Indian Oceans (Table 2), and is primarily caught in warm shallow waters > 20°C. Yellowfin is also a schooling tuna, and associates with floating objects, making it easier to catch. Various size classes of yellowfin are more vulnerable to certain fishing gears. Large yellowfin are caught by longline and in the dolphin-set purse seine fisheries, while smaller yellowfin are caught in the FAD, unassociated, and log-associated purse seine sets. Yellowfin play an important role in the pelagic ecosystem, as they are large predators and consume fish, crustaceans, and squid (Froese and Pauly 2005).

The intrinsic rate of increase for yellowfin is 0.20 (Au et al. in press in PFMC 2003). Yellowfin females reach maturity at about 2 years of age (Froese and Pauly 2005). In the Indian Ocean, the size at first maturity has been estimated at 110 centimeters (cm) (IOTC 2003); in the WCPO, size at 50% maturity has been estimated at 107.8 cm and 2.4 years (Sun et al. 2005); and in the EPO, size at 50% maturity has been estimated at 92.1 cm (Schaefer 1998).

Estimates of "k," the growth coefficient, range from 0.13 – 0.42 (Froese and Pauly 2005). However, there is evidence that growth patterns deviate from the von Bertalanffy model for yellowfin up to 80 cm (Gascuel et al. 1992; Lehodey and Leroy 1999). Wild (1986 in Maunder and Harley 2005) estimated L_∞ = 188.2 and annual k = 0.724. Yellowfin growth rates in the Indian Ocean may be slower than in other regions (IOTC 2004). Yellowfin have been measured at a maximum length of 201.5 cm FL (fork length) and a maximum weight of 181.3 kg (K. Schaefer, pers. comm.), although sizes over 180 cm are very seldom caught (A. Fonteneau, pers. comm.). According to Schaefer and Fuller (2006, p. 45): "The apparent longevity for yellowfin, based on an estimated maximum age of at least 8 years (Alex Wild, pers. comm.) and the estimated age of the longest-term recapture of 8 years from the Secretariat of the Pacific Community, Oceanic Fisheries Programme tuna tagging database (John Hampton, pers. comm.), is at least 8 years."

Tunas are repetitive broadcast spawners, and are highly fecund (Schaefer 2001). Adult yellowfin spawn in waters warmer than 24°C – 25°C (Schaefer 1998, 2001; Itano 2000). In the Indian Ocean, spawning mainly occurs from December to March, with the main spawning grounds between 50 – 70°E longitudes (IOTC 2003). In the Atlantic, spawning occurs from January to April in the equatorial zone of the Gulf of Guinea, with additional spawning grounds in the Gulf of Mexico, the southeastern Caribbean Sea, and waters off Cape Verde (ICCAT 2004). In the eastern tropical Pacific (ETP) yellowfin spawning occurs continuously throughout the year, with no pronounced seasonal patterns in intensity (Schaefer 1998). In the WCPO, spawning occurs throughout the year, with a peak from February to June (Sun et al. 2005), and yellowfin spawn almost daily when they are reproductively active (Sun et al. 2005).

Overall, spawning occurs throughout the year in equatorial waters where sea surface temperature (SST) does not drop below 25°C, and occurs seasonally at higher latitudes. Yellowfin is highly fecund, with average batch fecundity estimated at 2.5 million oocytes, or 67.3 oocytes per gram of body weight, by Schaefer (1996), 2.71 million oocytes by Sun et al. (2005), and 3.45 million oocytes by Itano (2000).

Table 2. Life history characteristics of yellowfin.

Intrinsic Rate of Increase (r)	Age at Maturity	Growth Rate	Max Age	Max Size	Fecundity	Species Range	Special Behaviors	Sources
0.20	2 yrs	vBgf[5]: L_∞ = 188.2, annual k = 0.724	8 yrs	201.5 cm fork length (FL)	Highly fecund	Atlantic, Pacific, and Indian Oceans	Associates with floating objects, dolphins in EPO, whales, and whale sharks	Wild 1986; PFMC 2003; Brown et al. 2004; Froese and Pauly 2005

[5] vBgf = a commonly used growth function in fisheries science to determine length as a function of age. L_∞ is asymptotic length, and k is body growth coefficient. Note that maximum size may be larger than L_∞ due to individual variation around L_∞.

Synthesis
Compared to other finfishes, yellowfin matures at an early age (2 years), and is moderately long-lived, with a maximum age of 8 years. Yellowfin has a broad species range, and is found in the Atlantic, Pacific, and Indian Oceans. Although yellowfin is a schooling species and is attracted to floating objects, thereby increasing ease of capture, yellowfin is considered inherently resilient to fishing pressure due to the above life history characteristics.

Inherent Vulnerability Rank:

Resilient	Moderately Vulnerable	Highly Vulnerable

<u>Criterion 2: Status of Wild Stocks</u>

The stock status of yellowfin varies by stock (see Table 3 at the end of this section for a summary). Additionally, increases in the use of FADs has added uncertainty to many stock assessments due to changes in fishing effort, fishing locations, and the size of tuna caught (Fonteneau et al. 2000). The large number of FAD fisheries operating worldwide could possibly lead to overfishing of many tuna stocks (Fonteneau et al. 1999).

Pacific
Eastern Pacific
The most recent stock assessment for yellowfin in the EPO was conducted in 2009 using an age-structured, catch-at-length analysis (Maunder and Aires-da-Silva 2009). The stock assessment for yellowfin in the EPO defines 16 different fisheries based on gear type, type of purse seine set, and length-frequency sampling area or latitude; catch and effort data are stratified according to these fishery definitions (Maunder and Aires-Da-Silva 2009). The 2009 assessment uses different software than the previous assessment (2008), allowing modeling of sex-specific data and the inclusion of abundance indices rather than just effort. Catch and length frequency data were updated to include 2008 data. Catch data include catch and discards for the large purse seine fisheries, and only retained catches for the pole and line and longline fisheries. There is also a subset of purse seine fisheries that set on floating objects, and catch the small fish discarded in the larger purse seine fisheries (Figure A3 in Appendix I) (Hoyle and Maunder 2005). While more fish are caught in purse seine fisheries that associate with dolphins, the floating-object and unassociated purse seine fisheries have a greater impact on yellowfin spawning biomass due to their catching of younger fish (Maunder and Aires-da-Silva 2009).

The IATTC convention provides that the biomass must be at a level that allows permitting MSY year after year. Apart from that, the IATTC has not defined target or limit reference points for yellowfin. The stock was assessed based on several measures, including spawning stock biomass and yield per recruit, discussed below.

The 2009 spawning stock biomass (SSB) for yellowfin in the EPO increased since the 2006 assessment, at which point SSB is thought to have been at its lowest level since 1983 (Maunder and Aires-da-Silva 2009). The estimated spawning biomass ratio at MSY (i.e. spawning biomass corresponding to MSY or SBR_{MSY}) decreased from 0.34 in the 2008 assessment to 0.27 in the

2009 assessment (due to changes in the assessment methodology as noted above). Current (beginning of 2009) SBR is estimated at 0.35, which implies that the current spawning stock biomass is above the level corresponding to MSY (.35/.27 = 1.3) (Figure 9) (Maunder and Aires-da-Silva 2009). Furthermore, the entire 95% confidence interval range (0.27 and 0.43) is at or above SBR_{MSY}. Maunder and Aires-da-Silva 2009) indicate that the $F_{curren}t/F_{MSY}$ ratio (0.92) is just below that which would produce MSY, indicating that the stock is fully exploited and that overfishing is not occurring. Biomass is thus projected to remain at or above MSY for the next five years under current fishing levels (the average of 2006-2008) and average environmental conditions (Figure 9) (Maunder and Aires-da-Silva 2009).

Restrictions on fishing effort in the form of a temporal purse seine fishery closure and limits on longline catches have been implemented through IATTC resolutions and recommendations in 2004 (Resolution C-04-09), 2006 (Resolution C-06-02), and 2009 (Recommendation C-09-02). Fishing mortality has been highly variable for the various age classes of yellowfin in the EPO, and short-term increases in fishing mortality on the majority of age classes corresponds with short-term declines in stock abundance (Figure 10) (Maunder and Aires-Da-Silva 2008). It is unknown if the population is skewed relative to the unfished condition.

The 2009 assessment authors note the SBR estimates are reasonably precise, as shown by the relatively close 95% confidence intervals. Nonetheless, they note that there is still uncertainty about recent and future recruitment and biomass levels and some indication that recent recruitment may have been overestimated. The results are also sensitive to some of the assumptions made, such as no stock-recruitment relationship, natural mortality, the method used to model sensitivity, and maximum length (Maunder and Aires-da-Silva 2009). In particular, the model assuming a stock-recruitment relationship, which was run as a sensitivity analysis, results in more pessimistic estimates, including a current biomass estimate below the level corresponding to MSY ($B_{current}/B_{MSY}$=0.78; Figure 9). The model with a stock-recruitment relationship (steepness = 0.75) fit the data better than the base case assuming recruitment was independent of stock size; however, this pattern could also be explained by a regime shift that affected both stock size and recruitment (Maunder and Aires-da-Silva 2009). Indeed, the WCPO yellowfin stock assessment (see discussion in WCPO section below) does use the assumption that there is a stock-recruitment relationship with steepness=0.75, noting that "For tuna species, there are no strong empirical data available to inform the model regarding the likely range of values of steepness of the SRR that underpin the *MSY* based stock indicators." (Langley, Harley et al. 2009 p4).

Furthermore, it appears there have been two, and possibly three, different environmental regimes affecting the productivity of yellowfin since the 1970s, and the levels of MSY and B_{MSY} may differ among the regimes (Maunder and Aires-da-Silva 2009). The population may have recently switched from the high productivity regime to the moderate productivity regime (Maunder and Aires-da-Silva 2009), suggesting current MSY and biomass corresponding to MSY may be lower than in earlier decades.

The stock status of yellowfin based on yield per recruit indicates that the average weight of yellowfin caught in all of the fisheries is far less than the critical weight for yellowfin in the EPO, which is estimated at 35.2 kg (IATTC 2008). Thus, the yield per recruit is generally not being maximized in these fisheries, with only the longline and dolphin-associated fisheries catching yellowfin larger than the critical weight (Maunder and Aires-Da-Silva 2008). The average weight of yellowfin caught in the EPO remained between 12 – 22 kg from 1975 – 2007 in all the fisheries combined, although these averages vary between the different gear types (Maunder and Aires-Da-Silva 2008). Theoretically, SBR levels would increase if effort were diverted to those fisheries catching larger yellowfin (i.e., the dolphin-associated purse seine and longline fisheries) (IATTC 2008).

According to the latest stock assessment, the EPO yellowfin stock is not subject to overfishing, and has recovered from the overfished condition it has been in since the mid 2000s. Short and long-term trends are variable, and there is still moderate uncertainty associated with various elements of stock status. Biomass is estimated to be above B_{MSY} according to the base model, but a sensitivity analysis exploring the model's assumptions suggests that biomass may still be moderately below B_{MSY}, depending on biological attributes of the stock that are unknown. Accordingly, the status of this stock is considered a moderate conservation concern according to Seafood Watch® criteria.

Seafood Watch® will continue to monitor the fishing mortality as a result of effort reductions specified in IATTC Resolution C-09-02.

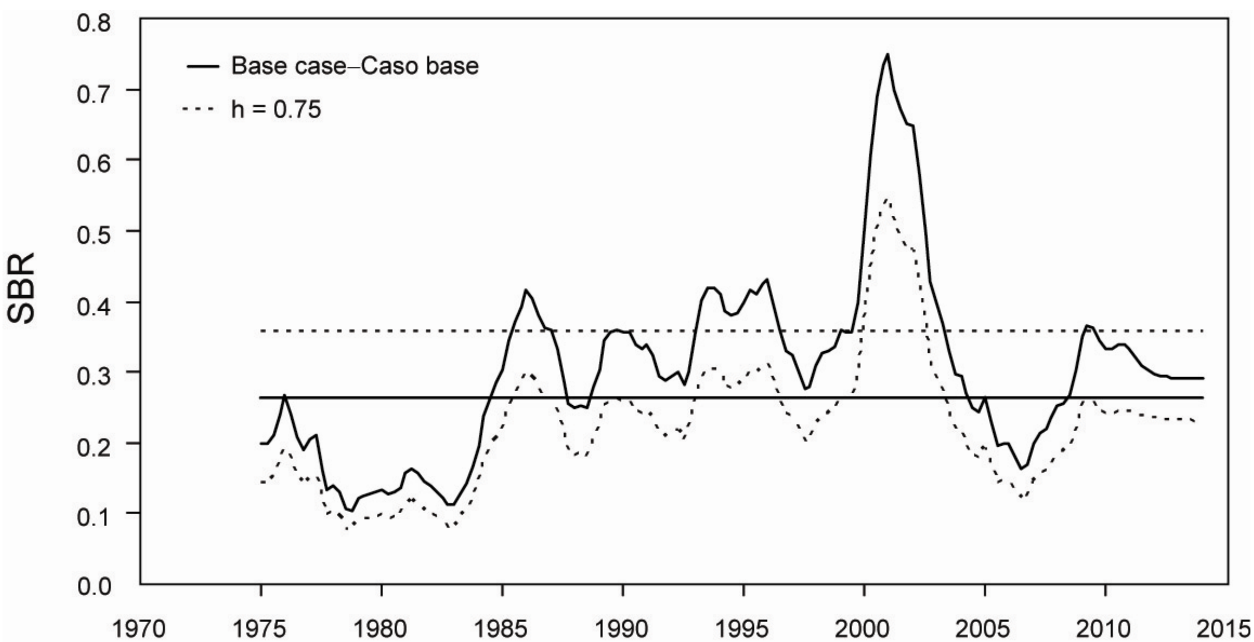

Figure 9. Comparison of estimates of the spawning biomass ratios (SBRs) projected during 2009-2013 for yellowfin tuna from the analysis without (base case) and with (steepness = 0.75) a stock-recruitment relationship. The horizontal lines represent the SBRs associated with MSY for the two scenarios (Figure and caption text from Maunder and Aires-da-Silva 2009).

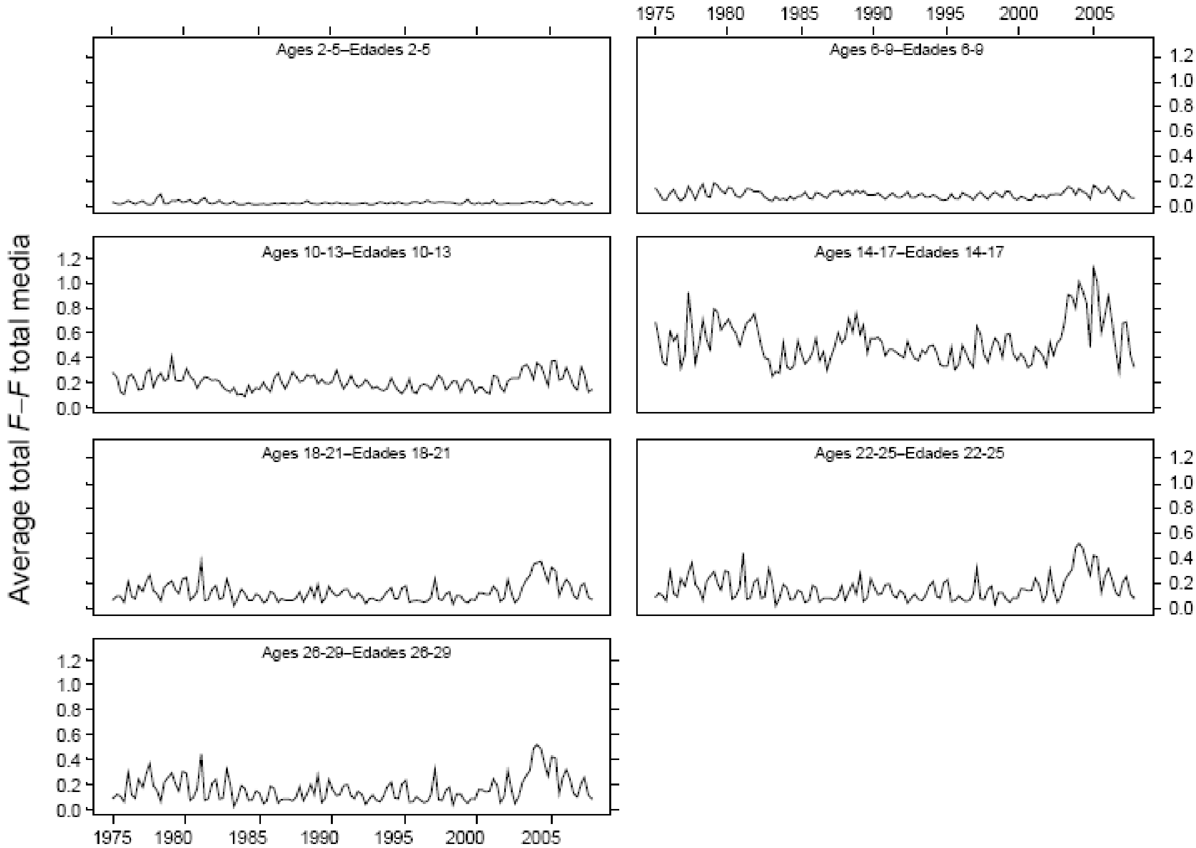

Figure 10. Average fishing mortality at age on yellowfin in the EPO. Ages shown are in quarters (Figure from Maunder and Aires-Da-Silva 2008).

Western and Central Pacific

The most recent stock assessment for yellowfin in the WCPO was conducted in 2009 (Langley, Harley et al. 2009). The assessment used updated catch, effort, length-frequency, and weight-frequency fishery data, as well as the tag release-recapture data that were used in the previous assessment (Langley et al. 2007). In the 2007 and 2009 assessments, the model analysis of yellowfin stock status is spatially structured into six separate regions (Figure A4 in Appendix I) comprising 19 fisheries, based on the CPUE data collected from the combination of gear types and flags. This differs from the previous (2006) assessment in that one of the regions (the area north of 20°N) was divided into two regions, and the boundary between the western and eastern regions was shifted from 160°E to 170°E. The Chinese and Taiwanese longline data are defined separately from the other longline fisheries due to the different size composition of yellowfin caught by these fleets, which may be related to the fact that these fisheries have shallow, night sets (Hampton et al. 2004). The 2009 assessment model inputs differ from the 2007 assessment in a few ways, most particularly in the use of alternative catch history data for the purse seine fleet, which includes a substantially higher level of catch for the associated purse seine fishery (Langley, Harley et al. 2009).

Six models were used to assess the yellowfin stock in the WCPO, providing a range of biomass and fishing mortality estimates. Biomass trends also vary based on the different fisheries, reflecting differing CPUE trends. Likely estimates of $B_{CURRENT}/B_{MSY}$ range from 1.23 – 1.67, while current spawning biomass ($SB_{CURRENT}$)/SB_{MSY} estimates range from 1.28 – 1.89 (Langley, Harley et al. 2009). The highest $F_{CURRENT}/F_{MSY}$ ratio was 0.87 for the most heavily fished region (region 3); the ratio was considerably lower in all other regions. The key source of uncertainty is that of the stock-recruitment relationship, but even with various values used for this parameter (i.e., the 'steepness' parameter), most model options still estimated that biomass (either B or SB) is well above the B_{MSY} level and fishing mortality is well below the level that would lead to MSY (F_{MSY}) (Langley, Harley et al. 2009).

While the six models give different biomass levels, the trends are similar (Figure 11) (Langley, Harley et al. 2009). Biomass trends were generally stable from the 1970s – 1990s, and have declined by approximately 50% since (Hampton et al. 2005a; Langley et al. 2007; Langley, Harley et al. 2009). In particular, the region with the highest biomass (region 3) has exhibited a strong declining trend, which is reflected in the overall biomass trend for the WCPO. Throughout the WCPO, fishing mortality has exhibited an increasing trend, and catches may have exceeded MSY over the course of several years (from 1998 – 2000) (Hampton and Fournier 2001). It is unknown if the population is skewed relative to the unfished condition.

Region 3, the region with the highest catch, also exhibits the greatest depletion of any region in the WCPO. The WCPO stock as a whole is depleted to about 60% of unfished levels, well above the target reference point of 35% -40% of unfished biomass. However, if regions were analyzed separately, region 3 would be considered fully fished (at approximately 30% of unexploited levels) while the other regions would be considered under-exploited. As any increase in fishing pressure would likely occur in region 3, the use of stock-wide reference points may obscure any regional depletion that could occur in region 3 in the future, and it would be more conservative to use regional reference points (Langley, Harley et al. 2009).

According to the latest stock assessment, the WCPO yellowfin stock is not subject to overfishing, nor is it overfished. Short and long-term trends are down for biomass and up for fishing mortality. Despite moderate uncertainty, all estimates of biomass indicate it is above B_{MSY}, and all estimates of fishing mortality indicate it is below MSY (even when a stock-recruitment relationship is assumed). Stock status is thus deemed a low conservation concern according to Seafood Watch® criteria. However, several factors are a concern: moderate uncertainty, steeply increasing fishing mortality, the potential for localized depletion in the region with the highest catch, the previous (2007) assessment indicating that overfishing may be occurring, and the new (2009) assessment being based on the model outputs of a new software program. Seafood Watch will thus continue to closely monitor the fishery.

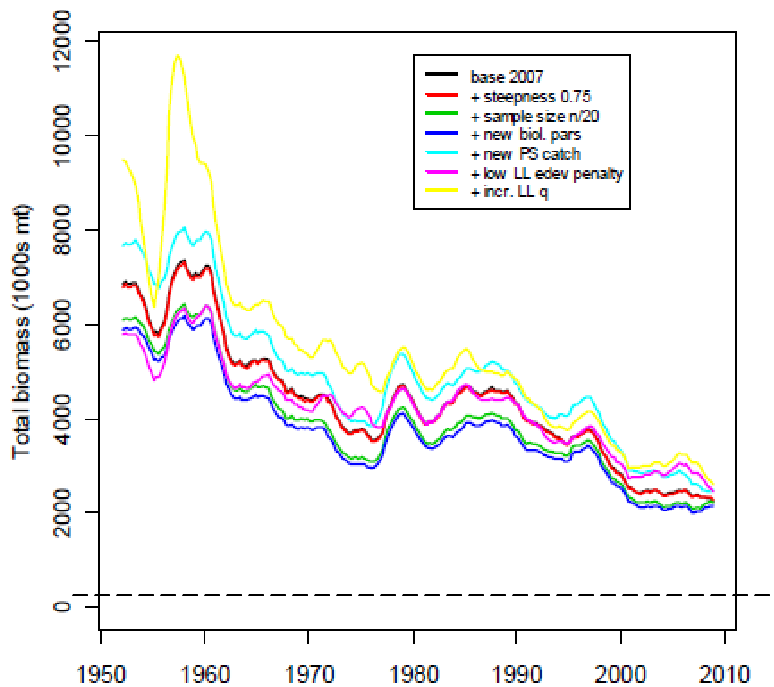

Figure 11. Estimates of WCPO yellowfin biomass (thousands of mt) from the model outputs in the 2009 stock assessment (Figure from Langley, Harley et al. 2009). Dashed line is an approximation of estimated B_{MSY} for illustration (actual value range 1.6 – 1.98 million mt).

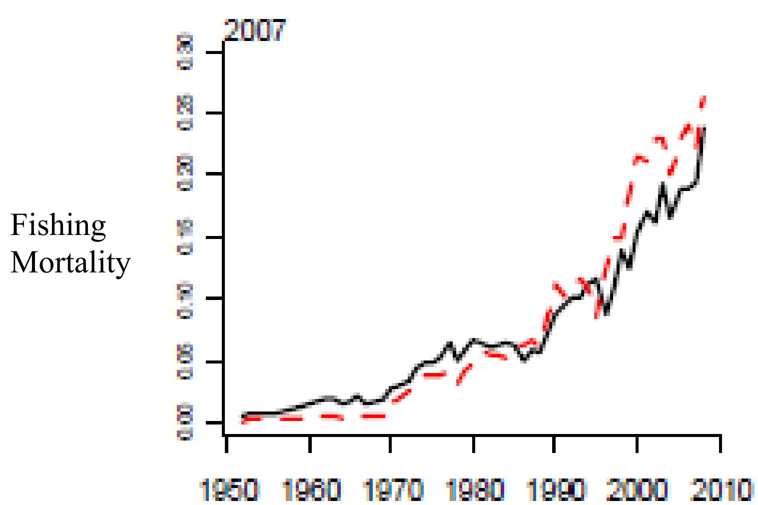

Figure 12. Estimated annual fishing mortality for adult (black line) and juvenile (red dashed line) yellowfin in the WCPO, from the model with the best fit to the composite data and prior assumptions (Base 2007 model) (Figure from Langley, Harley et al. 2009).

Atlantic
The most recent stock assessment for yellowfin in the Atlantic was conducted in 2008 (SCRS 2008). Two models, a non-equilibrium production model (ASPIC) and a virtual population analysis (VPA) model, were applied to fishery catch and effort data through 2006; no fishery independent data were used. Estimates of B_{2006}/ B_{MSY} and F_{2006}/ F_{MSY} vary with model and model assumptions but there is general agreement of a long and short-term declining trend in biomass with a flattening-out or increase in the last couple of years (Figures 13a, 13b). The VPA model estimates B_{2006}/B_{MSY}=1.09 and F_{2006}/F_{MSY}=0.84, while the ASPIC model gives more pessimistic results, estimating B2006/BMSY=0.83 and F2006/Fcurrent=0.89 (SCRS 2008).

The VPA analysis indicates that, while overfishing ($F>F_{MSY}$) has occurred in recent years, current status is neither overfished nor is there overfishing occurring. The ASPIC model indicates the stock has been overfished ($B<B_{MSY}$) and experiencing overfishing in recent years, but that overfishing was not occurring in 2006 ($B_{2006}/B_{MSY}<1$ however indicating the stock is still overfished). Furthermore, there is moderate uncertainty around the different model outputs. When this is taken into account (using a statistical approach known as bootstrapping), there is only a 40% chance that the stock is not overfished and overfishing is not occurring (Figures 13 and 14) (SCRS 2008).

Catch at age data show an increase in the catch of age-0 and age-1 yellowfin, particularly from 1998 – 2001 (ICCAT 2004). CPUE data from Taiwanese longline vessels in the Atlantic are highly variable, with a dramatic decline observed from 1968 until the mid 1970s (Figure 14). From the mid-1970s until the mid-1990s, CPUE remained at a relatively stable level (Ma and Hsul 1997).

Depending on the assessment model, biomass is either just above (109%) or slightly below (84%) B_{MSY}. Both indicate that overfishing is no longer occurring. However, there is moderate uncertainty which, when taken into account, indicates a good chance (60%) of the stock undergoing overfishing, being overfished, or both. Stock status is thus considered a moderate conservation concern according to Seafood Watch® criteria.

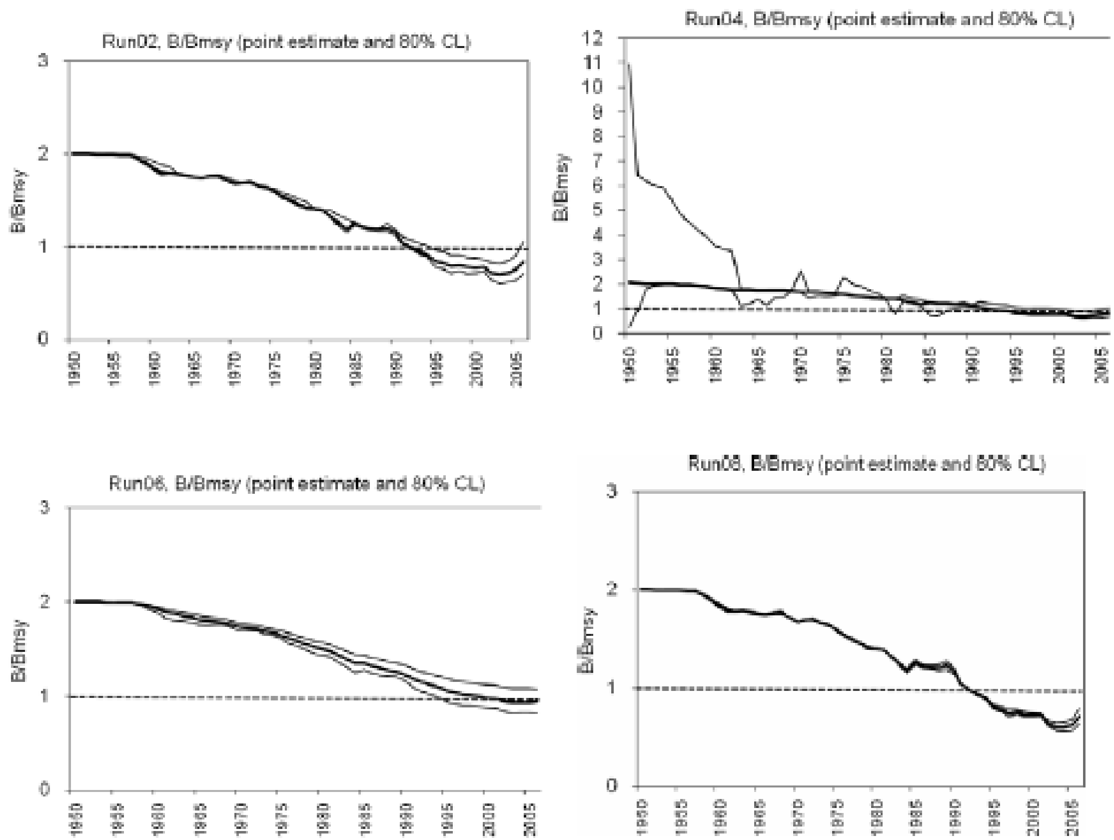

Figure 13: Estimated relative biomass trajectories and 80% confidence intervals estimated from 500 bootstraps (Figure from SCRS 2008).

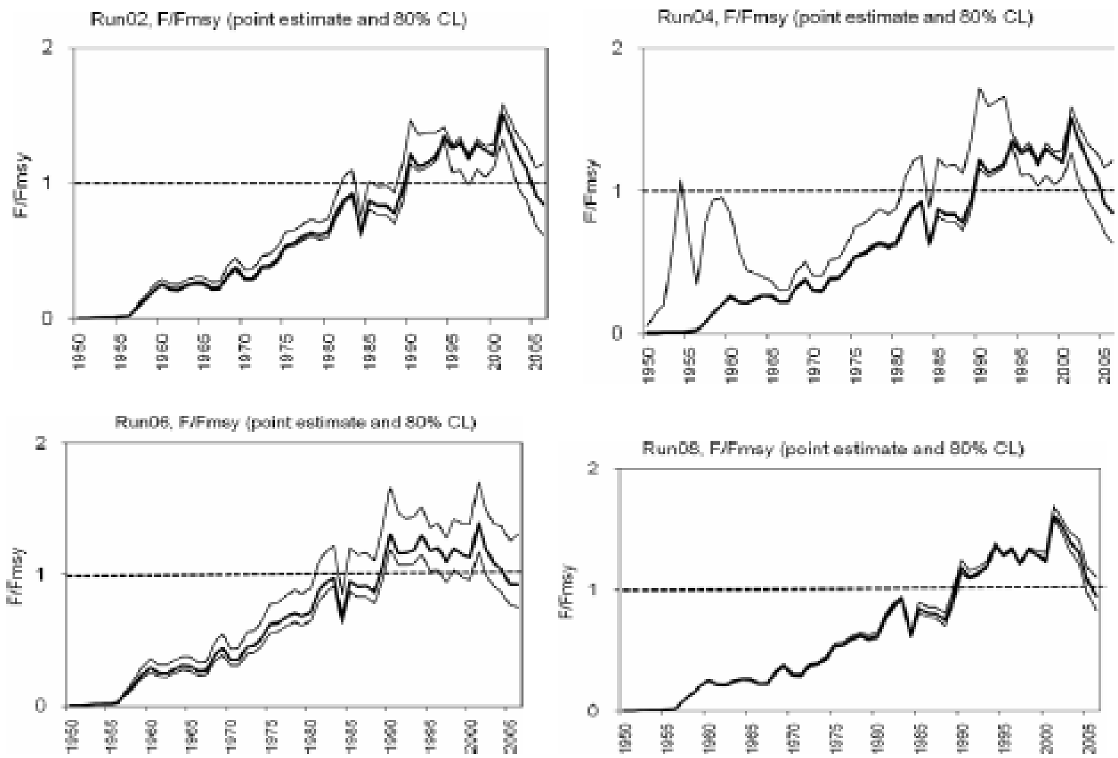

Figure 14. Estimated relative biomass trajectories and 80% confidence intervals estimated from 500 bootstraps (Figure from SCRS 2008).

Indian Ocean

Yellowfin stock status in the Indian Ocean has been estimated by the IOTC Scientific Committee using a wide range of assessment models, most recently in 2008 (IOTC 2009). Catches have increased dramatically since the 1970s (Figure 15), while indices of abundance (based on longline CPUE) that include early time series data (1950s and 1960s) do not show the expected declines based on the increasing catches. This unexplained phenomenon makes assessment difficult and results in high uncertainty (IOTC 2009). The average catch taken during 1998-2002 (336,000 t) was a little above the estimated MSY (300,000 t), while catches from 2003-2006 (over 400,000 t) were far higher than MSY. Catch estimates for 2007 and 2008 are more in line with the period before 2003, but remain above MSY (IOTC 2009). Overfishing is thus still occurring (F_{2007}/F_{MSY}=1.16).

Biomass has declined over the time series, and declined particularly sharply during the period of extraordinarily high catches in 2003-2006 (Figure 16). B_{2007}/B_{MSY} is 0.9, while SB_{2007}/SB_{MSY} is 1.12, suggesting that current biomass is around the biomass corresponding with MSY. Recent analyses of environmental and oceanographic conditions suggest the large catches from 2003-2006 are most likely due to an increase in catchability rather than an increase in biomass, meaning that the catches probably resulted in stock depletion.

Although there is high uncertainty in the stock assessment, it appears that overfishing has been occurring on the stock for some years, and biomass levels have declined steeply to a point just below the biomass corresponding to MSY. Catches in 2008 and 2009 remained

above MSY. For these reasons, Seafood Watch® concludes there is a high conservation concern associated with the stock status of yellowfin in the Indian Ocean.

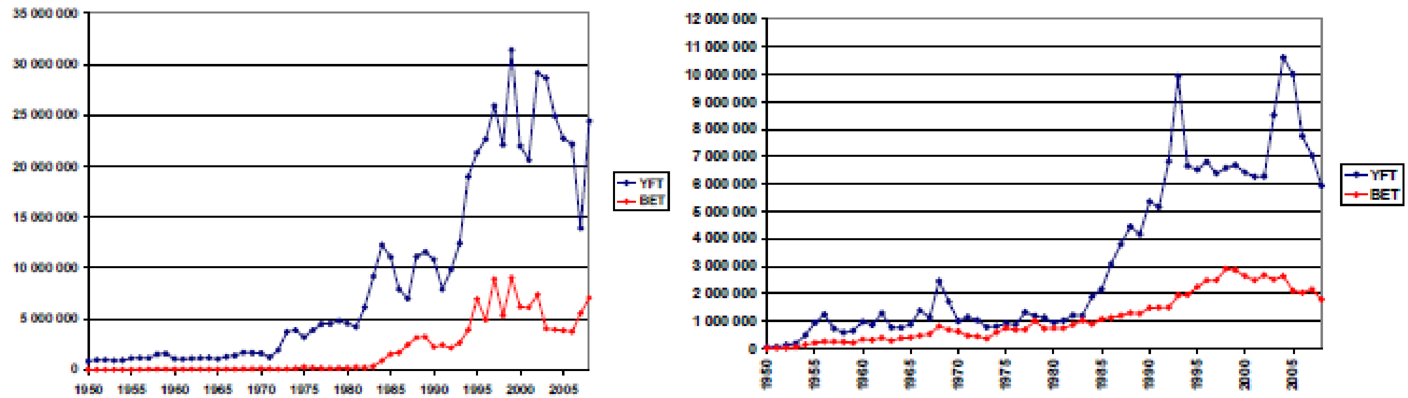

Figure 15. Annual catches of Indian Ocean yellowfin tuna for (a) small tuna, and (b) large (>90cm) tuna (Figure from IOTC 2009). Red lines are for bigeye tuna (these were part of the original charts).

Figure 16. Temporal trend in total and adult biomass (1000s mt) of Indian Ocean yellowfin tuna (Figure from IOTC 2009).

Table 3. Stock status of yellowfin. Where stock assessments are very recent, management classification may be out of date. In these cases, denoted with *, an estimate is made of the classification status based on the most recent stock assessment as summarized in these pages and table.

Region	Classification Status (Mgt. Body/ FAO)	B/ B_{MSY}	Occurrence of Overfishing	F/F_{MSY}	Abundance Trends/ CPUE	Age/Size/ Sex Distrib.	Degree of Uncertainty in Stock Status	Sources	SFW Rec.
EPO	Not overfished, overfishing not occurring*	B_{CURR}/B_{MSY} = 1.3 (base model) or B_{CURR}/B_{MSY} = 0.8 (alternate model)	Overfishing no longer occurring	F_{CURR}/F_{MSY} = 0.92	Variable	Unknown if skewed	Moderate	Maunder and Aires-da-Silva 2009	Moderate
WCPO	Not overfished, overfishing not occurring	B_{CURR}/B_{MSY} = 1.23-1.67; SB_{CURR}/SB_{MSY} = 1.28-1.89	Overfishing not occurring	F_{CURR}/F_{MSY} <= 0.87; fishing mortality increasing	Declining long and short-term trends	Unknown if skewed	Moderate	Langley, Harley et al. 2009	Low
Atlantic Ocean	Not overfished, overfishing not occurring	B_{CURR}/B_{MSY} = 0.83 (ASPIC model) or 1.09 (VPA model)	Classified as not overfishing; but chance stock is being overfished or is overfished	F_{CURR}/F_{MSY} = 0.84 (VPA) or 0.89 (ASPIC)	Long and short-term declining trend	Unknown if skewed	Moderate	SCRS 2008; NOAA 2009a	Moderate
Indian Ocean	Not overfished, overfishing occurring*	B_{2007}/B_{MSY} = 0.9; SB_{CURR}/SB_{MSY} = 1.12	Overfishing is occurring	F_{2007}/F_{MSY} = 1.16	Declining long-term trend, declining short-term trend in CPUE	Unknown if skewed	High	IOTC 2009	Poor

Synthesis

The stock status of Pacific yellowfin stocks appears to have improved since the last assessments. The EPO yellowfin stock is not subject to overfishing, and has recovered from the overfished condition it has been in since the mid-2000s. However, there is uncertainty in the status of the stock, and relaxing one of the key uncertain assumptions in the model would result in an estimate of biomass moderately below B_{MSY}. As such, this stock is considered a moderate conservation concern. The WCPO stock is also not being overfished and overfishing is not occurring, with B > B_{MSY} and F < F_{MSY}, and is therefore considered a low conservation concern according to Seafood Watch® criteria. There is moderate uncertainty associated with both the EPO and WCPO stocks, and Seafood Watch will closely monitor them.

Depending on the assessment model, biomass is either just above (109%) or slightly below (84%) B_{MSY}. Both indicate that overfishing is no longer occurring. However, there is moderate uncertainty which, when taken into account, indicates a good chance (60%) the stock is undergoing overfishing, is overfished, or both. Stock status is thus considered a moderate conservation concern according to Seafood Watch® criteria. Uncertainty over the status of the IO stock is high, overfishing appears to have been occurring for some years, and biomass levels have declined steeply to just below the biomass corresponding to MSY. Seafood Watch® therefore concludes there is a high conservation concern associated with the stock status of yellowfin in the Indian Ocean.

Status of Wild Stocks Rank:

Western & Central Pacific Ocean (40%):

Healthy | **Moderate/Rebuilding** | Poor | Critical

Eastern Pacific Ocean (23%);
Atlantic Ocean (10% of total catch):

Healthy | **Moderate/Rebuilding** | Poor | Critical

Indian Ocean (27%):

Healthy | Moderate/Rebuilding | **Poor** | Critical

Criterion 3: Nature and Extent of Bycatch

Seafood Watch® defines a sustainable wild-caught species as that captured using techniques that minimize the catch of unwanted and/or unmarketable species. Bycatch is defined as species that are caught but subsequently discarded because they are of undesirable size, sex, or species composition. Unobserved fishing mortality associated with fishing gear (e.g., animals passing through nets, breaking free of hooks or lines, ghost fishing, illegal harvest, and under or misreporting) is also considered bycatch. Bycatch does not include incidental catch (non-targeted catch) if it is utilized, accounted for, and managed in some way.

Specific bycatch data for the yellowfin fishery may not be available in all the regions where yellowfin is fished, and extrapolations from tuna longline and purse seine fisheries in general have been applied to the yellowfin fishery in this analysis. In addition, fishing practices (e.g., the type of purse seine sets) vary among the different fisheries for yellowfin. There may also be spatial differences within regions (Solana-Sansores 2001). For instance, Mexican and Venezuelan fleets commonly set on dolphins, while Ecuadorian fleets commonly set on FADs.

Pole and Line & Handline Gear

In addition to being caught in longline and purse seine fisheries, yellowfin is caught by pole and line and handline. Fishers use a pole with fixed length line that has a barbless hook with either an artificial lure or live bait. In this way, fish are caught one at a time, and fishers can immediately throw back any unwanted catch. In the surface fisheries (i.e., pole and line & handline) for yellowfin, bycatch is negligible compared to bycatch in the pelagic longline fisheries. Bycatch in troll fisheries is considerably less than in the longline fishery, although discards do occur if fish are undersized or damaged (Childers 2003). The average discard rate for HMS troll fisheries globally is 0.1% (Kelleher 2005). The average discard rate, or the proportion of total catch that is discarded, for highly migratory species (HMS) troll fisheries globally is 0.1% (Kelleher 2004).

Longlines

Yellowfin is caught in longline fisheries primarily in the western Atlantic and Indian Oceans, and to a lesser extent in the eastern Atlantic and WCPO. Although pelagic longlines are set at different depths and configured to target specific species, non-target species also interact with this gear. In longline fisheries, interactions occur with a range of species, including endangered and protected sea turtles, seabirds, marine mammals, sharks, and other fishes. These non-target animals approach or are attracted to baited longline hooks and may become hooked or entangled in the gear, causing them to be injured or drown NMFS 2001. Tuna are caught using deep-set longline gear, which generally results in one tenth the bycatch rates in the shallow-set fishery targeting swordfish (Lewison et al. 2004b; Kaplan 2005). However, mortality rates for some species, including sea turtles, are higher for deep-set longlines, as the animals cannot surface to breathe.

Although comprehensive global bycatch data are non-existent, there are some data for specific longline fisheries. Longline gear varies according to the size and intensity of the fishery, the configuration of the gear, the region in which the gear is used, and the country fishing with the gear. While these differences may result in differing levels of bycatch, Seafood Watch® adopts a precautionary approach in assuming that problematic bycatch levels in one tuna fishery are similar to other tuna fisheries, unless there are data to show otherwise. The average discard rate for HMS longline fisheries is 22% (Kelleher 2005). In the U.S., the discard to landings ratio for finfish in the HMS fishery (pelagic longline, bottom longline, and drift/set gillnets) is estimated to be 0.52. The discard to landings ratio for the pelagic longline fishery alone is 0.67, with swordfish and sharks comprising the major species that are discarded (Harrington et al. 2005). Of all the gears used to catch tuna in the Atlantic, longlines catch the highest diversity of both fish and seabirds (ICCAT 2005a). However, overall seabird bycatch is lower in the Atlantic than in other ocean basins. As evidenced by observer data in the WCPO, mortality rates differ for the various types of longlines (Figure 17).

According to Bailey et al. (1996), logsheet data from the WCPO longline fishery is limited. Due to low observer coverage in the western Pacific Ocean (WPO), observer data cannot be used to estimate overall bycatch levels (Bailey et al. 1996).

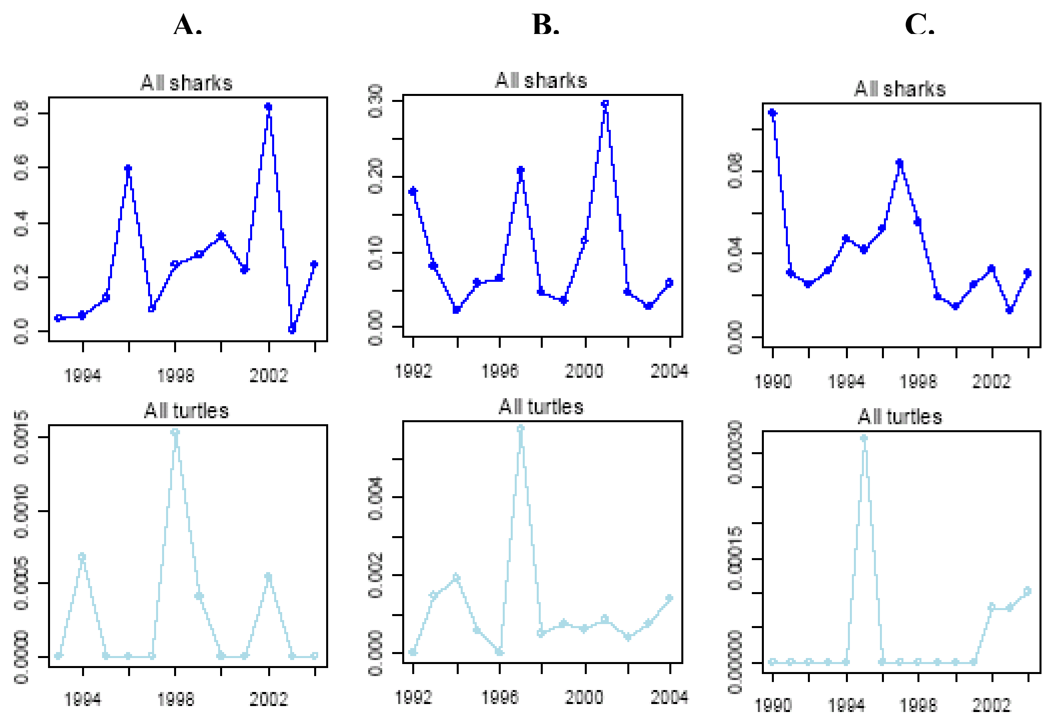

Figure 17. Mortality rates in the A. WCPO shallow set longline fishery, B. WCPO deep set longline fishery, and C. temperate albacore fishery. The x-axis is year and the y-axis is mortalities per 100 hooks. Noting the change in scale for each panel, sea turtle mortalities were highest in the deep set fishery and shark mortalities were highest in the shallow set fishery (figure from Molony 2005).

Fishes: bycatch rates

Discards of swordfish and tuna in the U.S. Atlantic pelagic longline fishery generally exhibited a gradual decline from 1995 – 2004 (NMFS 2006). Discards of these target species may be economic or regulatory discards. The only fish species for which discards were higher than landings were bluefin tuna. In 2004, the most recent year for which data are available, two times more bluefin tuna were discarded than were kept (NMFS 2006). For highly migratory species, both the number of individuals kept and the number of individuals discarded have declined over this time period, as has fishing effort (Figure 18) (NMFS 2004c). The reason for these declines is unknown.

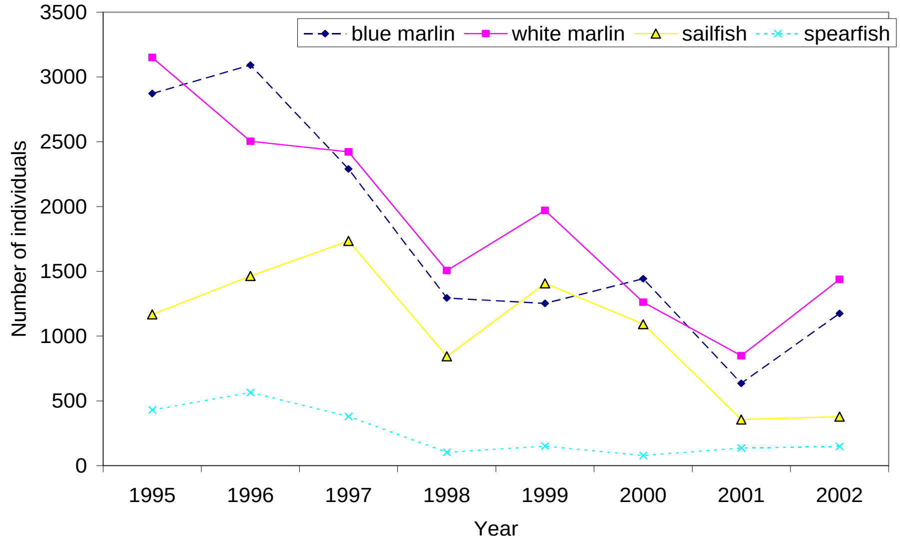

Figure 18. Decline of marlin, sailfish, and spearfish discards in the U.S. Atlantic pelagic longline fishery (NMFS 2004c).

Longline fisheries targeting tunas and swordfish are responsible for the majority of the fishing mortality of blue and white marlin (Goodyear 1999; Peel at el. 2003). In the Atlantic, the commercial sale of billfish was prohibited in 1991, and although the reported catch of billfish dropped greatly after this (Goodyear 1999), it is likely that reported bycatch rates in the logbooks are underestimates of the actual bycatch rates, based on observer coverage (Cramer 1996). For fisheries where logbook data are available, the catch ratio of billfish to the targeted species is low. Billfish catch is approximately 5% of the total combined catch of albacore, yellowfin, bigeye, bluefin, and southern bluefin (Uozumi 2003).

From 1998 – 2001, the catch in WCPO longline fisheries targeting bigeye and yellowfin comprised 65.9% tunas, 21.1% sharks and rays, 10.0% billfish, and 3.1% other fishes (Lawson 2004c). Non-tuna species caught in the WCPO longline fisheries include black marlin, blue marlin, Indo-Pacific sailfish, shortbill spearfish, striped marlin, swordfish, blue shark, mako sharks, oceanic whitetip shark, silky shark, other shark and ray species, barracudas, common dolphinfish, escolars, lancetfishes, oilfish, ocean sunfish, opah, pomfrets, wahoo, and other fishes (Lawson 2004c). While some of these species are kept in some fisheries and are thus not deemed bycatch, others such as moonfish and pomfret are largely discarded in other fisheries. Much of the catch that is not discarded is sold to Japan (Anonymous, pers. comm.). The bycatch of some of these species increased over the 1998 – 2001 period while the bycatch of others declined (Lawson 2004c).

Industrialized fisheries in the WCPO often retain billfish and shark catch (Molony 2005). It is important to note that recreational catch-and-release fisheries for billfish species also contribute to total mortality rates, although the magnitude of these mortalities is far less than for the pelagic longline fishery. For instance, over 99% of all white marlin are released in recreational fisheries (Goodyear and Prince 2003). The survival of these released marlin may be affected by the type of hook used. In the western North Atlantic recreational fishery, white marlin survival is higher when caught on circle hooks (100%) than when caught on J-hooks (65%) (Horodysky and Graves 2005). In addition, there are little data examining survival rates following stomach eversion (Horodysky and Graves 2005). Although this mortality affects the stock status of billfish, Seafood Watch® does not incorporate recreational fisheries effects when evaluating commercial fisheries. When 16/0 circle hooks were compared to 9/0 J-hooks in the U.S. Atlantic pelagic longline fishery, circle hooks were found to reduce mortality of non-target species, and may result in higher survival for undersize swordfish and billfishes (Kerstetter and Graves 2006). In addition, the use of 16/0 0º circle hooks was found to have a minimal impact on the catch of target species (Kerstetter and Graves 2006).

The mortality of billfish in longline fisheries targeting swordfish and tunas varies according to fishery and species. Blue marlin and yellowfin have the same area of distribution, and frequent catches of blue marlin in the longline fisheries is a concern for this stock (Goodyear 2000). When data sets from the U.S., Japanese, and Venezuelan fisheries were combined, the proportion of billfish that were dead when the gear was retrieved ranged from 0.472 for blue marlin in the Gulf of Mexico to 0.673 for white marlin in the northwest Atlantic (Farber and Lee 1991). Observer data from Japanese fisheries in Australia suggest that 74% of black marlin, 71% of blue marlin, and 60% of striped marlin were dead or moribund when the gear was retrieved (Findlay et al. 2003). There are, however, differences in billfish mortality rates in different fisheries operating in the same waters; Japanese and Australian fisheries operating in the same waters have been shown to have different billfish mortality rates due to differences in gear configuration (Findlay et al. 2003). According to the most recently available logbook data for the Atlantic pelagic longline fishery, discards of blue marlin declined from 1995 – 2002, but have been somewhat stable since 1998, averaging 1,160 individuals discarded annually from 1998 – 2002 (NMFS 2004c). White marlin discards exhibited a similar pattern, with an average of 1,404 individuals discarded annually from 1998 – 2002 (NMFS 2004c).

The Hawaii-based pelagic longline fishery targeting tuna and swordfish also catches, and often lands, several billfish species including blue and striped marlin. There are no specific management measures for either of these marlin species (Dalzell and Boggs 2003). CPUE data for striped marlin in Hawaiian fisheries from 1990 – 1999 indicate a declining trend in the recreational, commercial longline, and commercial troll fisheries (Dalzell and Boggs 2003). However, CPUE data may not be an accurate indicator of abundance due to increases in the proportion of the fleet setting deep-set longlines. The most recent stock assessment shows that stocks are at about the MSY level, and given the uncertainty with the assessment the results could be more optimistic (Kleiber et al. 2003). While the population could have been subject to $F > F_{MSY}$ over the past several decades, high recruitment maintained the population near B_{MSY}. Deep-set longlines are likely to have lower marlin bycatch rates than shallow-set longlines targeting swordfish (Dalzell and Boggs 2003).

In the Indian Ocean, 2005 observer data from Western Australia longline vessels suggest that more than half of the species caught were bycatch, the most common of which were sharks. While some bycatch species are kept and sold, such as dolphinfish, there is no market for other species that are commonly caught, such as stingrays (IOTC 2005b).

In the Atlantic, U.S. longline fleets are prohibited from using live bait in the Gulf of Mexico fishery targeting yellowfin; however, the Mexican fleet operating in the same fishery often uses live bait. It is possible that this practice results in increased bycatch of billfish species such as Atlantic blue marlin, white marlin, sailfish, and swordfish, as well as bluefin tuna (50 CFR 635, August 1, 2000). The quantity of bycatch relative to the target species is low, however, with yellowfin accounting for more than 70% of the catch (Brown et al. 2004). The take of Atlantic bluefin in the pelagic longline fisheries in the Gulf of Mexico is a serious conservation concern, as recent data have shown that the northern slope waters of the Gulf of Mexico is a hotspot for bluefin spawning (Block et al. 2005). Time and area closures for longline fleets operating in these waters would reduce the bycatch of Atlantic bluefin (Block et al. 2005), which are overfished and undergoing overfishing (NMFS 2004a).

Yellowfin is the most important species caught in the Venezuelan pelagic longline fishery, accounting for 67.4% of the total catch in the Caribbean and 56% of the total catch in the Atlantic from 1986 – 2000 (Marcano et al. 2004). Incidental catch in this fishery includes white marlin, sailfish, blue marlin, swordfish, dolphinfish, and sharks (most commonly *Carcharhinus* and *Isurus* spp.) (Marcano et al. 2004). Overall, CPUE for white and blue marlin declined in both the Atlantic and Caribbean from 1986 – 2000 (Marcano et al. 2004). In the small Venezuelan longline fisheries, yellowfin accounts for 83 – 96% of the catch in the Caribbean (Gúzman et al. 1994; Salazar and Marcano 1994 in Marcano et al. 2004). Mexican longline vessels also report incidental catches of billfish, sharks, and bluefin tuna (Gónzalez-Ania et al. 2001).

Fishes: population impacts
The stock status of billfish species varies by ocean basin and species (Table 4). The pelagic longline fisheries targeting yellowfin and bigeye tuna and swordfish cause the highest mortality of Atlantic marlin (Peel et al. 2003). In the Atlantic, biomass estimates for blue marlin, white marlin, and sailfish are all below B_{MSY} while fishing mortality on these stocks is above F_{MSY} (Peel et al. 2003; Uozumi 2003). The Atlantic blue marlin stock is at 40% of B_{MSY}, current fishing mortality is four times F_{MSY}, and overfishing has been occurring for the last 10 – 15 years (ICCAT 2001a). The only management measure in place for Atlantic blue marlin is a reduction of pelagic longline and purse seine landings to 50% of 1996 or 1999 levels, whichever is greater (ICCAT 2001a). White marlin occurs only in the Atlantic; the most recent assessment for this species was in 2000, and indicated that biomass throughout the late 1990s was about 15% of B_{MSY} while fishing mortality was more than five times F_{MSY} (ICCAT 2001a). Similar to blue marlin, the only management measure in place for white marlin is a limit on longline and purse seine landings to 33% of the 1996 or 1999 level (ICCAT 2001a). For Atlantic sailfish, MSY is not estimated and there are no management measures in place (ICCAT 2001b).

Observer data from the U.S. pelagic longline fishery in the Atlantic show that the number of bluefin tuna discarded has been higher than the number kept every year from 1995 – 2002. Both East and West Atlantic bluefin stocks are overfished and experiencing overfishing, and considered overexploited and depleted, respectively (NMFS 2004c; Majkowski 2004). Thus, any dead discarding of bluefin tuna in Atlantic pelagic longline fisheries removes individuals from stocks that are already in critical shape, warranting a critical conservation concern for these longline fisheries.

Although no stock assessments were conducted for marlin, sailfish, and spearfish in the Indian Ocean in the 1990s, previous assessments indicate that biomass of blue marlin, striped marlin, and black marlin are either at or above MSY (Uozumi 2003). The status of sailfish and spearfish in the Indian Ocean is unknown. High uncertainty exists concerning the status of all of these stocks, as well as the level of discarding. Catch of non-tuna species has not been well documented in the Indian Ocean, and the level of discarding in the industrial fisheries may be high, based on data from other oceans (IOTC 2005b). The level of bycatch in the artisanal fisheries in the Indian Ocean is likely very low (IOTC 2005b).

In contrast to the Atlantic, blue and striped marlin biomass in the Pacific is either at or above the MSY level. In addition, current fishing mortality is below F_{AMSY} (fishing mortality at which the average maximum sustainable yield is produced) for striped marlin in the North Pacific (Hinton and Maunder 2004) and Southwest Pacific (Langley et al. 2006). The status of black marlin, sailfish, and spearfish in the Pacific is unknown (Uozumi 2003). Blue marlin in the Pacific is close to being fully exploited, although due to model uncertainty the situation may be more optimistic (Kleiber et al. 2003). Uncertainty associated with stock assessment results derived from production models is often due to uncertainty in catch and abundance indices, particularly as these data are from fisheries that do not target billfish (Uozumi 2003). In addition, changes in both spatial coverage and vertical coverage over time may result in a misinterpretation of CPUE data for billfish if changes in the fisheries do not adequately cover billfish habitat (Uozumi 2003). At this time, there does not appear to be a critical conservation concern associated with billfish bycatch in the Pacific, although caution is warranted, as the stock status of many of these species is unknown. Billfish bycatch in the Atlantic, on the other hand, is a critical conservation concern due to the poor stock status of billfish species, as well as the bycatch of bluefin tuna.

Table 4. Stock status of billfish in the Atlantic, Pacific, and Indian Oceans (Table from Uozumi 2003).

Species	Stock	Stock status
Atlantic blue marlin	Atlantic	Lower than MSY
White marlin	Atlantic	Lower than MSY
Atlantic sailfish	East Atlantic	Lower than MSY
Longbill spearfish	Atlantic	Unknown
Indo-Pacific blue marlin	Indian	At MSY level
Striped marlin	Indian	Higher than MSY
Black marlin	Indian	At MSY level
Indo-Pacific sailfish	Indian	Unknown
Shortbill spearfish	Indian	Unknown
Indo-Pacific blue marlin	Pacific	Higher than MSY
Striped marlin	North Pacific	At or higher than MSY
Striped marlin[6]	SW Pacific	Almost at MSY ($B_{CURRENT}/B_{MSY} = 0.90$)
Black marlin	Pacific	Unknown
Indo-Pacific sailfish	Pacific	Unknown
Shortbill spearfish	Pacific	Unknown

[6] Striped marlin data from the SW Pacific are from Langley et al. 2006.

Sea turtles: bycatch rates

All seven species of sea turtles are listed as threatened or endangered under the U.S. Endangered Species Act (ESA) of 1978, and six of these species are also listed on the IUCN Red List of Threatened Species (Table 5). Some of these sea turtle species are caught as bycatch in the pelagic longline fisheries targeting tuna and swordfish, particularly green, hawksbill, Kemp's ridley, leatherback, loggerhead, and olive ridley. Sea turtles are caught more frequently in shallow-set fisheries targeting swordfish compared to deep-set fisheries targeting tunas (Beverly et al. 2004), and are caught in both tropical and temperate regions. Loggerhead sea turtles have been shown to spend the majority of their time at depths shallower than 100 m, and the elimination of shallow-set longlines would result in reduced bycatch of loggerheads (Polovina et al. 2003). Even in deep-set longlines, however, there is the potential for hooks to be present at shallow depths when the gear is being set and retrieved, or if the line does not sink to the appropriate depth (Polovina et al. 2003). Although some turtles are hooked in the esophagus and others are hooked only in the jaw, there does not appear to be a difference in the survivability between light and deeply-hooked turtles (Polovina et al. 2000; Parker et al. in press). Leatherback sea turtles are attracted to squid bait used on longlines (Skillman and Balazs 1992), and commonly get entangled in the lead lines even if they don't bite the hooks (NMFS and USFWS 1998). Estimates of sea turtle post-release mortality using satellite tracking has been both controversial and problematic (Hays et al. 2003; Chaloupka et al. 2004a; Chaloupka et al. 2004b; Hays et al. 2004a) with estimates ranging from 0.08 for lightly-hooked turtles, and 0.38 for deeply-hooked turtles (Chaloupka et al. 2004a). In general, takes greatly exceed documented mortalities in longline fisheries, although there are little data on delayed mortality.

Table 5. Global conservation status of sea turtles that interact with pelagic longline fisheries.

Species	Status under the U.S. ESA	Status on the IUCN Red List
Green	Threatened, Endangered	Endangered
Hawksbill	Endangered	Critically endangered
Kemp's ridley	Endangered	Critically endangered
Leatherback	Endangered	Critically endangered
Loggerhead	Threatened	Endangered
Olive ridley	Threatened	Endangered

Although more countries are beginning to collect bycatch data, they are generally not available and therefore a thorough analysis of sea turtle bycatch interactions with international vessels is difficult. However, Lewison, Freeman et al. 2004 attempted to quantify the incidental take of loggerhead and leatherback sea turtles on a global scale. By integrating catch data from more than 40 nations and bycatch data from 13 international observer programs, the authors estimated that over 200,000 loggerheads and 50,000 leatherback sea turtles were taken as bycatch in pelagic longline fisheries in the year 2000. This amounted to 20,000 to 40,000 leatherback and 30,000 to 75,000 loggerhead sea turtles caught as bycatch in the Pacific Ocean alone (Lewison et al. 2004b). These authors suggest that a large number of interactions with protected species continue regularly with the international longline fleet, and jeopardize the continued survival of these endangered and threatened sea turtle species.

Other studies estimate that sea turtle takes are much lower in the Pacific; Hatase et al. (2002) estimate that in 2000 international pelagic longline fisheries resulted in 800 to 1,266 loggerhead takes and 139 to 222 loggerhead mortalities. Certain areas in the Pacific may also have less sea turtle bycatch than other areas; for instance, leatherbacks have rarely or never been seen in the waters of American Samoa, Guam, the Republic of Palau, the Commonwealth of the Northern Marianas, Republic of the Marshall Islands, and the Federated States of Micronesia (NMFS and USFWS 1998), thereby reducing the potential for fishery interactions in these areas.

It is estimated that Australian longline vessels incidentally take about 400 turtles per year, which is lower than estimates from other longline fisheries (Robins et al. 2002). The average catch rate of sea turtles in the Australian longline fishery is estimated at 0.024 turtles/1,000 hooks (Robins et al. 2002). Bycatch rates in the temperate western Pacific have been estimated at 0.007 turtles/1,000 hooks for both the deep-set fresh and freezer vessels, with annual estimates of 129 turtle takes and 564 turtle takes, respectively (Robins et al. 2002). Observer data from <1% of the longline fleet in the WCPO suggest that 2,182 turtles are taken in this fishery annually, with a 23 – 27% mortality rate (OFP 2001 in NMFS 2005c). The highest CPUEs are in the tropical shallow set longline fishery, although the highest mortalities are in the tropical deep set fishery. Turtle bycatch is lower in the temperate albacore fishery (Molony 2005). The Japanese tuna longline fleet is estimated to take 6,000 turtles annually in the ETP, with a 50% mortality rate (Meeting Minutes, 4th Meeting of the Working Group on Bycatch, IATTC, January 14-16, 2004, in NMFS 2005c). Sea turtle bycatch rates in the Costa Rican longline fleet have been estimated ranging from 19.43 turtles/1,000 hooks with an 8.8% mortality rate to 14.4 turtles/1,000 hooks with a 0% mortality rate (Arauz 2001).

The Hawaii-based longline fishery was closed from 2001 to 2004 due to high sea turtle takes in the fishery. In 2004, the fishery was re-opened with gear and bait restrictions in the shallow-set component of the fishery, as well as a bycatch cap. The maximum number of leatherback interactions allowed in the shallow-set fishery is 16; if this number is reached in the shallow-set fishery the fishery is closed. This regulation does not apply to the deep-set fishery, however.

Sea turtle mortalities in the Hawaii-based longline fishery have dropped considerably since the 2001 closure (Figure 19). From 2002 – 2004, interactions with green turtles remained relatively stable, leatherback and olive ridley interactions increased, and loggerhead interactions declined to zero in both 2003 and 2004 (NMFS 2005c; PIR 2005a). In 2004, it was estimated that 0 loggerheads, 15 leatherbacks, 46 olive ridleys, and 5 green turtles were taken as bycatch in the Hawaiian deep-set longline fishery (PIR 2005a). In 2004, the first year that the shallow set fishery targeting swordfish re-opened, two sea turtles, one leatherback and one loggerhead, were observed as takes; both were released injured (PIR 2005a). However, 2004 data from the shallow-set fishery should not be considered a source of new information due to low fishing effort (NMFS 2005c). Sea turtle takes were slightly higher in 2005 and 2006 in the deep-set fishery (Table 6) (PIRO 2007a). In March 2006 the shallow-set fishery was closed when the bycatch cap for loggerheads was reached (Table 7) (PIRO 2007b). With 26.1% observer coverage in 2005, four olive ridleys were observed as "released dead" and one leatherback was "released injured" in the deep-set fishery; with 100% observer coverage in the shallow-set component of the fishery, 10 loggerheads and eight leatherbacks were "released injured" (PIRO 2005b). Mortality rates based on observer data are 0.86 for green turtles, 0.34 for leatherbacks, 0.44 for loggerheads, and 0.96 for olive ridleys (Boggs 2005 in NMFS 2005c).

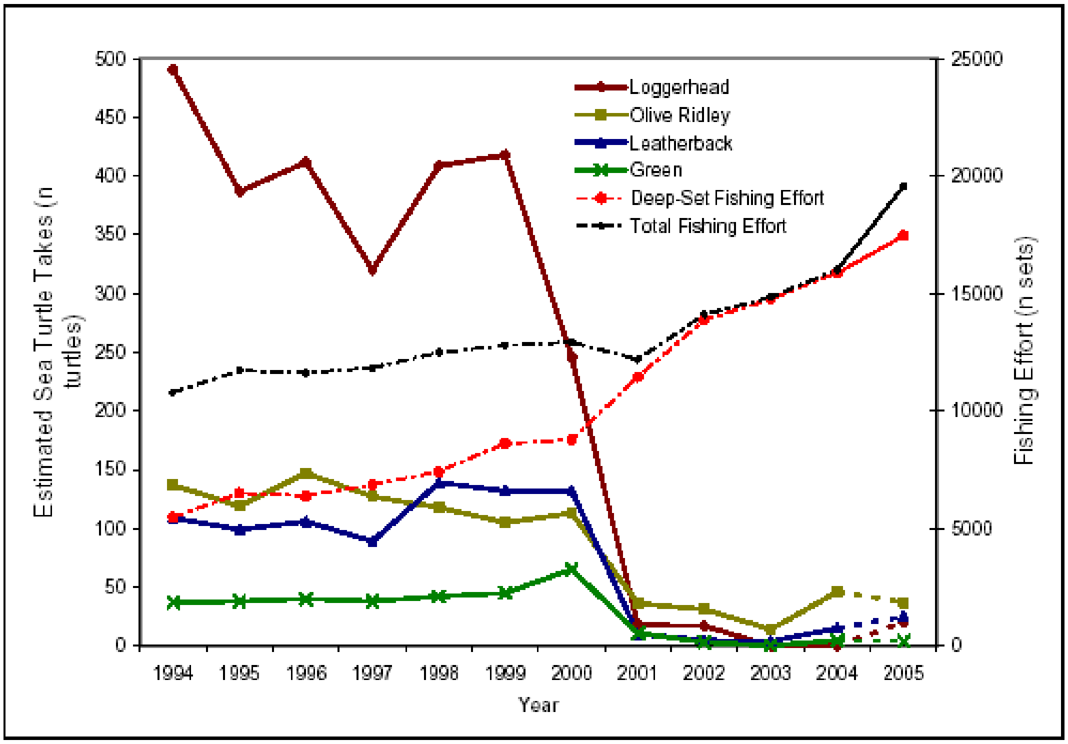

Figure 19. Sea turtle mortalities in 1994 – 2004 and projected for 2005 in the Hawaii-based longline fleet (Figure from NMFS 2005c).

Table 6. Sea turtle interactions in the Hawaii-based deep-set longline fishery. Data from PIRO 2007a.

Sea Turtle Species	2005 (26.1% observer coverage)		2006 (21.2% observer coverage)		2007 (7.0% observer coverage in Quarter 1)	
	Released Injured	Released Dead	Released Injured	Released Dead	Released Injured	Released Dead
Green	0	0	0	2	0	0
Leatherback	1	0	0	2	0	0
Olive ridley	0	4	1	10	0	0

Table 7. Sea turtle interactions in the Hawaii-based shallow-set longline fishery. The shallow-set fishery was closed in March 2006 for the remainder of the year when the bycatch cap was reached. Data from PIRO 2007b.

Sea Turtle Species	2005 (100% observer coverage)		2006 (100% observer coverage)		2007 (100% observer coverage in Quarter 1)	
	Released Injured	Released Dead	Released Injured	Released Unknown	Released Injured	Released Dead
Leatherback	8	0	2	0	2	0
Loggerhead	10	0	15	2	7	0
Unidentified hardshell	0	0	1	1	0	0

Off the southern coast of Brazil, loggerheads and leatherbacks have been taken in the longline fishery targeting swordfish, sharks, and tunas (including *Thunnus albacares, T. alalunga,* and *T. obesus*) (Kotas et al. 2004). Over the course of three trips and 34 sets, 145 loggerheads (4.31/1,000 hooks) and 20 leatherbacks (0.59/1,000 hooks) were taken (Kotas et al. 2004). Of these turtles, 19 loggerheads and 1 leatherback were released dead (Kotas et al. 2004). These mortality levels may be underestimated, however, due to post-release mortality related to hooking wounds and stress from capture (Kotas et al. 2004). It has been estimated that in 2000, Japanese longline vessels targeting tuna in the eastern Pacific resulted in 25 leatherback mortalities (166 total leatherback takes) and approximately 3,000 mortalities of all other sea turtle species, most of which were olive ridleys (IATTC 2004b). In Uruguay, loggerhead and leatherback bycatch has been estimated at 1.8 individuals/1000 hooks, with incidental mortality at 1.9% (Achaval et al. 1998).

Although the pelagic longline fishery in the Atlantic interacts with other sea turtle species, loggerheads and leatherbacks are the primary concern due to their high interaction rates (Figure 20). Sea turtle bycatch estimates for the U.S. pelagic longline fishery in the Atlantic in 2002 were 575 loggerhead takes[7] (2 mortalities), 962 leatherback takes (33 mortalities), and 50 unidentified turtle takes (NMFS 2004d). The number of loggerhead and leatherback turtle takes was variable from 1992 – 2005, although there was a peak in loggerhead takes in 1995. Leatherback takes peaked in 2004, and declined in 2005 to approximately 400 interactions (Walsh and Garrison 2006).

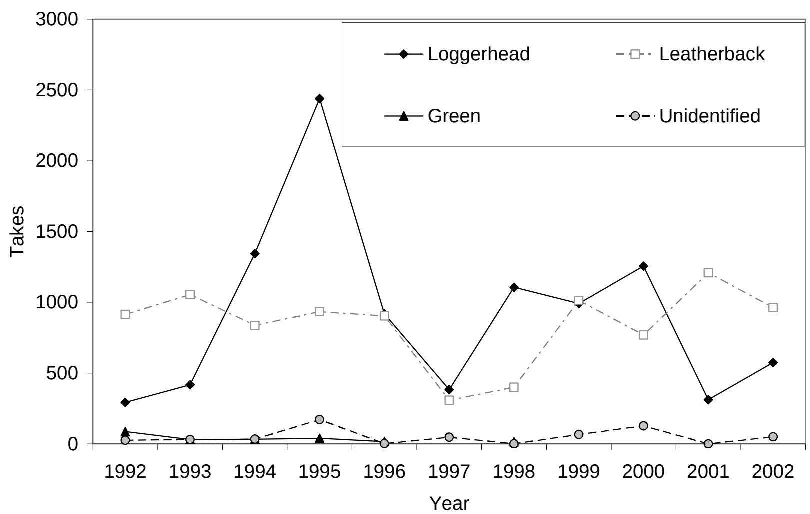

Figure 20. Estimated takes in the U.S. Atlantic pelagic longline fishery, 1992 – 2002. Takes do not imply mortalities (NMFS 2004d).

Though total loggerhead takes appear high in the Atlantic longline fisheries, the estimated mortalities are low; the average annual loggerhead morality from 1992 – 2002 was 7 individuals, with an estimated 2 loggerheads killed in 2002 (NMFS 2004d). The mortality data for leatherbacks are far more variable, with an estimated 88 leatherbacks killed in 1992, and then zero mortalities until 2002, when 33 leatherbacks were estimated killed in this fishery (NMFS

[7] These take estimates do not include any estimates of post-release mortality.

2004d). The estimated zero mortalities may be a reflection of the low level of observer coverage in this fishery, rather than low sea turtle bycatch, however. From 1995 – 2000, observer coverage ranged from 2.5 – 5.2% (NMFS 2004d). The 2004 Biological Opinion (BiOp) found that the expected number of takes and mortalities in the Atlantic HMS fishery is likely to reduce the survival or recovery of leatherbacks.

For the pelagic longline fishery, the most effective management measures are likely to be gear modifications, rather than area closures (which potentially result in the displacement of effort to other areas where bycatch may be higher) (James et al. 2005). Hook and gear modifications were required in the U.S. Atlantic pelagic longline fishery in mid-2004, and in 2005 the take of leatherbacks was greatly reduced (NMFS 2006). If this declining trend continues, the conservation concern for this fishery will continue to be ranked differently than the international longline fleets. Mexican longline vessels targeting tunas in the Gulf of Mexico have been shown to catch 5 turtles/100 trips with incidental mortality at 1.6 turtles/100 trips (Ulloa Ramírez and González Ania 2000).

Additional bycatch estimates from longline fisheries in the South Atlantic have found that the CPUE for loggerheads and leatherbacks combined was 0.37/1,000 hooks from 86 sets (Achaval et al. 2000). With over 13 million hooks set in 1999 by Brazilian boats alone in the southwest Atlantic (ICCAT 2001c), the potential for large amounts of sea turtle bycatch is high. In addition, fishery closures in the North Atlantic due to overfished species such as swordfish and tunas may result in effort being displaced to the South Atlantic, possibly increasing sea turtle bycatch there (Kotas et al. 2004). Lewison et al. (2004b) estimate that 1.4 billion hooks were set on pelagic longline gear in the year 2000 alone, with 1.2 billion of those hooks targeting tunas. In the Indian Ocean, South African observer data suggest a catch rate of 0.05 turtles/1,000 hooks; turtles were alive in 85% of these interactions (IOTC 2005b). In the eastern Atlantic, olive ridleys and leatherbacks have been observed interacting with longlines targeting swordfish and tunas, with a CPUE of 0.09 for olive ridleys and 0.39 for leatherbacks. In the Gulf of Guinea, the CPUE for olive ridleys was 0.38 and the CPUE for leatherbacks was 0.64. Of the 40 leatherbacks caught, 5% were observed mortalities (Carranza et al. 2006). There were no estimates for post-release mortality for either of these species in the Carranza et al. (2006) study.

All these studies demonstrate that sea turtle bycatch occurs in many fisheries across most ocean basins. Although there is not observer coverage or logbook data for every fishery targeting tuna, the available data suggest that sea turtle bycatch is an issue in many, if not all, of these fisheries.

Sea turtles: population impacts

Sea turtle populations face several threats including incidental take in fisheries, the killing of nesting females, egg collection at nesting beaches, habitat loss, and pollution and debris. The population impacts of sea turtle bycatch vary according to the sea turtle species and the region.

Pacific

In the Pacific Ocean, nesting populations of both loggerhead and leatherback sea turtles have exhibited severe declines, with loggerheads exhibiting an 80 – 86% decline over the last 20 years (Figure 21) (Kamezaki et al. 2003; Limpus and Limpus 2003) and leatherbacks exhibiting a decline of greater than 95% (Crowder 2000; Spotila et al. 2000) over the same time period. The number of nesting females at several nesting beaches in Japan have been declining since 1990 (Sato et al. 1997), and population declines of loggerheads nesting in Japan have been attributed to the bycatch of small females in pelagic longline fisheries in the Pacific (Hatase et al. 2002). More recent data suggest that loggerhead nesting is increasing on some Japanese beaches (I. Kinan, pers. comm.; Sea Turtle Association of Japan unpubl. data).

Some sea turtle species, such as green turtles in the Hawaiian Islands, are recovering (Balazs and Chaloupka 2004); however, there is an overall declining trend for green turtle abundance worldwide (Seminoff 2004). While research has shown that leatherbacks have migratory pathways in the Pacific, the same is not true in the Atlantic, where leatherbacks are likely to disperse widely from the main nesting beaches in French Guiana and Suriname (Ferraroli et al. 2004; Hays et al. 2004). The distribution of leatherbacks in the Atlantic also shows that these animals spend time and forage in the same areas and depths where pelagic longline fisheries operate (Ferraroli et al. 2004; Hays et al. 2004b). Spotila et al. (2000) estimate that if leatherbacks in the eastern Pacific can sustain 1% annual anthropogenic mortality, this is equal to the loss of 17 adult females and 13 subadult females per year. The 2005 BiOp on the Hawaii-based, pelagic longline fishery concluded that the continued authorization of this fishery *is not likely* to jeopardize the continued existence of green, leatherback, loggerhead, and olive ridley sea turtles (NMFS 2005e).

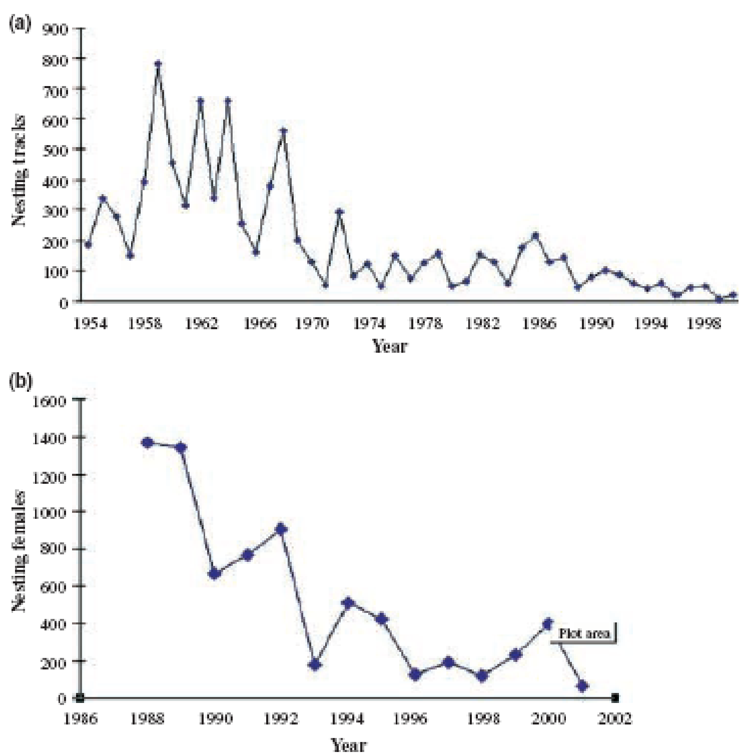

Figure 21. a) Declines in nesting loggerheads in Japan (Figure from Kamezaki et al. 2003 in Lewison et al. 2004b), and b) declines in nesting leatherbacks in Costa Rica (Figure from Spotila et al. 2000 in Lewison et al. 2004b).

Mediterranean

The conservation of loggerheads is threatened by the level of loggerhead bycatch associated with longline fisheries in the Mediterranean (Laurent et al. 1998). Loggerheads found in the

Mediterranean are from several populations, including loggerheads from the southeast U.S. (Laurent et al. 1998), thus Mediterranean longline fisheries impact more than just the loggerheads from the Mediterranean population. Even considering that bycatch in deep-set longline fisheries is lower than in shallow-set longline fisheries, this level of bycatch is still cause for concern.

Atlantic

Population data for leatherbacks in the Atlantic are uncertain and conflicting. However, the main nesting beaches in French Guiana and Suriname have exhibited a declining trend, with nesting declining at about 15% annually (NMFS 2004d). Leatherback bycatch in the Atlantic pelagic longline fishery has more severe population consequences than loggerhead bycatch for several reasons. Approximately half of the leatherbacks taken in the pelagic longline fishery are mature breeders while the other half are sub-adults; because leatherbacks are sexually mature in 5 – 15 years, the bycatch of leatherback sub-adults has more severe population consequences than does bycatch of loggerheads, which mature later (NMFS 2004d). Using the estimates of turtle bycatch from Lewison et al. (2004b), as well as post interaction mortality estimates, sex ratio data, and adult to juvenile ratio data, total leatherback mortality for adult females was estimated at 4,100 leatherbacks per year in the international fisheries in the Atlantic and Mediterranean (NMFS 2004d). While the U.S. longline fleet in the Atlantic accounts for only 1.2 – 1.4% of this mortality per year, the annual mortality of adult and sub-adult females in the U.S. fishery is “not discountable” (NMFS 2004d p. 6-8). In addition, there is considerable uncertainty associated with the status and trends of leatherbacks in the Atlantic. It has been shown that a combination of 18/0 circle hooks and mackerel bait reduces loggerhead interaction rates by 90% and leatherback interactions by 65% (Watson et al. 2005). The 2004 BiOp concludes that the proposed management measures in the U.S. Atlantic pelagic longline fishery *are likely* to jeopardize the continued existence of leatherbacks, but not the existence of the other turtle species that are taken as bycatch in this fishery. NMFS’ jeopardy finding was based on estimated annual mortalities in the U.S. fishery of approximately 200 leatherbacks, continuing indefinitely (NMFS 2004d).

Seabirds: bycatch rates

There are an estimated 61 seabird species that are affected by longline fisheries, 25 of which are threatened with extinction as a result of being caught as bycatch in longlines (Brothers et al. 1999). Estimates for seabird bycatch in longline fisheries in the North Pacific alone are approximately 35,000 albatross takes per year (Cousins et al. 2001). In addition, observed mortalities of seabirds may be underestimated, as seabirds may fall from hooks before being hauled on deck (Cousins and Cooper 2000; Ward et al. 2004); mortality estimates for some seabirds may be underestimated by as much as 45% (Ward et al. 2004). According to the FAO (1998), tuna longlines in the temperate waters of the North Pacific and in the Southern Ocean catch large numbers of seabirds as bycatch. Lewison and Crowder (2003) estimate that approximately 10,000 black-footed albatrosses are killed each year in all of the fleets in the North Pacific, and this level of mortality is likely contributing to population declines. The U.S. rate was estimated at 2,000 individuals per year while the international rates were estimated, as a moderate-case scenario, at 8,000 individuals per year (Lewison and Crowder 2003). In the northeast Pacific, black-footed albatrosses have been shown to overlap with the distribution of longline fisheries both spatially and temporally (Hyrenbach and Dotson 2003). Recent data from the Hawaii-based deep-set longline fishery indicate that takes of black-footed and Laysan albatrosses have declined, with only 16 black-footed and 10 Laysan albatrosses estimated as takes in 2004 (Figure 22); these numbers are far lower than they were in the 1990s, when upwards of 3,200 seabirds were taken per year (PIR 2005a). As of the writing of this report in 2005, 11 black-footed albatrosses, 6 Laysan albatrosses, and 1 brown booby had been released dead in the deep-set Hawaii fishery; observer coverage was 16.3% in the first quarter, 22.7% in the second quarter, and 37.9% in the third quarter (PIRO 2005b). One cause of these dramatic declines in seabird bycatch is a side-setting technique that has been developed that eliminates virtually all bird takes in longlines, which is now used by the Hawaii-based fleet.

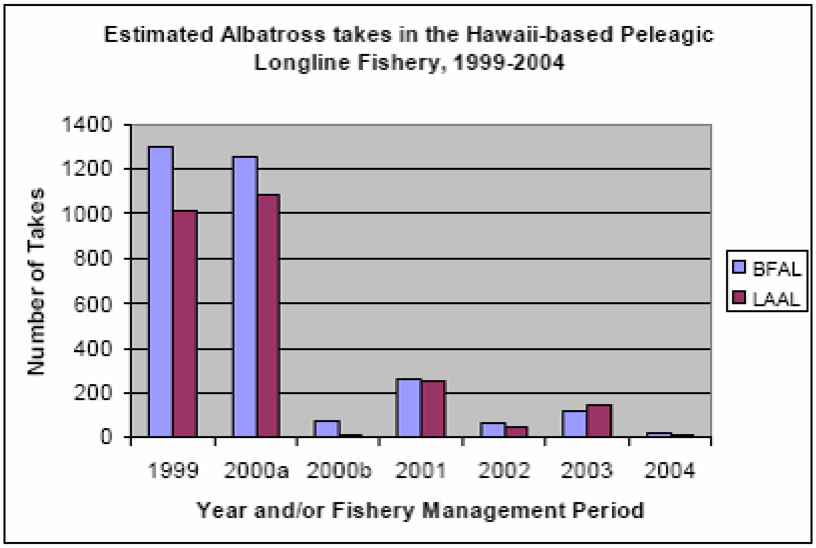

Figure 22. Total estimated takes of black-footed (BFAL) and Laysan albatrosses (LAAL) in the Hawaii-based longline fishery, 1999 – 2004 (Figure from PIR 2005a).

High seabird bycatch rates are also found in the Japanese longline fishery, where the mean catch rate is 0.92 birds/1,000 hooks. Catch rates have even been shown to be higher in the Australian fishery, possibly due to a lack of bird-scaring devices such as tori lines (Brothers and Foster 1997). There has been a recent decrease in seabird bycatch in Australian and New Zealand fisheries, however, which has been attributed to both an increase in the use of mitigation measures and a decrease in effort (Tuck et al. 2003).

In addition to the bycatch of endangered albatrosses there is also bycatch of seabird species that are not listed on either the U.S. ESA or the IUCN Red List. Cory's shearwaters, for instance, are caught in large numbers in the Mediterranean. Spanish longlining vessels alone have been estimated to catch as much as 4 – 6% of the local breeding population each year, which is considered unsustainable for the long-term existence of this colony (Cooper et al. 2003). In the western Mediterranean, however, Spanish longline vessels targeting albacore have been shown to have a seabird bycatch rate of only 0.0234 birds/1,000 hooks, which is lower than the bycatch rates shown for South African and Japanese fleets in Australian waters (Valeiras and Camiñas 2003). In general, there are little data concerning seabird bycatch in the Mediterranean (Cooper et al. 2003).

Though seabird bycatch mitigation measures are likely necessary in the WCPO, none are required (Small 2005). Observer data suggest that annual seabird takes in WCPO longline fisheries are from 0 – 9,800, with annual mortality rates from 24 – 100% (Molony 2005). Seabird takes in the Atlantic, on the other hand, are low, which is likely due to the night-setting of pelagic longlines (NMFS 2004e), as well as the absence of albatross species in the region.

In the Indian Ocean, an estimated 100,000 albatrosses and 300,000 other seabirds are killed annually (IOTC 2005b). Of the albatross species that interact with longline fisheries in the Indian Ocean, 19 out of the 21 are threatened with extinction (IOTC 2005b). Observer data from South African vessels indicate that the most common seabird species caught are white-chinned petrel, black-browed albatross, shy albatross, and yellow-nosed albatross (IOTC 2005b). The catch rate for South African fisheries averaged 0.2 birds/1,000 hooks in the domestic fleet and 0.8 birds/1,000 hooks in the foreign fleet (IOTC 2005b).
It is important to note that it cannot be assumed that fisheries with higher fishing effort have higher levels of seabird bycatch or that the population impacts of fisheries with higher effort are more substantial (Tuck et al. 2003).

Seabird bycatch: population impacts
Seabirds are particularly vulnerable to population decreases, as they are long-lived, have low reproductive rates, and mature late (Tuck et al. 2003). The bycatch of seabirds in longline fisheries worldwide is one of the principal threats to their populations (Gilman 2001). Some seabird species are at risk of becoming extinct, and their survival is threatened by the global presence of longline fisheries (Gilman 2001). For example, Lewison and Crowder (2003) conclude that U.S., Japanese, and Taiwanese longline vessels are the largest source of mortality to the black-footed albatross; the combined mortality due to U.S. and international longline vessels is likely above an estimated PBR threshold of 10,000 birds per year (Lewison and Crowder 2003).

Pelagic longlines also result in seabird bycatch in the Southern Ocean and the Mediterranean (Prince et al. 1998; Belda and Sanchez 2001). Fishing effort in the Southern Ocean, particularly by Taiwanese vessels, has been expanding since the 1970s, and seabirds in the region have shown dramatic declines attributed to incidental take in longline fisheries (Brothers 1991; Cooper 2000; Nel et al. 2002). The continuation of current fishing levels in the Southern Ocean, without the presence of mitigation measures and combined with the effects of IUU fishing, may be jeopardizing the sustainability of these seabird populations (Tuck et al. 2003).

Marine mammals: bycatch rates
In the Pacific, the Hawaii-based longline fishery for swordfish, tuna, and billfish is listed as a Category I fishery[8] in the NOAA Fisheries List of Fisheries for 2004, due to interactions with humpback whales, false killer whales, Risso's dolphins, bottlenose dolphins, spinner dolphins, short-finned pilot whales, and sperm whales. While there has been one observed interaction of an endangered sperm whale with the longline fishery in the Hawaiian EEZ, the effects of

[8] To be considered a Category I fishery, the annual mortality and serious injury of a marine mammal stock in the fishery is greater than or equal to 50% of the PBR level. The PBR level is "the maximum number of animals, not including natural mortalities, that may be removed from a marine mammal stock while allowing that stock to reach or maintain its optimal sustainable population" (69 CR 153, August 10 2004).

interactions with the Hawaii-based longline fishery in U.S. and international waters is unknown (Caretta et al. 2005). However, one cetacean species, the false killer whale (*Pseudorca crassidens*), is presently categorized as a "strategic" stock under the 1994 Marine Mammal Protection Act (MMPA) (Caretta et al. 2002). According to the CRS Report for Congress (Buck 1994), a strategic stock is defined as:

> Any marine mammal stock: (1) for which the level of direct human-caused mortality exceeds the potential biological removal level; (2) which is declining and likely to be listed as threatened under the Endangered Species Act; or (3) which is listed as threatened or endangered under the Endangered Species Act or as depleted under the MMPA.

All marine mammals, regardless of whether or not they are listed under the ESA, are protected under the MMPA. In 2004, 28 false killer whales were estimated taken (but not necessarily killed) in the Hawaii-based deep-set longline fishery. Uncertainty in population size and stock structure of false killer whales make it difficult to evaluate population-level impacts of the fishery on this species (K. Forney, SWFSC, pers. comm.). Efforts are presently underway by NMFS to address these critical research needs Carretta, Muto et al. 2002.

The U.S. longline fishery for large pelagics in the Atlantic Ocean, Gulf of Mexico, and Caribbean is also a Category I fishery due to interactions with humpback whales, minke whales, Risso's dolphins, long-finned pilot whales, short-finned whales, common dolphins, Atlantic spotted dolphins, pantropical spotted dolphins, striped dolphins, bottlenose dolphins, harbor porpoises, and pygmy sperm whales (69 FR 153, August 10, 2004). The only two species in this fishery that are listed as endangered under the ESA, and therefore strategic under the MMPA, are Humpback whales and pygmy sperm whales in the western North Atlantic.

Additionally, of all the protected species interactions, pelagic longlines do not generally result in as much marine mammal bycatch as other gear types such as gillnets (Lewison et al. 2004a; Reeves et al. 2005).

Note that these bycatch rates are only for the U.S. components of the pelagic longline fishery, and the international bycatch levels of marine mammals may be greater than these levels. Additionally, of all the protected species interactions, pelagic longlines do not generally result in as much marine mammal bycatch as other gear types such as gillnets (Lewison et al. 2004a; Reeves et al. 2005).

Marine mammals: population impacts

The annual PBR for the Hawaiian stock of false killer whales is 1.0, while the estimate of mortality and serious injury of this species in the Hawaii-based longline fishery is 4.4 individuals (Caretta et al. 2005). The contribution of pelagic longline gear to humpback whale mortalities is not included in the most recent humpback whale stock assessment; however, the average annual fishery-related mortality exceeds the PBR for this species (NMFS 2005d). There has also been one report of serious injury to a pygmy sperm whale in the pelagic longline fishery off Florida, and the average annual estimated mortality is 6 for this stock of marine mammals. Because the PBR is 3, this stock is considered strategic (NMFS 2005d).

Sharks and rays: bycatch rates

Despite their known vulnerability to overfishing, sharks have been increasingly exploited in recent decades, both as bycatch, from the 1960s onward, and as targets in directed fisheries, which expanded rapidly beginning in the 1980s Baum, Myers et al. 2003. The most common shark and ray species caught in longline fisheries are blue sharks, silky sharks, pelagic stingrays, and oceanic whitetip sharks (Williams 1997). As with the other species caught as bycatch in pelagic longline fisheries targeting tunas, the type and quantity of shark bycatch may vary with fishing location, gear configuration, etc. In the New Zealand longline fishery for tuna, in which albacore is the most commonly caught species, blue, porbeagle, and shortfin mako sharks compose most of the shark catch (Francis et al. 2001). In New Zealand waters in general, blue shark bycatch has declined by about 40% from 1988/89 to 1990/91 while porbeagle and mako shark bycatch was variable over the same time period (Francis et al. 2001). In the Japanese longline fishery operating in the EPO, the most common shark species caught are blue, silky, oceanic whitetip, crocodile, shortfin mako, longfin mako, salmon, bigeye thresher, and pelagic thresher. From 1971 – 1997, the total shark catch in this fishery generally increased, although catch declined in 1996 and 1997 due to decreases in fishing effort (Okamoto and Bayliff 2003).

Based on observer data (42 sets observed in 2001 – 2002) in the U.S. west coast pelagic longline fishery, the discard rate varies greatly by species. During 2001 – 2002, economically valuable species such as swordfish had a discard rate of approximately 14% while 100% of the blue sharks caught were discarded (PFMC and NMFS 2003). Blue sharks are the most commonly discarded species in the pelagic longline fishery, as well as *Carcharinus* spp. (Kelleher 2005). Data from the observer program in the U.S. Atlantic longline fishery targeting swordfish and tunas suggest that 69% of the blue sharks caught are released alive (Diaz and Serafy 2005). Discard mortality is also higher in younger blue sharks (Diaz and Serafy 2005). Other than the recent work on the decline of Atlantic shark species by Baum et al. (2003), few data are available detailing the international exploitation of sharks, particularly in the Pacific. Earlier studies, such as that conducted by Stevens 1996 suggest that high seas Pacific fisheries take millions of blue sharks each year, with unknown consequences to the population structure of this species. Estimates of annual fishing mortality range from 10 – 20 million blue sharks worldwide (IUCN 2004).

Limited observer data (an average of 6% observer coverage) from 1999 – 2003 in the WCPO show that after tunas (bigeye, yellowfin, and albacore), blue sharks were the most common species caught in the western tropical Pacific shallow set fishery, the western tropical Pacific deep set fishery, and the western South Pacific albacore fishery during that time period (Langley et al. 2005b). The number of blue sharks discarded relative to the number caught is not available in Langley et al. (2005b). In general, sharks and billfish were the most common non-tuna species caught. Molony (2005) found that shark CPUE was highest in the tropical shallow set longline fishery, although levels were similar in the tropical deep set longline fishery and the temperate albacore longline fishery. It is likely that shark catch is equivalent to shark mortality, as anecdotal evidence suggests that possibly all of the sharks brought on board are killed before being discarded (Molony 2005). In the central WCPO, total shark mortalities have been estimated at 500,000 – 1.4 million sharks annually based on observer data from the longline fisheries (Molony 2005).

In the U.S. pelagic longline fleet in the Atlantic, discards of pelagic shark are greater than retained catch of pelagic sharks; in 2003 the discard/catch ratio for pelagic sharks was 0.88 (NMFS 2005e). Off the South Atlantic coast of the U.S., pelagic longline vessels targeting swordfish also land tunas. In this fishery, sharks are the most common species caught as bycatch (Anderson 1985 in Beerkircher et al. 2004) and include dusky, night, silky, oceanic whitetip, tiger, blue, shortfin mako, and scalloped hammerhead sharks (Anderson 1985 in Beerkircher et al. 2002 in Beerkircher et al. 2004). From 1992 to 2000, swordfish and tuna comprised 53% of the catch in this fishery, while sharks were 15% of the total catch (Beerkircher et al. 2004). Over this time period, both oceanic whitetip and shortfin mako sharks exhibited a declining CPUE trend, while CPUE trends for other species (e.g., silky, dusky, tiger sharks) were variable (Beerkircher et al. 2004). Overall, dead discards of pelagic sharks in the U.S. Atlantic, Gulf of Mexico, and Caribbean declined from 1987 to 2000, with peaks in 1993 and 1996 (Cortés 2002). In 1987, a total of 13,092 pelagic sharks were discarded dead and in 2000 a total of 7,495 pelagic sharks were discarded dead in the pelagic longline fishery (Cortés 2002); recent estimates suggest that between 26,000 – 37,000 mt of blue sharks were discarded dead in the Atlantic in 1987 (ICCAT 2005).

In the Gulf of Mexico, oceanic whitetip sharks have declined by 99% while silky sharks have declined by 90%, based on catch rates using pelagic longline data from longline fisheries targeting yellowfin tuna (Baum and Myers 2004). In addition, the mean size for these species is at or below the size at maturity, which may increase the rate of decline (Baum and Myers 2004). Baum and Myers (2004) conclude that it is possible that similar declines in oceanic sharks have occurred in other regions. A preliminary ICCAT stock assessment concluded that the biomass of blue sharks is likely above B_{MSY}, while the shortfin mako stock may be below B_{MSY} (ICCAT 2005).

In the Indian Ocean, South African observer data (from 9% of the hooks set) suggest a catch rate of 7 sharks/1,000 hooks, with blue and mako sharks the most commonly caught shark species (IOTC 2005b).

A recent study found that shark catch rates vary by longline fishery and gear configuration, ranging from 0.7 sharks/1,000 hooks in the Italian swordfish longline fishery in the Mediterranean to 17 sharks/1,000 hooks in the Hawaii-based swordfish longline fishery (Gilman et al. 2007). The range of catch rates expands when less confident data are used (Table 8) (Gilman et al. 2007).

Table 8. Shark catch rate in 12 pelagic longline fisheries (Table from Gilman et al. 2007).

Pelagic Longline Fishery	Shark Catch Rate (number per 1,000 hooks)	Shark Retention (fins and/or carcass) % of total number caught sharks
Australia—tuna and billfish[9]	5.5	Not available
Chile—artisanal mahi mahi and shark[10]	24	> 99
Chile—swordfish	8	> 99
Fiji—tuna	1.1	78 – 90
Italy (Mediterranean)—swordfish	0.74	Not available
Japan—distant water tuna[11]	0.021	Not available
Japan—offshore longline	0.175	Not available
Japan—nearshore longline	0.020	Not available
Peru—artisanal mahi mahi and shark	0.99	84
South Africa—tuna and swordfish	4.0	80
U.S. (Hawaii)—tuna	2.2	2.1
U.S. (Hawaii)—swordfish	16.7	0.2

Both ICCAT and the IATTC have banned shark finning in the Atlantic and EPO, respectively (Gilman et al. 2007). Individual countries may also have shark finning bans in their respective EEZs (e.g., Australia, Italy, South Africa, and the U.S.) while other vessels from other countries may comply with such regulations while fishing in other countries' EEZs (Gilman et al. 2007). Some fleets, such as Fiji, are known to fin sharks (Gilman et al. 2007). Implementation of shark finning regulations has been shown to decrease shark mortality is countries such as Australia, where now more than 75% of sharks caught are released (Rose and McLaughlin 2001; Hobday et al. 2004 in Gilman et al. 2007). There is a minimum size limit for retained sharks in the Peru longline fishery, but enforcement is poor, as fishermen are known to retain sharks smaller than the minimum size, if they are even aware of the regulation (Alfaro and Mangel 2002 in Gilman et al. 2007). Despite the existence of shark finning regulations, concern remains over the increased demand for shark meat and the lack of catch restrictions for sharks (Gilman et al. 2007; Hareide et al. 2007; Oceana 2007). In addition, Hareide et al. (2007) question the effectiveness of the EU shark finning ban, as total imports and exports of shark fins greatly exceed reported landings. Although studies have shown circle hooks to be effective certain species and size classes of sea turtles, there is some evidence suggesting that shark catch increases with the use of circle hooks (Gilman et al. 2007); thus multi-species impacts of these hooks should be considered. Concurrent conservation measures such as the use of circle hooks and catch-and-release of sharks and marlins is more likely to increase the abundance of these species (Kaplan et al. 2007).

Sharks and rays: population impacts

Blue sharks have been shown to be sensitive to low exploitation rates (Schindler et al. 2002), but in the Atlantic, blue shark biomass appears to be above B_{MSY} (ICCAT 2005b). A 2001 assessment of MSY for blue sharks in the North Pacific concluded that for the population of blue sharks in this region, there is no danger of the stock collapsing (Kleiber et al. 2001). The status of the Atlantic shortfin mako stock, however, is highly uncertain, and it is possible that current

[9] Australian data are a rough estimate based on unpublished data.
[10] Chilean data are a rough estimate based on interview responses from fishers.
[11] Japanese data based on logbook data.

biomass levels are below B_{MSY}, particularly in light of the 50% depletion seen in the CPUE data (ICCAT 2005b). Although blue sharks are not protected under the U.S. ESA, the IUCN Red List of Threatened Species categorizes the blue shark as "Lower Risk," and it is close to qualifying for the "Vulnerable" category (IUCN 2004). The IUCN defines "Vulnerable" as facing a high risk of extinction in the wild (IUCN 2004).

Most sharks caught in the Pacific are considered incidental catch and are not retained; the exceptions are thresher and mako sharks, whose meat has market value with no special processing required NMFS 2003. Post-release mortality of discarded sharks is unknown. Given the observed declines in CPUE of heavily fished sharks in the Atlantic Ocean Crowder and Myers 2001, and the fact that fishing pressure in the Pacific is greater than the Atlantic (52% of global fishing effort in 2000 was in the Pacific, 37% in the Atlantic, 11% in the Indian Ocean) Lewison, Freeman et al. 2004, it seems reasonable to assume the incidental catch of many shark species in the Pacific may be having a negative impact on population levels.

As with seabirds and sea turtles, the impacts of longline fisheries on shark populations are not fully understood. The population consequences of bycatch of shark species in the Pacific is not well known, but the findings of Baum et al. (2003) in the Atlantic Ocean indicate caution is warranted for these highly vulnerable species. For more information on sharks, please see the Seafood Watch® Sharks Report at:
http://www.mbayaq.org/cr/cr_seafoodwatch/content/media/MBA_SeafoodWatch_SharksReport.pdf.

Purse Seines
Bycatch in purse seine sets on FADs is estimated to be 10% of the total catch per set, a level which is cause for concern, while bycatch from unassociated sets is estimated to be much lower at 1 – 2% of the total catch per set (Bromhead et al. undated). The most common bycatch taken in unassociated school sets are sharks, rays, and marlins (Bromhead et al. undated). These estimates are similar to bycatch rates described in Bailey et al. (1996), which estimated school set bycatch at 0.35 – 0.77% of the total catch by weight and log sets higher at 3.0 – 7.3%. Bromhead et al. (undated, p. 63) cite five reasons why FAD sets are cause for concern:

1) Catch efficiency of purse seiners has increased dramatically with the use of FADs.
2) Species composition of tuna caught under FADs differs to that of free schooling tuna.
3) Juvenile tuna are significantly more vulnerable to capture using FADs.
4) Advent of FADs means some species are now caught by multiple gears, both as young and adults.
5) FADs may trap tuna in unproductive regions, with implications for condition growth and biological productivity.

From 1993 – 1995 in the EPO, the bycatch/catch ratio for purse seines targeting yellowfin was 0.4 – 1.5% for dolphin sets, 1.0 – 2.5% for school sets, and 14.4 – 18.5% for FAD sets (García and Hall 1997). There is considerable spatial variation for some of the species caught as bycatch, such as dolphinfish, while there is a more uniform distribution of other bycatch species such as silky sharks and sailfishes (García and Hall 1997). With the prominence of the tuna-dolphin issue, purse seine sets on floating objects increased and the fishery expanded geographically (Figure 23) (Hall 1998). The switch from purse seines setting on dolphins to setting on floating objects has resulted in an increase in bycatch of juvenile tuna and other fishes associated with FADs as well as vulnerable species such as sea turtles and sharks (Hall 1998; IATTC 2004a). Dolphin sets have far less bycatch of both tunas and sharks than floating object or FAD sets. For instance, for every 1,000 mt of tuna landed in the EPO from 1993 – 1996, 2,000 and 4,000 times more mahi and wahoo, respectively, were discarded in log sets than in dolphin sets (Table 9) (Hall 1998).

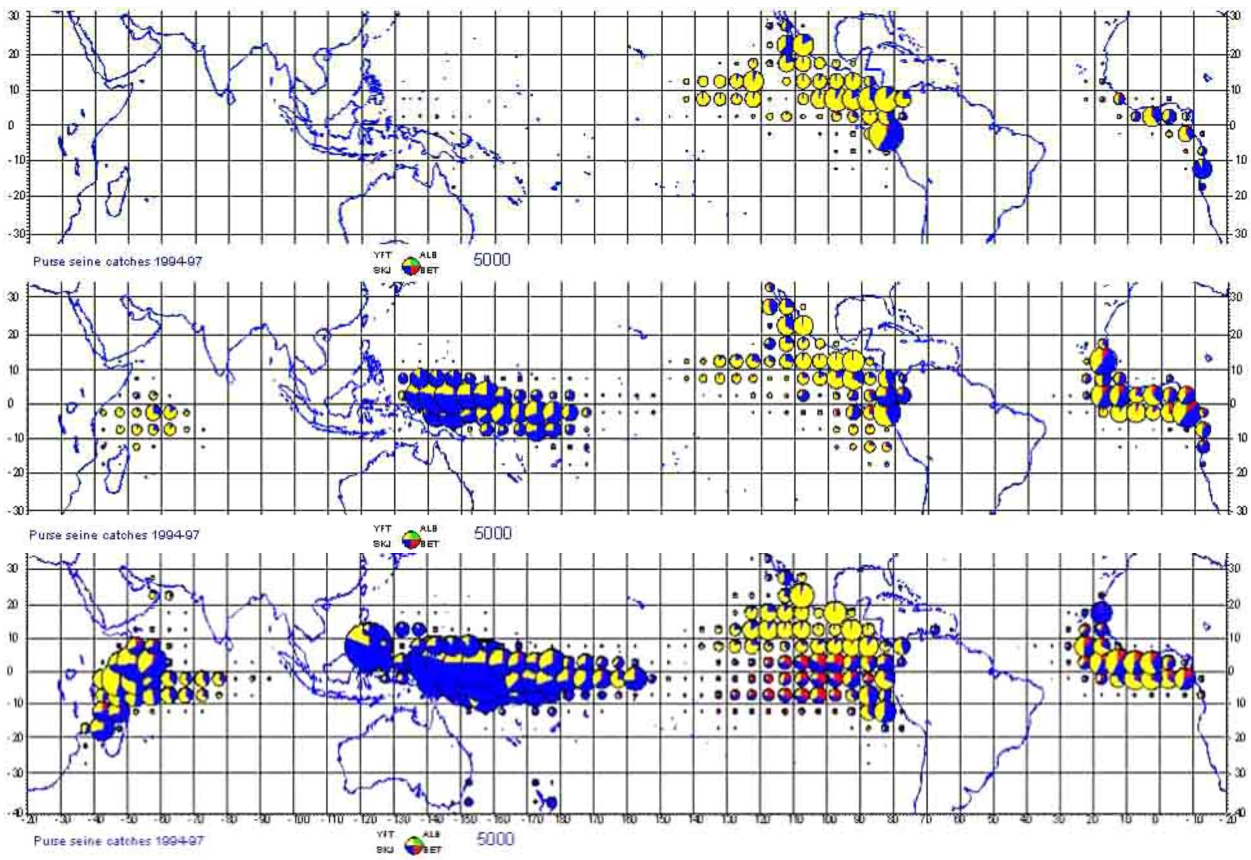

Figure 23. Expansion of the purse seine fishery over time. The top map shows purse seine catch from 1970 – 1973; the center map shows 1982 – 1985, and the bottom map shows 1994 – 1997 (Figures from Fonteneau 2003).

Table 9. Bycatch (in numbers of individuals) and tuna discards (in mt) per 1,000 mt of tuna catch for log sets, school sets, and dolphin sets (Table from Hall 1998).

Species	Log sets (n = 10,607)	School sets (n = 13,112)	Dolphin sets (n = 19,570)
Dolphins	0.0	0.1	34.1
Marlins	10.2	4.1	1.5
Sailfish	0.4	6.6	2.9
Other billfishes	0.7	0.3	0.1
Blacktip sharks	145.2	89.2	15.8
Silky sharks	51.1	16.3	3.8
Whitetip sharks	34.8	3.6	2.4
Other sharks and rays	59.3	86.1	17.0
Mahi mahi	4722.7	193.8	2.4
Wahoo	2034.6	26.7	0.6
Yellowtail	110.7	553.8	9.9
Rainbow runner	130.0	36.5	0.0
Other large teleosts	54.1	457.3	0.2
Triggerfishes	4774.6	75.6	7.4
Other small teleosts	7286.3	1091.5	358.3
Unidentified teleosts	7.3	4.6	10.6
Sea turtles	0.6	0.6	0.3
All tuna discards (tons)	228.5	33.6	9.9

Bycatch in the tropical purse seine fishery may also be high, and as with the EPO depends on the type of purse seine set (Romanov 2002). Observer data from Russian purse seiners operating in the Indian Ocean from 1986 – 1992 indicate that average bycatch levels were 27.1 mt/1,000 mt of target species (Romanov 2002). In the western Indian Ocean (WIO), FAD associated schools are the most common type of schools found, and non-tuna bycatch (most commonly sharks and rays, marlins, and sailfish) was 22% in these types of sets (Romanov 2002). Russian purse seines in the WIO also set on whale-associated and log-associated schools; bycatch in the log-associated schools was the highest of all set types, as well as the most diverse (Romanov 2002). In the WIO, estimated bycatch for the combined Spanish, French, Russian Federation, Japanese, and Mauritian purse seiners increased from 1985 – 1994 (Figure 24). In the Atlantic, it has been noted that a large fraction of the typical bycatch species caught under FADs are most often landed and sold to the local markets in Ghana, Ivory Coast, and Senegal.

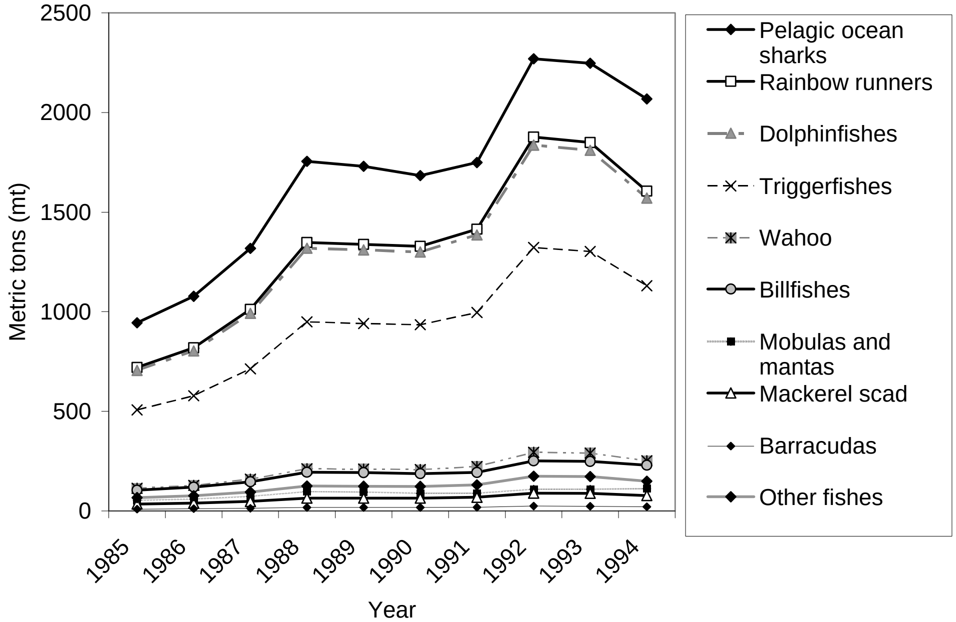

Figure 24. Bycatch in the French, Spanish, Russian Federation, Japanese, and Mauritian purse seine fleets operating in the WIO, 1985 – 1994 (Data from Romanov 2002).

Marine mammals: bycatch rates

In the WIO, whale mortality is likely very low despite the fact that purse seines are set on whale-associated schools (Romanov 2002). Marine mammal bycatch is also most often very low in FAD sets. Thus, there are not thought to be any severe population impacts due to marine mammal bycatch in these types of purse seine sets.

In the EPO, on the other hand, large yellowfin (10 – 40 kg) associate with several species of dolphins, including spotted dolphins (*Stenella attenuata*), spinner dolphins (*S. longirostris*), and common dolphins (*Delphinus delphis* and *D. capensis*) (IATTC 2004a)—only large yellowfin are found with dolphins, as smaller yellowfin cannot match the swimming speed of these marine mammals (Edwards 1992). To decrease marine mammal bycatch, when a purse seine net is hauled in, fishers "backdown" the net by reversing the vessel once the net is closed; this causes the corks and the top of the net to sink below the surface of the water (Figure 25) (Hall 1998), allowing dolphins to escape. Purse seine nets are also modified with a "Medina" panel, which is located at the top of the net, and is made of smaller mesh so that dolphins do not get entangled in the gear (Hall 1998). An additional measure used to reduce dolphin mortality in purse seine nets is the use of rescue rafts to rescue dolphins that may be trapped in the net (Hall 1998). The bycatch of dolphins in the purse seine fishery in the EPO has declined dramatically since the 1980s, despite the increase in dolphin sets (Figure 26) (IATTC 2004a). This reduced mortality is due to changes in the way that fishers use the gear, as well as gear modifications. There was, however, an increase in dolphin mortality in the mid-1980s due to the presence of international fleets, which began to replace the diminishing U.S. fleet (DeMaster 1992 in Gosliner 1999). This increased dolphin mortality was due to a lack of crew experience and ill-equipped vessels. Trade sanctions and international cooperation have resulted in decreased dolphin mortality in purse seines worldwide (Gosliner 1999). The U.S. purse seine vessels do not set on dolphins, and mortality of dolphins in other country's sets have declined by 99%, with less than 0.1% of current dolphin populations killed in purse seine sets on dolphins (Bayliff 2004).

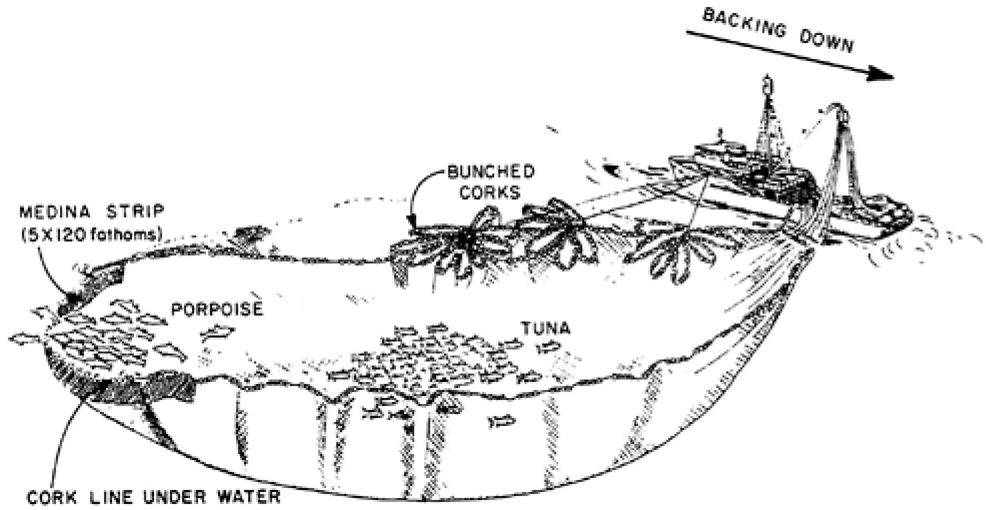

Figure 25. Purse seine vessel backing down to release dolphins (Figure from NRC 1992).

Annual estimates of mother dolphins killed without their calves, or the calf deficit, also declined markedly from 1973 – 2000, from 1.5 missing calves per set in the mid-1970s to 0.01 missing calves per set in the late 1990s (Archer et al. 2004). However, the number of mothers killed may be an underestimate due to unobserved or unreported mortalities (Archer et al. 2004).

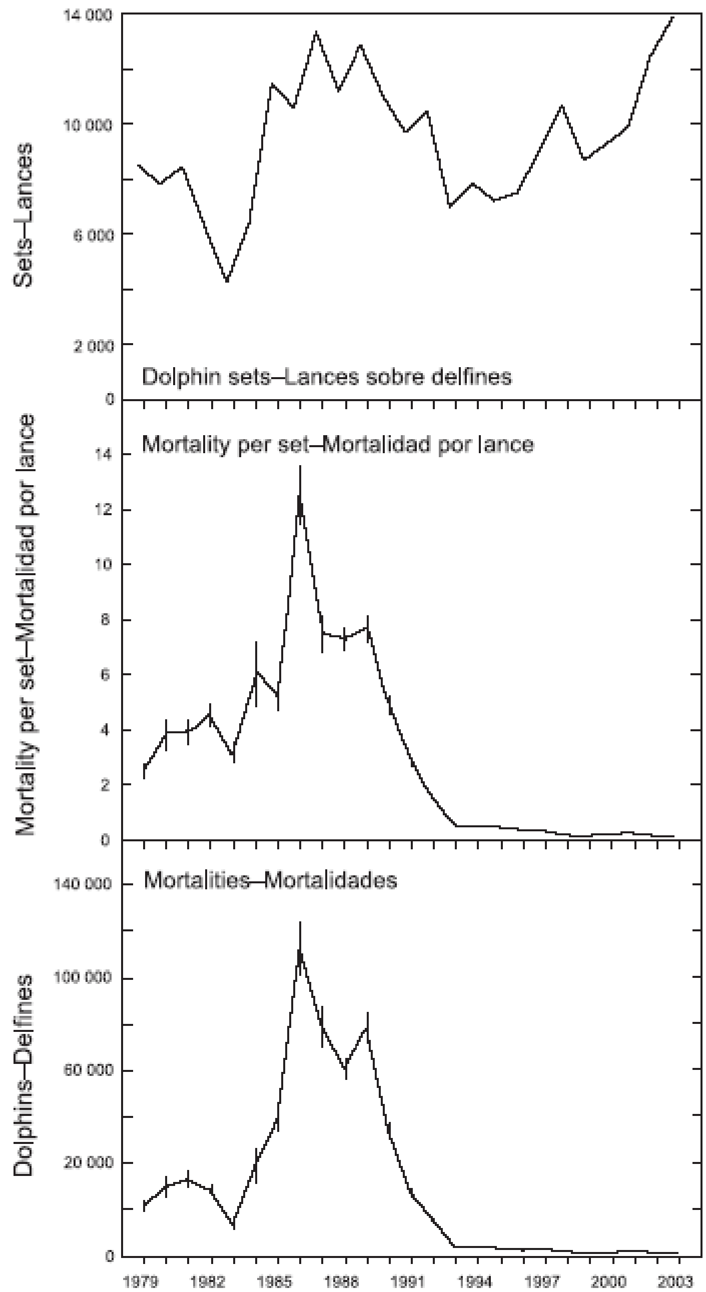

Figure 26. Number of dolphin sets, mortality per set, and decline in dolphin mortalities,1979 – 2003. Although the number of dolphin sets has increased, dolphin mortality has declined dramatically (Figure from IATTC 2004a).

Marine mammals: population impacts

Due to the historical high levels of dolphin mortality in the tuna purse seine fishery, populations of dolphins have declined dramatically. There is some controversy concerning the current status of dolphins, with "little evidence of recovery" observed (Reilly et al. 2005, p. 3). There are several hypotheses as to why dolphin populations have not recovered at their expected rate, including a change in the environment, a lag period following the reduction/elimination of dolphin bycatch, and fishery effects beyond the reported bycatch (Reilly et al. 2005). One or more of these hypotheses may be working in concert to limit the recovery of northeastern offshore spotted dolphins and spinner dolphins (Gerrodette and Forcada 2005). Unobserved mortalities have also been hypothesized to explain why some dolphin populations are not recovering at expected rates (Archer et al. 2004).

A recent study focused on reproductive data for the northeastern pantropical spotted dolphin (*S. attenuata attenuate*) in the eastern tropical Pacific found that annual number of purse-seine sets on dolphins was a predictor of two measures of reproductive output, namely the proportion of adult dolphins with calves and the length of calves when they disassociated with their mothers (Cramer et al. 2008). The link between fishing activity and these measures of reproductive output is further evidence that the population effects of purse seine sets goes beyond that of direct mortality (Cramer et al. 2008). Purse seine sets on dolphin schools may disrupt the swimming energy that calves gain from their mothers, resulting in increased calf loss (Weihs 2004 in Moore 2004). In particular, adult spotted dolphins are known to increase their swimming speeds during a purse seine set, which the calves are unlikely able to maintain (Edwards 2006).

To date, population growth of dolphins has been slow compared to theoretical numbers for both northeastern offshore spotted dolphins and eastern spinner dolphins, with growth rates of -2% to 2% per year (Reilly et al. 2005). Given the stock status of these species, these low growth rates are cause for concern (Reilly et al. 2005). Over the past 21 years, no trend was detected for either northeastern offshore spotted dolphins or eastern spinner dolphins (Figure 27) (Gerrodette and Forcada 2005).

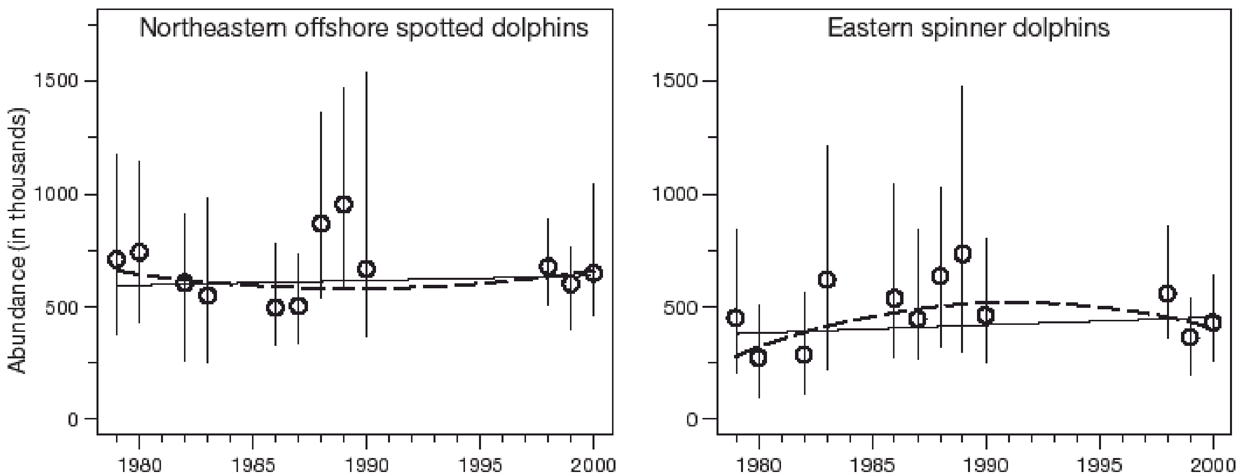

Figure 27. Estimates of northeastern offshore spotted and eastern spinner dolphins, 1979 – 2002. 95% confidence intervals are represented by vertical lines, the linear model is represented by the solid line, and the quadratic model is represented by the dashed line (Figure from Gerrodette and Forcada 2005).

Northeastern offshore spotted dolphins are currently at 20% of pre-fishery levels, while eastern spinner dolphins are at 35% of pre-fishery levels (Reilly et al. 2005). However, the IATTC concludes that the purse seine fishery is not having a significant adverse impact on the depleted dolphin stock in the ETP, and suggests that abundance surveys conducted by the SWFSC (Southwest Fisheries Science Center) show a stable or increasing trend for dolphin stocks over the last 20 years (IATTC 2002). In 2002, the U.S. Department of Commerce concluded that the dolphin set fishery was not having a significant adverse impact on dolphin stocks; this decision was overturned in a 2004 court case when the previous decision was found to not be based on science (Gerrodette and Forcada 2005). The degree to which the tuna fishery continues to affect dolphin populations remains uncertain.

It has been shown that the number of dolphin mortalities can be reduced in purse seine sets on dolphins, and there has recently been a shift towards supporting dolphin sets, as the ecosystem effects of other purse seining methods are more detrimental (Sharp 2001).

In the WCPO, limited observer coverage (an average of 6%[12]) shows that from 1995 – 2004, a total of 713 marine mammals were observed as bycatch in the equatorial purse seine fishery (Langley et al. 2005). The species composition and population impacts of this bycatch are unknown.

Fishes: bycatch rates

In general, there is less discarding of small tunas in the Atlantic and Indian Oceans, where there is a market for these small tuna, than there is in the Pacific (Romagny et al. 2000 in Fonteneau et

[12] Observer coverage varies greatly by fleet. The U.S. and Pacific Islands fleets have observer rates > 20% while Taiwan, Korea, and Japan have observer rates <5% (Langley et al. 2005b).

al. 2000). The average amount of bycatch in the FAD fishery is 10% of the tuna catches, with small tunas comprising most of the bycatch (Fonteneau et al. 2000).

In 1998, discard rates of undersized yellowfin in the U.S. purse seine fishery in the western Pacific were 0.4 mt/set for FADs, 0.3 mt/set for log sets, and 0.2 mt/set for unassociated sets (Coan et al. 1999). The discards of bycatch species were 0.4 mt/set, 1.1 mt/set, and 0.1 mt/set, respectively (Coan et al. 1999). These data show that FAD and log sets result in higher bycatch of undersized tuna and bycatch species. The percentage of tunas discarded in the dolphin, school, log, and FAD fisheries generally declined from 1992 – 1998, and the largest decrease was observed from 1992 – 1994. In general, discards of tuna in the dolphin and school sets were less than 10%, while tuna discards in the log and FAD fisheries ranged from 7 – 29% from 1992 – 1998 (Lennert-Cody and Hall 2000). Although discards of juvenile bigeye and yellowfin may be low in weight, it is a large amount of fish in numbers, and these fish are discarded due to their low market value (Sharp 2001). Other estimates put bycatch on log sets as 3.0 – 7.3% of the total catch (Lawson 1997 in Désurmont and Chapman 2000).

There are a number of fishes caught as bycatch in the non-dolphin tuna purse seine fisheries, especially on FAD associated schools including (in the EPO): juvenile bigeye, yellowfin, and skipjack tuna; small tunas such as bullet (*Auxis rochei*), frigate (*A. thazzard*), black skipjack (*Euthynnus lineatus*), and bonito (*Sarda* spp.); billfishes such as striped marlin (*Tetrapturas audax*), black marlin (*Makaira indica*), blue marlin (*M. nigricans*), sailfish (*Istiophrus platypterus*), and swordfish (*Xiphias gladius*); dolphinfish (*Coryphaena hippurus* and *C. equisetis*); wahoo (*Acanthocybium solandri*); rainbow runner (*Elagatis bipinnulata*); yellowtail (*Seriola* spp.); fish from the Serranidae and Carangidae families; and triggerfish from the Balisitidae family (García and Hall 1997). The above species are also observed caught in the WCPO purse seine fisheries based on limited observer data (Langley et al. 2005). The proportion of these species relative to the target species is small, although the diversity of species is high. In the EPO, dolphinfish, wahoo, and juvenile tuna are three of the most common bycatch species caught in FAD sets (Solana-Sansores 2001). Very similar species are also observed associated with FADs in other oceans.

In particular, the catch of juvenile bigeye has been increasing in FAD fisheries worldwide since the early 1990s, with serious concerns of recruitment overfishing being reflected biologically within the next 3 – 10 years (Fonteneau et al. 2000). The catch of juvenile yellowfin is also a concern according to the most recent stock assessment for yellowfin conducted in the WCPO. In addition, these increased catches are likely underestimated, as very small bigeye may be landed as yellowfin or skipjack. In the Atlantic, skipjack catches have been unexpectedly decreasing, and there has been a concurrent reduction in the average size of skipjack caught (Fonteneau et al. 2000). In the waters off the Philippines, 90% of the skipjack landed are around 16 cm in length (Dickson and Natividad 2000).

The quantity of billfish bycatch by the Spanish and French purse seiners in the eastern Atlantic is low relative to the targeted landings, at less than 0.021% of the total tuna catches (Gaertner et al. 2002). A temporary[13] moratorium on the use of FADs in the European purse seine fishery in the eastern Atlantic is thought to have decreased billfish bycatch by approximately 50%, although

[13] The moratorium was in place from November 1 – January 31 in 1997-98 and 1998-99.

sailfish bycatch has doubled (Gaertner et al. 2002). Marlin bycatch occurs in 35% of FAD sets but in only 4% of unassociated school sets (Gaertner et al. 2002). From October 1997 – September 1998, European purse seiners caught more tuna in school sets (88,456 mt) than FAD (49,214 mt) or seamount sets (1,285 mt). Marlin bycatch was almost five times higher in the FAD sets than the school sets during that time period (Gaertner et al. 2002).

Observer data from floating object sets in the EPO is available for discarded tunas and billfishes (IATTC 2004a). From 1997 – 2003, tuna (bigeye, yellowfin, skipjack, black skipjack, and bullet) discards in floating object sets declined. From 1997 – 2002, the trends in billfish discards varied by species. While discards of striped marlin and blue marlin showed a slight increase, discards of black marlin did not show a strong trend in either direction (IATTC 2004a). As there is no observer coverage on small (≤ 363 mt carrying capacity) purse seine vessels in the EPO, data from large vessel observer programs may not be applicable to the smaller vessels (Lennert-Cody and Hall 2000).

Fishes: population impacts

The large-scale removal of juvenile tuna in the purse seine fishery is cause for concern (Dickson and Natividad 2000; Fonteneau et al. 2000; Bromhead et al. undated), although there may be regional differences in the quantity of this bycatch. In the WCPO, for example, most of the purse seine catch is adult tuna. There is concern over the stock status of some of these tuna species (Table 10), and the increased mortality due to bycatch in the purse seine fisheries may have serious population consequences. Although the impact of FAD fisheries on the ecosystem as a whole may be low to moderate, caution may be warranted for local sub-populations, which may be vulnerable to overexploitation (Cury and Anneville 1998 in Fonteneau et al. 2000).

Romanov (2002) concludes that the bycatch levels of billfishes and other finfishes in the purse seine fisheries of the WIO are not likely to have negative impacts on their populations. There are no target fisheries in the WIO for the finfishes that are caught as bycatch in these purse seine fisheries, such as rainbow runner, dolphinfish, triggerfishes, wahoo, mackerel scad, and barracuda (Romanov 2002), and there is less billfish bycatch in the purse seine fisheries than in the longline fisheries targeting tuna and swordfish. There is also little population impacts of billfish bycatch in the eastern Atlantic purse seine fisheries (Gaertner et al. 2002). Stock status for billfish species is poor, however; in the Atlantic, biomass estimates for blue marlin, white marlin, and sailfish are all below B_{MSY} while fishing mortality on these stocks is above F_{MSY} (Peel et al. 2003; Uozumi 2003). The Atlantic blue marlin stock was estimated to be at 40% of B_{MSY}, current fishing mortality is four times F_{MSY}, and overfishing has been occurring over the last 10 – 15 years (ICCAT 2001). Fonteneau et al. (2002) and Gaertner et al. (2002) indicate that there may be ecosystem effects as a result of removal of high quantities of these large predators from the ocean.

Overall, FAD fisheries have the potential to cause serious problems for the conservation of tropical tuna stocks, particularly bigeye, and FAD fisheries may also be having a strong negative impact on the yield per recruit of many species (Fonteneau et al. 2000). The decreases in spawning stocks could lead to recruitment overfishing for several tropical tuna stocks, which has not been seen to date (Fonteneau et al. 2000). Extreme caution is warranted given the uncontrolled growth of this fishery (Fonteneau et al. 2000).

In the Gulf of Guinea (in the eastern equatorial Atlantic), there has been a change in the species composition of unassociated schools, with most small tuna appearing to aggregate under FADs rather than in unassociated schools; this possibly a result of the rapid growth of the FAD fishery in this area (Fonteneau et al. 2000b).

Table 10. Stock status of tunas commonly targeted and caught as bycatch in purse seine fisheries (Data from ICCAT 2008; Harley, Hoyle et al. 2010 IOTC 2009; Langley, Harley et al. 2009; Maunder 2009; Maunder and Aires-da-Silva 2009; NOAA 2009a; Hoyle, Kleiber et al. 2010; IATTC 2010). Note that the status of these stocks is not necessarily a direct result of the purse seine fishery.

Species	Stock Status by Ocean		
	Atlantic Ocean	**Pacific Ocean**	**Indian Ocean**
Bigeye	Rebuilding, not overfished	Overfishing occurring	Not overfished, fully exploited-overexploited
Skipjack	Unknown	Not overfished, overfishing not occurring	Moderately exploited
Yellowfin	Not overfished, overfishing not occurring	Not overfished, overfishing not occurring	Not overfished, overfishing occurring

Seabirds: bycatch rates and population impacts

Seabird bycatch is not thought to be a concern in the purse seine fisheries for tuna. There has been no seabird bycatch documented by any observer program on purse seiners and it can be concluded that purse seine fisheries have no direct impact on seabirds.

Sea turtles: bycatch rates

The sea turtle species caught by purse seines include olive ridley, green, leatherback, hawksbill, and loggerhead sea turtles. The majority of purse seine sea turtle bycatch occurs in purse seines set on floating objects, in particular the FAD fisheries (Figure 28) (IATTC 2004b; Molony 2005). Although these catches are quite limited in numbers and most sea turtles are released live (IATTC 2004b), some turtles may be injured or killed. Turtles entangled in the purse seine net may drown if they cannot surface to breathe, or may be lifted out of the water when the net is hauled in and get injured as they fall from the net or pass through the power block (IATTC 2004b). An additional issue that needs to be addressed is the entanglement of sea turtles in the webbing that is often hung from FADs to increase catches (IATTC 2004b). In the EPO, these nets may be as long as 50 m (Fonteneau et al. 2000).

IATTC observer data[14] for the purse seine fishery show that annual average mortality from 1993 – 2003 was 140 turtles (IATTC 2004b). Sea turtle bycatch in the purse seine fisheries declined over this time period, and the estimate of sea turtle bycatch in 2004 was 17 turtles (IATTC 2006). In the EPO, sea turtle bycatch in the purse seine fisheries was generally stable from 1993 – 2001, and declined in 2002 (IATTC 2004b). The level of sea turtle bycatch varied greatly according to the type of purse seine set, although olive ridleys were consistently the most

[14] These observer data are only from IATTC observers on large purse seiners, and do not include data from national observer programs or trips from small vessels that do not carry observers.

common sea turtle species caught as bycatch from 1993 – 2002 (IATTC 2004b). Small numbers of turtle bycatch in the purse seine fisheries in the WIO and the Atlantic have also been reported (Stretta et al. 1998; Romanov 2002).

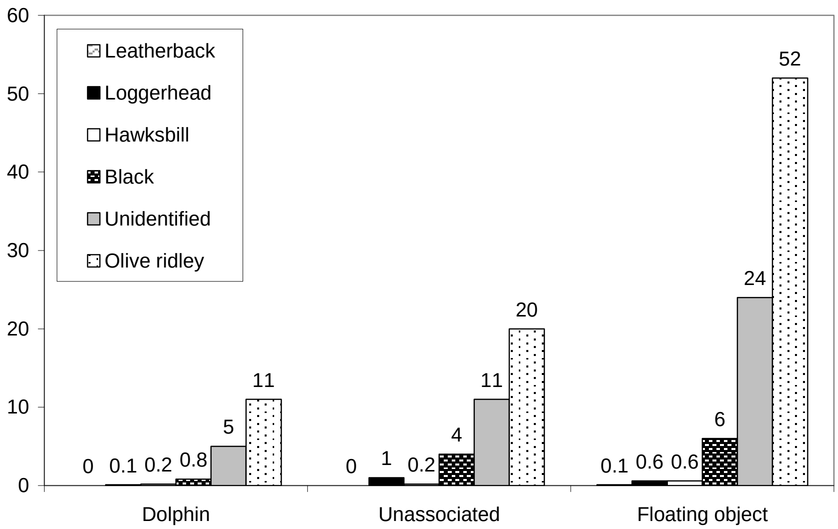

Figure 28. Average annual sea turtle mortality in EPO purse seine fisheries, by set type, 1993 – 2002. The bars representing the different sea turtle species appear in the same order as they are listed in the figure legend (IATTC 2004b).

Observer data from the purse seine fisheries of the EPO show that sea turtle bycatch in floating object sets was lower in 2003 that it was in 1993, but that in the years between, sea turtle bycatch was much higher than in both these years (Figure 29) (IATTC 2004a). Observer data from the WCPO suggests that approximately 200 turtles were taken annually in the purse seine fishery from 1994 – 2004, with less than 20 mortalities per year (Molony 2005).

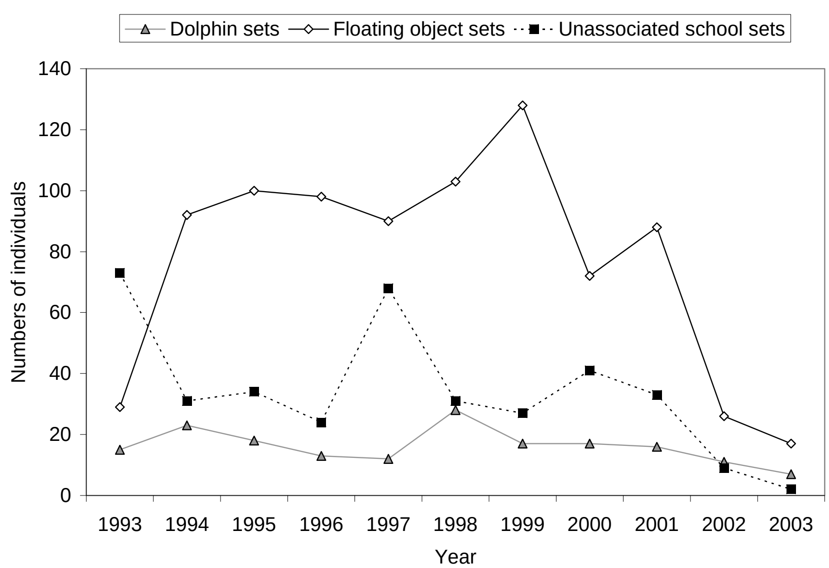

Figure 29. Trend in observed sea turtle bycatch (dead discards) in purse seine fisheries of the EPO, 1993 – 2003 (Data from IATTC 2004a).

Sea turtles: population impacts
All seven species of sea turtles are either endangered or threatened, with sea turtle populations facing several threats, including incidental take in fisheries, the killing of nesting females, egg collection at nesting beaches, habitat loss, and pollution and debris. The population impacts of sea turtle bycatch in the purse seine fisheries is unknown, but is less severe than for the pelagic longline fisheries due to the lower sea turtle numbers taken in purse seine fisheries. However, caution may be warranted due to global increasing effort in the FAD fishery. Population impacts may also vary by species.

Sharks and rays: bycatch rates
Sharks and rays caught as bycatch in non-dolphin purse seine sets include hammerhead (*Sphyrna* spp.), blacktip (*Carcharhinus limbatus*), whitetip (*C. longimanus*), silky (*C. falciformis*), dusky (*C. obscurus*), and other sharks (*Carcharhinus* spp.), as well as manta rays (*Mobula* spp., *Manta birostris*) and pelagic sting rays (*Dasyatis violacea*) (García and Hall 1997). In the EPO, silky sharks (*Carcharhinus falciformis*) and blacktip sharks (*C. limbatus*) are two of the most common species caught in purse seine sets on FADs (Solana-Sansores 2001). Although shark bycatch is high in the purse seine fishery, it is likely higher in the pelagic longline fishery. Pelagic longlines have been considered one of the primary sources of global shark bycatch due to high effort in the fishery (Bonfil 1994).

The shark species most commonly caught in the purse seine fisheries in the WCPO are silky sharks and oceanic whitetip sharks, while the following species are caught less frequently: pelagic thresher, silvertip, tiger, short-finned mako, long-finned mako, blue, and crocodile sharks, and manta rays (Williams 1997). As with most other bycatch species, the diversity of most of the shark species is higher in purse seine sets on associated schools (associated with floating objects or dolphins) than in sets on unassociated schools (Williams 1997).

Observer data from the EPO from 1993 – 2003 show a general decline in the bycatch of sharks and rays in floating object sets, as well as differences in bycatch species composition between unassociated and dolphin sets (Figure 30) (IATTC 2004a). There are many possible explanations for the decrease in shark and ray bycatch, one of which is that the populations of these species are declining. In this case, the downward trend of shark bycatch is not necessarily a reflection of decreased mortality, as it is with the decline of dolphin bycatch in the purse seine fishery. In addition, it is difficult to determine the population impacts of this bycatch when the population abundance of the bycatch species is unknown. Observer data from the WCPO shows that shark bycatch is highest in floating object sets, and there is considerable uncertainty regarding the mortality rate, as the condition and fate of most sharks was recorded as unknown during 1993 – 2003 (Molony 2005).

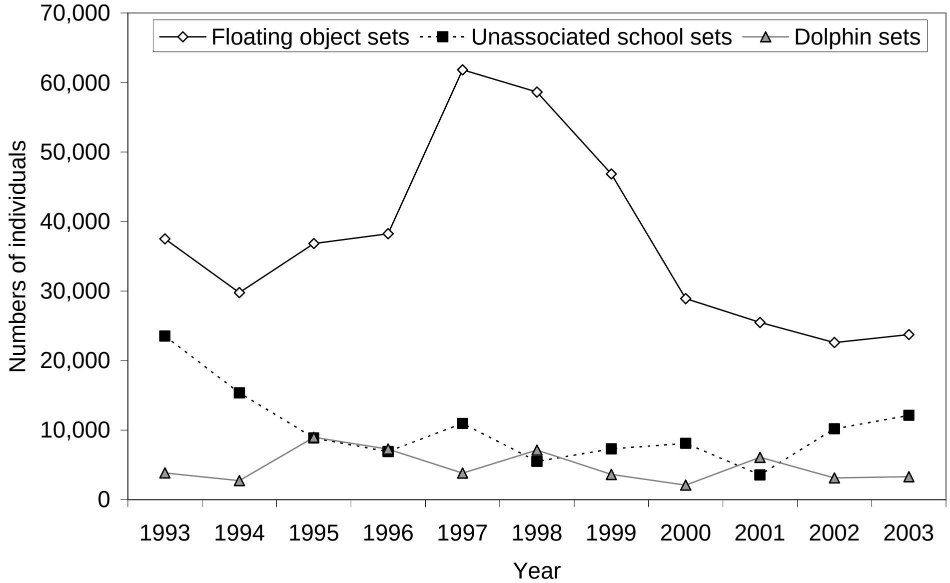

Figure 30. Shark and ray bycatch (dead discards) in the purse seine fisheries of the EPO, 1993 – 2003 (Data from IATTC 2004a).

Sharks and rays: population impacts[15]

Sharks and rays are generally not resilient to fishing pressure (Hoenig and Gruber 1990 in Musick et al. 2000), as they have a low intrinsic rate of increase (Smith et al. 1998), low fecundity, slow growth rates, and mature late in life (Camhi et al. 1998 in Musick et al. 2000). Sharks are in fact probably some of the most sensitive species to fishing pressure and so generalizations about declines in all predatory fishes may underestimate the declines in shark species. Indeed, the high sensitivity of sharks to fishing pressure means that they may be twice as likely to go extinct as bony fishes at moderate fishing pressures (Myers and Worm 2003). Although the best data are from the North Atlantic, many shark populations seem to have declined worldwide (Myers and Ottensmeyer 2005). This has led to considerable concern in national and international organizations such as the IUCN, CITES, and the FAO (Musick et al. 2000). Indeed, there are more elasmobranch species (263) than other marine fish (210) on the IUCN Red List of Threatened Species; 199 of these are sharks (the other 64 species are rays and skates). Due to the high unreported catches of pelagic shark species in many fisheries (mainly longliners but also purse seine fisheries operating in the WIO) there may be severe population impacts on many shark species (Romanov 2002). Throughout the world's oceans, sharks are facing an increasing threat from tuna fisheries, as they are frequently caught as bycatch (Fonteneau 2003). Several of the shark and ray species that are caught as bycatch in the purse seine fisheries are on the IUCN Red List of Threatened Species (Table 11).

[15] Portions of this section were taken verbatim from the Seafood Watch® Sharks Report available at: http://www.mbayaq.org/cr/cr_seafoodwatch/content/media/MBA_SeafoodWatch_SharksReport.pdf.

Many shark species have exhibited population declines, as exhibited by decreasing CPUE rates; however, other than the recent work on the decline of Atlantic shark species by Baum et al. (2003), few data are available detailing the international exploitation of sharks, particularly in the Pacific. Moreover, the magnitude of the declines found by Baum et al. (2003) has been challenged based on a number of factors, such as inadequate data and the exclusion of data sets such as stock assessments (Burgess et al. 2005). Earlier studies, such as that conducted by Stevens 1996 suggest that high seas Pacific fisheries take millions of blue sharks each year, with unknown consequences to the population structure of this species. Estimates of annual fishing mortality ranges from 10 – 20 million blue sharks worldwide (IUCN 2004).

Table 11. Shark and ray species that are caught as bycatch in the purse seine fishery and also on the IUCN Red List.

Species	Status on the IUCN Red List	Description	Source
Blacktip shark (*Carcharhinus limbatus*)	Lower Risk/near threatened	NW Atlantic population assessed; highly vulnerable to fishing pressure	Shark Specialist Group 2000a
Blue shark (*Prionace glauca*)	Lower Risk/near threatened	Annual fishing mortality as bycatch is likely affecting global population; inadequate data to assess the scale of possible decline	Stevens 2000a
Crocodile shark (*Pseudocarcharias kamoharai*)	Lower Risk/near threatened	Vulnerable as bycatch in pelagic longline fisheries; population decline probable but no CPUE records available	Compagno and Musick 2000
Hammerhead sharks (*Sphryna* spp.)	Data Deficient, Lower Risk/near threatened, Near Threatened	Some declines reported; lack of data on population trends; probable bycatch in tropical longline fishery	Denham 2000; Kotas 2000; Mycock 2004
Manta rays (*Mobula* spp.)	Near Threatened, Vulnerable	*M. japanica* commonly caught in surface gillnets targeting tuna	White 2003
Manta rays (*Manta birostris*)	Data Deficient	Highly vulnerable life history; bycatch in global fisheries thought to be rare, but declines have been observed in locations where targeted	Ishihara et al. 2002
Shortfin mako shark (*Isurus oxyrinchus*)	Lower Risk/near threatened	Wide-ranging; low reproductive capacity; significant targeted catch and bycatch in some regions	Stevens 2000b
Dusky shark (*Carcharhinus obscurus*)	Lower Risk/near threatened with a declining trend	Highly vulnerable to depletion due to low intrinsic rate of increase; high mortality rate when taken as bycatch	Shark Specialist Group 2000b
Tiger shark (*Galeocerdo cuvier*)	Lower Risk/near threatened	Fast growing and fecund, but declines have been observed in populations that are heavily fished	Simpfendorfer 2000
Whitetip shark (*Carcharhinus longimanus*)	Lower Risk/near threatened	Common bycatch species in tuna fishery; bycatch is inadequately reported or not recorded; population impacts unknown	Smale 2000

Synthesis
Troll/pole fishing methods have minimal bycatch, and are considered to be of low conservation concern. Bycatch in pelagic longlines, on the other hand, though there are limited data regarding international bycatch levels and trends, remains a critical conservation concern for the majority

of tuna longline fisheries due to the continued bycatch of sea turtles, seabirds, marine mammals, sharks, billfish and other pelagic fishes.

In the absence of data demonstrating that bycatch rates are declining, Seafood Watch® must adopt the precautionary approach in considering the severity of the bycatch problem in global longline fisheries. Even for those fisheries which can demonstrate low or declining bycatch as a result of sufficient observer coverage and management measures, the bycatch of species with vulnerable life histories (e.g., sea turtles and sharks) or species with a critical stock status (e.g., some species of billfish or bluefin tuna) remains a high conservation concern. The jeopardy finding for leatherbacks in the Atlantic results in a critical conservation concern for the international fishery. As leatherback interactions have declined in the U.S. fleet after the mandated use of hook/bait combinations, this fishery is ranked as a high conservation concern. If the bycatch trend increases it would be considered a critical conservation concern. In addition, there are several marine mammal species for which the PBR is exceeded in the Atlantic pelagic longline fishery, and the continued bycatch of marlin species with critical stock status remains a concern.

In the Pacific, seabird bycatch also remains a concern, in addition to sea turtle bycatch. Observer data from the Hawaii-based longline fishery indicates that bycatch concerns in this longline fishery are only a high concern whereas there remain critical bycatch concerns associated with international longline fisheries. Although there are no available data from the Indian Ocean, Seafood Watch® must adopt the precautionary approach and conclude that bycatch levels for protected and highly vulnerable bycatch species in this region are a critical conservation concern. For the purposes of this report, generalizations are made in order to make recommendations to the general public, although Seafood Watch® recognizes that there are differences between the various tuna longline fisheries. Country or fishery-specific data could be used to refute these generalizations.

There are clear differences between the different types of purse seine sets—dolphin sets, unassociated sets, and FAD sets—and their bycatch concerns. Dolphin mortalities in purse seine sets have been reduced dramatically through successful efforts on the part of managers and fishers. Although two populations of dolphins, the northeastern offshore spotted and eastern spinner dolphins are not recovering at expected rates, the degree to which setting on dolphins continues to affect these populations remains unknown. Bycatch in this fishery is thus considered a moderate conservation concern. Should evidence emerge that the population consequences are more severe than currently thought this would be a high concern. Bycatch in school sets is characterized primarily by small and large bony fishes. Purse seine sets on floating objects such as FADs result in high bycatch of juvenile tuna, other pelagics such as dolphinfish and wahoo, sharks, and sea turtles. Juvenile bigeye and yellowfin in particular have been identified as bycatch species of concern in the floating object fishery. Observer data from the EPO suggests a declining trend in bycatch, but there are no comprehensive international data regarding bycatch in the global FAD fisheries, and the expansion of this fishery is cause for concern. Bycatch in the purse seine fishery on FADs or other floating objects thus ranks as a critical conservation concern.

Nature of Bycatch Rank:

Troll/pole (all oceans):

Low	Moderate	High	Critical

Dolphin purse seine sets;
Unassociated purse seine sets:

Low	**Moderate**	High	Critical

Hawaii-based longline;
U.S. Atlantic longline:

Low	Moderate	**High**	Critical

International longline (all oceans);
Floating object/FAD purse seine sets:

Low	Moderate	High	**Critical**

Criterion 4: Effect of Fishing Practices on Habitats and Ecosystems

Habitat Effects

The gear used to catch yellowfin (i.e., pole and line and handlines, pelagic longlines, and purse seines) has minimal effects on the seafloor, as they are either pelagic or surface gears and do not come into contact with the benthic environment (Chuenpagdee et al. 2003).

Ecosystem Effects

It has been suggested by Myers and Worm (2003) that the global oceans have lost 90% of the large predators (such as tunas) due to the expanding and pervasive pelagic longline fishery. Based on CPUE data, these authors found that while catches in a previously unfished area remained high at first, local catches declined after several years of fishing pressure. However, this argument has proved to be highly controversial, with questions raised concerning the methodology used (Walters 2003), and the period and magnitude of the declines (Hampton et al. 2005b; Sibert et al. 2006). A recent study (Sibert et al. 2006) concluded that the magnitude of the decline in the biomass of large predators varied by stock and region; for instance, exploited bigeye and yellowfin declined in the western Pacific while skipjack increased. The authors acknowledge that more conservative management measures may be needed for ecosystem-based management (Walters et al. 2001 in Sibert et al. 2006). Both climate change and fishing pressure have been linked to ocean-wide declines in large predator diversity, with fishing being the primary driver behind long-term variation (Ward and Myers 2005; Worm et al. 2005). According to Worm et al. (2005), diversity in the world's oceans has declined by 10 – 50% over the last 50 years.

In the tropical Pacific, large-scale commercial fishing has been linked to ocean ecosystem changes, such as declines in large predator abundance and increases in small species abundance (Ward and Myers 2005). Ward and Myers (2005) looked at scientific survey data from the 1950s and observer data from the 1990s and found that the number of fish caught declined from 58 fish/1,000 hooks to 25 fish/1,000 hooks over this time period. However, other studies have found dissimilar results (Cox et al. 2002). Using an ecosystem model, Cox et al. (2002) found fewer declines of large predators such as tunas and billfishes in a larger area of the Pacific.

Kitchell et al. (2002) found that central North Pacific tuna and swordfish are likely more important predators than blue sharks. Pauly and Palomares (2005) found that the total length of tuna and billfish caught worldwide exhibited a continual decline from 1950 – 2000, and that "fishing down the foodweb" is more prevalent than previously thought. The removal of apex predators by commercial fisheries may have a large impact on trophic dynamics and thus pelagic ecosystems, even with sustainable fishing mortality rates (Essington et al. 2002).

The removal of large predators, such as tunas, sharks, and billfishes, from the ecosystem may affect the interactions between these species, as well as result in considerable top-down effects (effects on prey species populations and the food chain below these large predators) (Fonteneau 2003). The potential ecosystem effects of removing these predators from the world's oceans, and the bycatch of vulnerable and threatened species have been identified as two environmental risks associated with the increased pressure by tuna fisheries (Fonteneau 2003).

With increasing use of FADs in the purse seine fisheries, the risk of negative impacts, such as increased removal of juvenile tuna and bycatch species, increases (Sakagawa 2000). FADs may also affect tuna species by attracting them to remain in an area where they would normally pass through, possibly affecting characteristics such as growth population dynamics and distribution (Sakagawa 2000). The ecosystem effects of the potential FAD impacts on tunas are highly uncertain, and caution may be warranted (Sakagawa 2000). FADs may serve as ecological traps, artificially shifting the movement patterns of tunas and other species that associate with FADs (Marsac et al. 2000).

The environmental impacts of fishing are not limited to the direct impacts on the fisheries resource, but include emissions (e.g., from fossil fuel and anti-fouling paint) from the operating of these industrial fisheries (Hospido and Tyedmers 2005).

Synthesis

Purse seine, pelagic longline, and troll/pole gear have negligible habitat effects. The ecosystem effects of removing large predators such as tunas, billfishes, and sharks, however, remain controversial. Due to the nature of the ecosystem effects caused by the removal of large predators from the ecosystem, combined with the benign habitat effects of the gear used, the conservation concern for troll/pole and dolphin-set and unassociated purse seine gear types is low, while the conservation concern for floating object/FAD purse seines and pelagic longlines is moderate.

Effect of Fishing Practices Rank:

Troll/pole;
Purse seine (unassociated and dolphin-set):

Benign | Moderate | Severe | Critical

Purse seine (floating object/FAD sets only);
Longline:

Benign | **Moderate** | Severe | Critical

Criterion 5: Effectiveness of the Management Regime

Management of yellowfin tuna varies by ocean basin (Table 12). Illegal, unreported, and unregulated (IUU) fishing, where vessels from one country are registered in another to avoid compliance with regulations, remains problematic throughout the world's oceans for the tuna fisheries, particularly the longline fisheries. In the 1980s, for example, when quotas were implemented by the regional fishery management organizations (RFMOs), vessel owners registered their vessels in non-contracting parties to avoid the RFMO regulations. Additionally, some catches by IUU fishing may be transferred to legal fishing vessels at sea (IOTC 2002).

The existence of IUU fishing vessels introduces added uncertainty to the issue of bycatch in the pelagic longline fishery, as the incidental mortality of certain bycatch species may be substantial on these vessels, but its magnitude is unknown (Tuck et al. 2003). It is believed that IUU fishing is more prevalent in the Atlantic and Indian Oceans than in the Pacific Ocean (Tuck et al. 2003), but there are great uncertainties worldwide regarding the trend and extent of these IUU longline fisheries. The most stringent measures that the tuna commissions can implement are trade measures, and ICCAT was the first to do so, as well as discouraging buyers to buy from IUU vessels (Miyake 2005b). The IOTC and IATTC have followed suite by maintaining and publishing the list of IUU vessels fishing in their respective oceans (Miyake 2005b). In addition, smaller longline vessels are considered a different type of IUU vessel; because they are too small to be listed on the positive list of fishing vessels, they are not subject to the regulations that are imposed on the vessels that are listed (Miyake 2005b). As of June 2004, it was estimated that there are 30 IUU longliners in operation (Miyake 2005b). To address the issue of IUU, the U.S. has implemented a HMS international trade permit for all dealers who import or export bluefin tuna, swordfish, southern bluefin tuna, and bigeye tuna.

The complexity of tuna management is increased by the fact that tuna caught in one ocean may be transported to another region for processing, and fleets licensed in a country in one ocean may fish in other oceans (Bayliff et al. 2005). Despite management measures implemented by the tuna commissions, vessels are sometimes registered in countries that do not require their vessels to comply, purposely to avoid these regulations (Bayliff et al. 2005).

Overall, the decline of some tuna stocks has been in part due to the open-access nature of the tuna fisheries, and additionally there is little regulation on the non-industrial fleets (Bayliff et al. 2005). Thus, a rights-based management system that also considers the non-industrial fleets may be the best option to be effective and curtail the growth of the tuna fleets (Bayliff et al. 2005). Many countries have limits on the number of large-scale longliners, but not the small and medium sized longliners (Miyake 2005b). To improve tuna fisheries management, a Technical Advisory Committee to the FAO recommended some of the following changes (Bayliff et al. 2005):

- A moratorium on the entry of large-scale tuna vessels until there is an improved management system for fishing capacity.
- A system for the transfer of fishing capacity.
- Monitoring, surveillance, and control systems to manage fishing capacity.

Fishing capacity has been reduced by some countries; Japan for instance, reduced its fishing capacity (licenses given to large-scale tuna longliners) by 20% in 2001 as a result of the FAO's 1999 International Plan of Action (IPOA) (Miyake 2005a). In 2001, China adopted a limited-license system (Miyake 2005a). While some fleets have limited the number of licenses (Republic of Korea in the 1980s, Taiwan and China in 2003), other countries have continued to issue fishing licenses without any restrictions (Panama, Honduras, Belize, Vanuatu, Cambodia) (Miyake 2005).

Measures (both voluntary and mandatory) to reduce FAD fishing have been implemented since 1997 in the Atlantic, since 1998 in the Indian Ocean, and since 2001 in the Pacific (Miyake 2005b).

Pacific

The international management agencies responsible for yellowfin in the Pacific Ocean include the Inter-American Tropical Tuna Commission (IATTC) and the Western and Central Pacific Fisheries Commission (WCPFC). The WCPFC came into force in June 2004, and regulates and manages all HMS in the western and central Pacific; the IATTC manages tuna in the eastern Pacific Ocean. IATTC member countries include Costa Rica, Ecuador, El Salvador, France, Guatemala, Japan, Mexico, Nicaragua, Panama, Peru, Spain, the U.S., Vanuatu, and Venezuela. Cooperating non-parties to the IATTC include Canada, China, the E.U., Honduras, Korea, and Taiwan. Individual countries may be managed by additional management bodies.

The Pacific Islands Forum Fisheries Agency (FFA) and the Secretariat of the Pacific Community (SPC) serve as research and coordination agencies for Pacific Island nations. The FFA provides fisheries management and development advice to its member countries, which include Australia, the Cook Islands, Federated States of Micronesia, Fiji, Kiribati, Marshall Islands, Nauru, New Zealand, Niue, Palau, Papua New Guinea, Samoa, Solomon Islands, Tokelau, Tonga, Tuvalu, and Vanuatu (FFA 2005).

The most recent stock assessment for yellowfin in the EPO utilized fishery-dependent data such as catch, effort, and size-composition data for January 1975 through December 2003. IATTC collects data on a regular basis, and all data are summarized and analyzed on a quarterly basis

(Maunder and Harley 2005). Management measures implemented by the IATTC have included a ban on setting nets on floating objects, area closures, and a quota for yellowfin in the EPO (Lennert-Cody and Hall 2000). As of October 17, 2005, there are 20 active IATTC resolutions and 10 active AIDCP (Agreement on the International Dolphin Conservation Program) resolutions for tuna in the EPO. These resolutions are passed to individual countries, which are then expected to pass the corresponding regulations. The IATTC has collected observer data on discards and bycatch on purse seine vessels from 1992 – 2003 (IATTC 2004a). IATTC is currently conducting research on possible gear modifications to reduce the catch of the small yellowfin and bigeye in purse seines that are primarily targeting skipjack (IATTC 2004a). The IATTC has banned supply vessels, which are used to deploy and maintain FADs as well as monitor the quantity of tuna under them (Fonteneau et al. 2000). In the EPO, an observer must be on board all purse seine sets in the IATTC convention area, regardless of whether the vessel will be setting on dolphins; though this only applies to vessels larger than 400 short tons (363 mt) (PFMC 2003).

In the EPO, the IATTC manages the Tuna-Dolphin Program, which monitors dolphin mortality in the purse seine fishery and works with fishers to reduce this mortality (Bratten and Hall 1997). The AIDCP has an observer program comprising the IATTC's international observer program and the national observer programs of Ecuador, the European Union, Mexico, and Venezuela (IATTC 2004a). The AIDCP was implemented in 1999, the goal of which is to reduce the number of dolphin mortalities in the purse seine fisheries that set on dolphin-associated tuna schools. The AIDCP has been ratified by Costa Rica, Ecuador, El Salvador, Guatemala, Honduras, Mexico, Nicaragua, Panama, Peru, the U.S., Vanuatu, and Venezuela. The AIDCP observer program mandates 100% observer coverage for all purse seine vessels with a carrying capacity greater than 363 mt (IATTC 2004a). In addition, there is an annual dolphin mortality limit for the international fleet, which was 5,000 dolphins in 2003 (IATTC 2004a). The tuna-dolphin problem is a prime example illustrating the importance of ecosystem-based management. As a result of addressing the mortality of a single species in the purse seine fishery, bycatch of numerous other species has increased due to the growth of the FAD fishery. Instead of bycatch of dolphins, there is now increased bycatch of both commercial and vulnerable species such as juvenile tuna, sharks, sea turtles, and numerous other fishes.

In the WCPO, there are reporting requirements, regional and national observer programs, and a vessel monitoring system (Désurmont and Chapman 2000). However, there is less monitoring of the artisanal fisheries; for instance, although a logbook program is in place in New Caledonia the data are not specific enough (Désurmont and Chapman 2000). In Papua New Guinea (PNG), the Solomon Islands, the Philippines, and Indonesia, FADs are set by the industrial sector, and there are some regulations regarding FADs in these countries. In PNG there are restrictions on the numbers of FADs that can be set, and in the Solomon Islands there are restrictions on who can set FADs, as recommended in the Solomon Islands National Tuna Management and Development Plan (Désurmont and Chapman 2000).

The Palau Arrangement of 1992 limits purse seine fishing effort in the EEZs of eight of the 16 member countries of the FFA (Bayliff et al. 2005). Most of the tuna catch in the WCPO is taken in the EEZs of these eight countries, and the Arrangement limits the number of purse seine vessels to 205 (Bayliff et al. 2005).

Indonesia
Fisheries in Indonesia are managed under the Ministry of Marine Affairs and Fisheries; all fisheries are managed under a TAC, and there are nine fishery management areas (FAO 2006). These include Malacca Strait, South China Sea, Java Sea, Makasar Strait and Flores Sea, Banda Sea, Seram Sea and Tomini Bay, Sulawesi Sea and Pacific Ocean, Arafura Sea, and the Indian Ocean (Retnowati 2006). In 2004, tuna composed approximately 17% of total fisheries production in Indonesia (FAO 2006). Although there is an overall TAC for Indonesian fisheries, issues remain concerning IUU fishing (Yamashita 2000). Specific regulations for the tuna fishery in Indonesian waters are unknown.

Philippines
Fisheries in the Philippines are managed by the Philippines Bureau of Fisheries and Aquatic Resources (BFAR), which administers a National Stock Assessment Program (NSAP). The NSAP has resulted in a TAC for Philippines fisheries in general, and a moratorium on new commercial fishing licenses in 2004 (Barut 2004). Data collection is limited to port sampling in the domestic fishery in the Philippines; sampling occurs on about 67% of the days (monthly) at each port, with length and weight measurements collected approximately 10% of the time (Williams 2004). As logbook data are not collected, there is no indication of spatial effort, and 100% port sampling would provide more reliable catch and effort data (Williams 2004). Commercial fishing permits have been required since 1998 (Barut 2004). Catch statistics combined yellowfin and bigeye tuna until 2005, and catch increased from 1994 to 2003, primarily from Philippines flagged vessels in international waters (Barut 2004). It is estimated that approximately 70% of the tuna catch was by vessels fishing in international waters (Barut and Garvilles 2006). Several fisheries management concerns have been identified in the Philippines (not specifically related to the tuna fisheries), such as resource depletion, overfishing, and illegal fishing (Barut 2004). In 1995, it was estimated that 10,000 mt of tuna were caught illegally in the waters of the Philippines, despite a prohibition of international vessels fishing in the Philippines EEZ (Barut and Garvilles 2006). Additional management entities include the MCS (Monitoring Control and Surveillance), which is known to be violated in several areas in the Philippines; and the Fisheries and Aquatic Resource Management Council (FARMC), regional management councils that are composed of stakeholders.

Management measures include a prohibition of large commercial vessels operating in municipal waters (within 15 km of the coastline), although this regulation is violated frequently (Barut and Garvilles 2006). Vessels from the Philippines that fish outside of the domestic EEZ are not required to report catches in logbooks, thus catch data are incomplete for this fishing sector—catch data for the domestic and international sectors are mixed (Barut and Garvilles 2006). There is no observer program for the Philippines tuna fleet, although Philippines vessels operating in PNG waters abide by the observer requirements there. Although a Philippine National Tuna Management Plan was developed in 2004, it has not yet been implemented (Barut and Garvilles 2006).

United States
U.S. fisheries are also managed by NMFS, the Pacific Fishery Management Council (PFMC) and the West Pacific Fishery Management Council (WPFMC). U.S. fisheries operating in the

western Pacific are also managed under an agreement with Pacific Island nations, the South Pacific Tuna Treaty (Sakagawa 2000); U.S. purse seining operations have increasingly shifted to operating primarily in the western Pacific region (Sakagawa 2000). In the western Pacific, data are collected by the Pacific Islands Forum Fisheries Agency and NMFS (for U.S. fisheries) (Sakagawa 2000).

Yellowfin in the U.S. EEZ around Hawaii and the U.S. Pacific Islands is managed under the Pacific Pelagics Fishery Ecosystem Plan. Management measures included in the plan include fishing permits, area closures, observer requirements, and catch reporting. The Hawaii-based longline fleet operates under a number of new management measures to minimize protected species interactions and bycatch. These measures include: an effort limit on the number of shallow-sets north of the equator (2,120 shallow sets per year); the requirement that all shallow-sets made north of the equator use circle hooks 18/0 or larger with a 10-degree offset and only use mackerel-type bait; and the provision that shallow sets made north of the equator must occur at night. There is also a limit on the number of allowable interactions with leatherbacks (16) and loggerheads (17); if either of these limits is reached the shallow-set fishery is closed for the remainder of the year (69 FR 64 April 2, 2004). These regulations do not apply to the deep-set longline fishery targeting several species of tuna, however. To clearly differentiate between shallow sets and deep sets, deep sets are required to have a minimum of 15 branch lines between successive floats, use a float line at least 20 m in length, set the main line using a line shooter, and not retain more than 10 swordfish per trip (Federal Register April 2, 2004, volume 69, pages 17329-17354). These regulations have resulted in longlines targeting tuna being set deeper in the water column, and possibly inadvertently reducing sea turtle interactions with the deep-set fishery. There is an average of 20% observer coverage on deep-set longline vessels.

Yellowfin caught in the U.S. EEZ off the west coast are managed under the Highly Migratory Species (HMS) Fishery Management Plan (FMP). Under the FMP, there are no quotas for any HMS, but there are permitting and reporting requirements. U.S. vessels fishing in the high seas and landing their catch in the U.S. must also follow the management measures specified in the HMS FMP. Area closures implemented under this FMP include the prohibition of longlines targeting HMS within the HMS management area (PFMC 2005).

There is no basin-wide observer program (either internationally mandated or Commission implemented) for the Pacific Ocean or logbook requirement program, although individual countries may have these programs in place. In several Central and South American countries (e.g., Ecuador, Costa Rica, Brazil, Chile, Peru, Columbia, Panama, and Guatemala) work is being conducted with fishermen to exchange J hooks for circle hooks in the pelagic longline fishery. Results from the first year of the program in Ecuador show that circle hooks reduced the hooking rates of sea turtles by 44 – 88% in the tuna fishery, as well as the hooking severity (Largacha et al. 2005).

In the WCPO, observer coverage varies by fishing method and region, and comprehensive observer programs have only been in place for the last 10 years (Langley et al. 2005b). Thus, observer data are limited and cannot be used to estimate overall catches by these fleets (Langley et al. 2005b). For instance, observer coverage for the U.S. and Pacific Island fleets operating in the WCPO is considered high, at >20%, while observer coverage for the Taiwan, Japan, and

Korea fleets is <5% (Langley et al. 2005b). In the WCPO, logbook data do not generally include non-commercial catch (i.e., protected species) (Molony 2005), and are thus not useful in tracking bycatch of non-commercial species.

Atlantic

The International Commission for the Conservation of Atlantic Tunas (ICCAT) is the international management agency responsible for yellowfin management in the Atlantic Ocean. Individual countries may have their own management measures, including observer programs. The Standing Committee on Research and Statistics (SCRS) is the fishery statistics body of ICCAT, and provides advice on issues such as stock status and fishing effort. Within the SCRS, there are several sub-committees, including a Sub-Committee on Bycatch, which is responsible for research and analysis of bycatch issues.

Since 1973, ICCAT has imposed a size limit on yellowfin catch in the Atlantic. The minimum size limit is 3.2 kg, with a 15% tolerance per landing. However, this regulation has not been adhered to, and was cancelled for bigeye tuna in 2004 and yellowfin in 2005. From 1997 – 2001, the catch of undersized yellowfin ranged from 54 – 72% for purse seiners and 63 – 82% for pole and line gear (ICCAT 2004). Because small yellowfin associate with adult skipjack, particularly under floating objects, the catching of undersized yellowfin may be unavoidable and ensuring avoidance would result in the loss of adult skipjack catch (ICCAT 2004). In 1993, it was recommended that fishing effort not increase above the 1992 level, but effort in 2001 appears to have approached or exceeded this level (ICCAT 2004). Since 2000 there has been a periodic moratorium on FAD fisheries in the Atlantic, but there are insufficient data to evaluate the effectiveness of this regulation (Anonymous 2004). The purpose of the moratorium was to reduce the catch of small fish, particularly bigeye (ICCAT 2004).

There is not a comprehensive observer program for international fisheries in the Atlantic, nor are there set requirements for logbook reporting; thus, there is no bycatch reduction plan in place in the Atlantic. Some fleets do have observer programs while others use logbook data to report bycatch (ICCAT 2005). For instance, an observer program has in place in Venezuela since 1991 (Marcano et al. 2004). The U.S. also has an observer program. Bycatch of sharks has not been addressed, as ICCAT has not implemented any management measures for shark species (ICCAT 2005). In addition, current shark statistics that are reported to ICCAT are not thought to represent the actual removals by the reporting fisheries (ICCAT 2005). ICCAT has ignored SCRS advice in the past.

U.S. fisheries operating in the Atlantic are managed by the HMS Division of NMFS. The U.S. fishery targeting tuna in the Atlantic is managed under the Fishery Management Plan for Atlantic Tunas, Swordfish, and Sharks. The minimum size for yellowfin is 27 inches (69 cm) FL (NMFS 2005e); there are also permitting requirements for the HMS fishery. The bycatch reduction program put into place by NMFS includes gear modifications and time/area closures. These requirements include mandatory use of circle hooks and particular types of bait and mandatory possession and use of sea turtle release equipment (69 FR 128, July 6, 2004). Bycatch assessments and corresponding time/area investigations are conducted. The use of live bait in the longline fishery in the Gulf of Mexico is prohibited under a "Regulatory" Amendment 1 to the HMS FMP due to concerns regarding billfish bycatch (NMFS 2004a). To date, the time/area closures established in the Atlantic appear to be successful at reducing the discarding of most HMS, excluding large coastal sharks (NMFS 2004a). In the Gulf of Mexico, all Mexican longline vessels are required to have an observer on board during all trips. Observer coverage for U.S. vessels in the Gulf of Mexico has ranged from 3 – 5% (Brown et al. 2004), although the management objective is 8% throughout the Atlantic, including the Gulf of Mexico and Caribbean, versus just 5% in the Gulf of Mexico (NMFS 2001b).

Indian Ocean

Yellowfin in the Indian Ocean is managed by the Indian Ocean Tuna Commission (IOTC), which is a fishery body of the FAO. There is a maximum of 70 purse seine vessels in the Indian Ocean (IOTC 2004). There are no specific regulations governing the management of yellowfin in the Indian Ocean (IOTC 2003), though the IOTC has passed numerous resolutions, such as recommendations to cooperating non-contracting parties (CPCs). Some of these resolutions include: a recommendation to CPCs to implement an International Plan of Action for Reducing Incidental Catches of Seabirds in Longline Fisheries; a request for Taiwanese vessels to limit bigeye catches in the Indian Ocean to 35,000 mt per year; and reporting requirements for catch and effort and size data. There is no quota for yellowfin in the Indian Ocean, and no comprehensive bycatch reduction plan. No action has been taken due to the conclusion that no action is needed. There are some national observer programs for vessels fishing in the Indian Ocean, but it is unknown whether enforcement of the pelagic longline and purse seine fisheries operating in the Indian Ocean is adequate, and it is unknown if scientific advice is followed or not. Overall, stock productivity of yellowfin in the Indian Ocean has not been maintained, as the yellowfin stock has experienced a steady decline in relative biomass and increased landings.

Table 12. Commercial management measures for the yellowfin fishery.

Region	Management Jurisdictions & Agencies	Total Allowable Landings	Size Limit	Gear Restrictions	Trip Limit	Area Closures	Sources
Atlantic Ocean	International: ICCAT Domestic: NMFS	None	ICCAT: 3.2 kg NMFS: 69 cm FL	Several gear restrictions and area closures designed to reduce non-target species bycatch in addition to protected species and sea turtles	None	Closed areas to reduce protected species bycatch (U.S. fishery)	NMFS 2004a; ICCAT 2005
Pacific Ocean	International: IATTC Domestic: NMFS, PFMC, WPFMC	None	None	Longlining prohibited in U.S. EEZ off the coast of CA, OR, WA	None	Closure to reduce fishing effort on yellowfin in the EPO, and closed areas to reduce protected species bycatch (U.S. fishery); purse seine closures in the WCPO	PFMC 2003; IATTC 2005
Indian Ocean	IOTC	None	None	None	None	None	IOTC 2003

Synthesis

There is no comprehensive observer program for the international pelagic longline fleets, although many countries are actively conducting research regarding bycatch mitigation. While several countries have begun to modify their longline gear with hook/bait combinations and other bycatch mitigation efforts, Seafood Watch® adopts a precautionary approach until these modifications are implemented as regulations. There is also no comprehensive international enforcement program, as enforcement is the responsibility of individual countries and not the international management agencies. Management of the tuna fisheries is complex, and while there are concerns with the management of some gear types, such as bycatch in the longline fishery, these same concerns may be minimal for other gear types, such as bycatch in the troll/pole fishery.

In the Pacific, there is a complete and robust stock assessment, and adequate scientific monitoring. Management of the Hawaii longline fishery is considered highly effective primarily due to the effectiveness of their bycatch reduction plan and enforcement of management measures. Management of the US-based Pacific troll/pole fisheries are also deemed highly effective due to enforcement, robust stock assessment, and a lack of bycatch concerns. In the Pacific, management of the unassociated purse seine fishery and international troll/pole fisheries are deemed moderately effective. There is limited observer coverage for these fisheries, and enforcement remains a concern for the non-U.S. fisheries. Management of the international longline and FAD fisheries operating in the Pacific is deemed moderately effective due to a lack of a bycatch mitigation plan and inadequate enforcement.

In the Atlantic, there is also a complete and robust stock assessment and adequate scientific monitoring. Management of U.S. troll/pole and longline fisheries in the Atlantic is deemed highly effective due to the adequate enforcement and data collection, as well as regulations regarding gear modifications in the longline fishery (i.e., hook and bait use). International longline and purse seine fishery management in the Atlantic is deemed moderately effective due to the combined issues of bycatch and enforcement.

In the Indian Ocean, management measures have not maintained stock productivity, and there is moderate uncertainty associated with the most recent stock assessment. Management of the longline and FAD fisheries in the Indian Ocean is deemed ineffective due these concerns as well as the lack of a bycatch mitigation plan and enforcement. Management of the pole and line and unassociated purse seine fisheries in the Indian Ocean is deemed moderately effective, as these fisheries do not have the same bycatch concerns as the longline fishery.

Effectiveness of Management Rank:

Eastern Pacific (U.S. troll/pole/handline);
WCPO (Hawaiian longline, U.S. troll/pole);
U.S. Atlantic troll/pole and longline:

Highly Effective Moderately Effective Ineffective Critical

WCPO (international troll/pole and longline; purse seine);
Eastern Pacific (international troll/pole and longline; purse seine);
Atlantic (international troll/pole and longline; purse seine);
Indian (troll/pole; unassociated purse seine):

Highly Effective **Moderately Effective** Ineffective Critical

Indian Ocean (longline and floating object/FAD purse seine):

Highly Effective Moderately Effective **Ineffective** Critical

IV. Overall Evaluation and Seafood Recommendation

Yellowfin tuna, *Thunnus albacares*, is caught in commercial fisheries throughout the world's oceans. Yellowfin matures at an early age, has a moderate lifespan, is highly fecund, and is widely distributed, making it inherently resilient to fishing pressure. The four stocks of yellowfin comprise the western and central Pacific, eastern Pacific, Atlantic, and Indian Ocean stocks. Current yellowfin stock status in the Western and Central Pacific Ocean (WCPO) is a low conservation concern, while that in the Atlantic and the Eastern Pacific Ocean (EPO) is a moderate conservation concern, and yellowfin stock status in the Indian Ocean is a high concern.

Yellowfin is caught with purse seines, as well as troll, pole and line, and pelagic longlines. The level of bycatch varies according to the gear type. Purse seine sets on floating objects or fish aggregating devices are deemed a high conservation concern due to the bycatch of juvenile tuna, other pelagic fishes, sharks, and sea turtles. Purse seine sets on dolphins and unassociated schools, on the other hand, are considered to have moderate bycatch, as dolphin mortalities have declined dramatically and are reduced to a minimum in the dolphin set fishery, and bycatch of other species is lower in these sets compared to floating object sets. Pelagic longlines also catch a number of incidental species, including endangered and threatened sea turtles, seabirds, marine mammals, and billfish. The Hawaii longline and U.S. Atlantic longline fisheries are considered a high conservation concern, rather than critical, for the bycatch criterion, because those fisheries have observer data demonstrating that their fishery has declining bycatch trends, or evidence that bycatch levels are not contributing to the decline or recovery of the species. All other pelagic longline fisheries are considered to have critical bycatch levels.

Troll/pole gear, purse seines, and pelagic longlines all have negligible habitat effects as they do not contact the seafloor, while the ecosystem effects of removing large predators such as tuna are unknown. The habitat and ecosystem effects of floating object-set purse seines and pelagic longlines are thus deemed of moderate conservation concern due to their larger ecosystem impacts, and the impacts of troll/pole gear and unassociated and dolphin-set purse seine are deemed of low conservation concern.

Management of yellowfin tuna is complicated by the fact that individual countries may have more or less stringent regulations than those of the international management bodies. As there are numerous countries landing yellowfin, generalizations have been made concerning the effectiveness of the management regime. In those cases where information is available to differentiate individual country management practices, Seafood Watch® has attempted to include this in the overall recommendation. U.S. troll/pole and longline fisheries management is ranked highly effective; international troll/pole and international longline and purse seine (except Indian Ocean) fisheries management is moderately effective, and Indian Ocean longline and FAD purse seine management is ineffective.

Overall, troll/pole-caught yellowfin from the U.S-based EPO, WCPO and Atlantic fisheries is considered a **Best Choice** due to the minimal impacts of this gear, the healthy/moderate status of the stock in this region, and highly effective management. The international troll/pole and unassociated purse seine fisheries for yellowfin tuna in the WCPO are also a **Best Choice** due to minimal to moderate bycatch, minimal impacts of the fishing gear, healthy stocks and moderately effective management. Troll/pole-caught yellowfin from the Indian Ocean, the international EPO and international Atlantic is a **Good Alternative**. Longline-caught yellowfin in the U.S. fishery in the Atlantic and Hawaii is also ranked as a **Good Alternative** due to a reduced bycatch concern in this fishery resulting from mitigation measures. Purse seine-caught yellowfin from unassociated and dolphin sets is also considered a **Good Alternative** due to the reduced bycatch levels in these fisheries compared to floating object purse seine and longline fisheries. While dolphin sets do continue to result in dolphin mortality, the population consequences of this bycatch are uncertain. Yellowfin caught in unassociated sets is a more environmentally friendly option, although it falls in the same category as dolphin sets. Yellowfin caught in the floating object/FAD purse seine fishery is recommended as **Avoid** regardless of which ocean it is from due to the bycatch and ecosystem concerns associated with this fishery. Various bycatch, management, and stock concerns throughout these oceans results in a ranking of **Avoid** for longline-caught yellowfin in international fisheries.

Table of Sustainability Ranks

	Conservation Concern			
Sustainability Criteria	**Low**	**Moderate**	**High**	**Critical**
Inherent Vulnerability	√			
Status of Stocks	**√ WCPO**	**√ EPO, Atlantic**	**√ Indian**	
Nature of Bycatch	**√ Troll/pole**	**√ Dolphin and unassociated purse seine**	**√ Hawaii longline; U.S. Atlantic longline**	**√ All other longline; FAD purse seine**
Habitat Effects	**√ Troll/pole; unassociated and dolphin set purse seine**	**√ Purse seine (FAD), longline**		
Management Effectiveness	**√ U.S. troll/pole; Hawaii longline; U.S. Atlantic longline**	**√ Int'l Troll/pole; Int'l LL (Pacific and Atlantic); Int'l purse seine (Pacific, Atlantic, and Indian unassociated sets)**	**√ Indian Ocean (longline, FAD sets)**	

About the Overall Seafood Recommendation:

- A seafood product is ranked **Best Choice** if three or more criteria are of Low Conservation Concern (green) and the remaining criteria are not of High or Critical Conservation Concern.
- A seafood product is ranked **Good Alternative** if the five criteria "average" to yellow (Moderate Conservation Concern) OR if the "Status of Stocks" and "Management Effectiveness" criteria are both of Moderate Conservation Concern.

- A seafood product is ranked **Avoid** if two or more criteria are of High Conservation Concern (red) OR if one or more criteria are of Critical Conservation Concern (black) in the table above.

Overall Seafood Recommendation:

Seafood Watch® Recommendation	Where Caught and Gear Used
Best Choice	U.S. Atlantic Ocean troll/pole
	U.S. Eastern Pacific troll/pole
	Western Pacific troll/pole
	Western Pacific unassociated purse seine
Good Alternative	U.S. Atlantic longline
	Hawaii-based longline
	Atlantic Ocean troll/pole (international)
	Indian Ocean troll/pole
	Eastern Pacific troll/pole (international)
	Eastern Pacific Ocean unassociated and dolphin purse seine
	Atlantic unassociated purse seine
	Western and central Pacific and Indian Ocean unassociated purse seine
Avoid	Eastern Pacific floating object purse seine
	Atlantic floating object purse seine
	Western and central Pacific and Indian Ocean floating object purse seine
	Pacific, Atlantic, and Indian Ocean longline (international)

Supplemental Information

Health consumption information on the Seafood Watch® pocket guides is provided by Environmental Defense. Environmental Defense applies the same risk-based methodology as the U.S. Environmental Protection Agency (EPA) to data from government studies and papers published in scientific journals. The Environmental Defense consumption advisory for yellowfin is based on mercury contamination. The number of meals of yellowfin that can safely be eaten each month is 3 for females, 3 for males, 2 for older children, and 1 for younger children. More detailed information about the Environmental Defense advisory can be found at http://www.oceansalive.org/eat.cfm?subnav=fishpage&fish=155.

Troll/pole caught yellowfin have lower mercury levels (average total mercury content of 0.14 ppm), as these gear methods catch younger tuna (Morrissey et al. 2004). Older tuna caught in deeper waters with longline gear are likely to have higher mercury levels in their tissue. Mercury concentrations in yellowfin sampled in 1971 range from 0.09 – 1.32 ppm, while 1998 data indicate a range of 0.012 – 0.68 ppm. There was no significant difference between the two data sets, but the smaller range may be a reflection of the smaller weight range of the tuna sampled in 1998 (Kraepiel et al. 2003).

Acknowledgements

Seafood Watch® thanks Dr. Kurt Schaefer of the Inter-American Tropical Tuna Commission, Dr. Tim Gerrodette of the Southwest Fisheries Science Center, and three anonymous reviewers who graciously reviewed this report for scientific accuracy.

Scientific review does not constitute an endorsement of the Seafood Watch® program, or its seafood recommendations, on the part of the reviewing scientists. Seafood Watch® is solely responsible for the conclusions reached in this report.

V. References

Adam, M. S., J. Sibert, D. Itano, and K. Holland. 2003. Dynamics of bigeye (*Thunnus obesus*) and yellowfin (*Thunnus albacares*) tuna in Hawaii's pelagic fisheries: analysis of tagging data with a bulk transfer model incorporating size-specific attrition. Fishery Bulletin **101**:215-228.

Alfaro, J., and J. Mangel. 2005. Pilot project to monitor the longline shark fishery in Peru. Final Report. Duke University.

Anonymous. 2004. 2003 ICCAT tropical tuna species working group session. Col. Vol. Sci. Pap. 56(2):283-352. International Commission for the Conservation of Atlantic Tunas, Madrid, Spain 29 September - 3 October 2003.

Archer, F., T. Gerrodette, S. Chivers, and A. Jackson. 2001. Annual estimates of the unobserved incidental kill of pantropical spotted dolphin (*Stenella attenuata*) calves in the tuna purse-seine fishery in the eastern tropical Pacific. Fishery Bulletin **102**:233-244.

Au et al. in press. Pacific Fishery Management Council. Accessed November 8, 2005. Available at: http://www.pcouncil.org/hms/hmsfmp.html.

Bailey, K., P. Williams, and D. Itano. 1996. Bycatch and discards in western Pacific tuna fisheries: a review of SPC data holdings and literature. South Pacific Commission. Accessed August 31, 2006. Available at: http://www.spc.int/OceanFish/Docs/Technical/TECH34.pdf.

Balazs, G. H., and M. Chaloupka. 2004. Thirty-year recovery trend in the once-depleted Hawaiian green sea turtle stock. Biological Conservation **117**:491-498.

Barut, N. C. 2004. Overview of fisheries in the Philippines. *in* The 7th North Pacific Rim Fisheries Conference. May 18, 2004 Available at: http://prfisheries.alaskapacific.edu/uploads/5-18-04%20Noel%20C%20Barut-%20Overview%20of%20the%20Philippine%20Fishery-Presentation.pdf. Busan, Korea.

Barut, N. C., and E. G. Garvilles. 2006. Philippine Fishery Report. Available at: http://www.wcpfc.int/sc2/pdf/SC2-FR-Philippines.pdf. WCPFC Scientific Committee 2nd Regular Session. Annual Report Part I - Information on Fisheries, Research, and Statistics. Republic of Philippines.

Baum, J. K., and R. A. Myers. 2004. Shifting baselines and the decline of pelagic sharks in the Gulf of Mexico. Ecology Letters **7**:135-145.

Baum, J. K., R. A. Myers, D. G. Kehler, B. Worm, S. J. Harley, and P. A. Doherty. 2003. Collapse and conservation of shark populations in the Northwest Atlantic. Science **299**:389-392.

Bayliff, W. 2004. 2002 annual report. IATTC, La Jolla, CA.

Bayliff, W. H., J. I. d. Leiva Moreno, and J. Majkowski. 2005. Management of tuna fishing capacity: conservation and socio-economics. Second Meeting of the Technical Advisory Committee of the FAO Project, Madrid Spain 15 - 18 March 2004.

Beerkircher, L. R., E. Cortes, and M. Shivji. 2004. Characteristics of shark bycatch observed on pelagic longlines off the Southeastern United States, 1992 - 2000. Marine Fisheries Review **64**:40-49.

Beverly, S. 2002. Albacore - the other sashimi tuna. SPC Fisheries Newsletter #103 - October/December 2002.

Block, B. A., J. E. Keen, B. Castillo, H. Dewar, E. V. Freund, D. J. Marcinek, R. W. Brill, and C. Farwell. 1997. Environmental preferences of yellowfin tuna (*Thunnus albacares*) at the northern extent of its range. Marine Biology **130**:119-132.

Block, B. A., S. L. H. Teo, A. Walli, A. Boustany, M. J. W. Stokesbury, C. J. Farwell, K. C. Weng, H. Dewar, and T. D. Williams. 2005. Electronic tagging and population structure of Atlantic bluefin tuna. Nature **434**:1121-1127.

Bonfil, R. 1994. World bycatches of sharks in high-seas fisheries: appraising the waste of a resource. Pages 41-44 *in* T. J. Pitcher and R. Chuenpagdee, editors. Bycatches in Fisheries and their Impact on the Ecosystem, Fisheries Centre Research Reports.

Bonfil, R. 1994. World bycatches of sharks in high-seas fisheries: appraising the waste of a resource. *in* T. J. Pitcher and R. Chuenpagdee, editors. Bycatch in fisheries and their impact on the ecosystem. Fisheries Centre Research Report Vol 2(1).

Bratten, D., and M. A. Hall. 1997. Working with fishers to reduce bycatch: the tuna-dolphin problem in the eastern Pacific Ocean. *in* Fisheries Bycatch: Consequences and Management. Alaska Sea Grant Program Report No. 97-02, University of Alaska Fairbanks.

Brill, R. W., B. A. Block, C. H. Boggs, K. A. Bigelow, E. V. Freund, and D. J. Marcinek. 1999. Horizontal movements and depth distribution of large adult yellowfin tuna (*Thunnus albacares*) near the Hawaiian Islands, recorded using ultrasonic telemetry: implications for the physiological ecology of pelagic fishes. Marine Biology **133**:395-408.

Brown, C. A., R. U. Pastor, and R. S. Sansores. 2004. Updating standardized catch rates for yellowfin tuna (*Thunnus albacares*) in the Gulf of Mexico longline fishery for 1992 - 2002 based upon observer programs from Mexico and the United States. Col. Vol. Sci. Pap. 56(2): 676-685. International Commission for the Conservation of Atlantic Tunas.

Camhi, M., S. Fowler, J. Musick, A. Brautigam, and S. Fordham. 1998. Sharks and their relatives: ecology and conservation. Occas. Pap. IUCN Species Surviv. Comm. 20.

Carranza, A., A. Domingo, and A. Estrades. 2006. Pelagic longlines: a threat to sea turtles in the equatorial eastern Atlantic. Biological Conservation **131**:52-57.

Childers, J. 2003. Summary of the 2002 U.S. North and South Pacific albacore troll fisheries. Administrative Report LJ-03-09. Southwest Fisheries Science Center, NOAA.

Chuenpagdee, R., L. E. Morgan, S. M. Maxwell, E. A. Norse, and D. Pauly. 2003. Shifting gears: assessing collateral impacts of fishing methods in US waters. Frontiers in Ecology **1**:517-524.

Coan, A. L., Jr., G. T. Sakagawa, D. Prescott, P. Williams, and G. Yamasaki. 1999. The 1998 US tropical tuna purse seine fishery in the Central-Western Pacific Ocean. unpublished manuscript, 22 p. Southwest Fisheries Science Center, La Jolla, CA.

Compagno, L. J. V., and J. A. Musick. 2000. *Pseudocarcharias kamoharai*. In: 2004 IUCN Red List of Threatened Species. The World Conservation Union. Accessed October 15, 2005. Available at: http://www.redlist.org.

Cortés, E. 2002. Catches and catch rates of pelagic sharks from the northwestern Atlantic, Gulf of Mexico, and Caribbean. ICCAT Coll. Vol. Sci. Pap. 54(4):1164-1181.

Cox, S. P., S. J. D. Martell, C. J. Walters, T. E. Essington, J. F. Kitchell, C. Boggs, and I. Kaplan. 2002. Reconstructing ecosystem dynamics in the central Pacific Ocean, 1952-1998. I. Estimating population biomass and recruitment of tunas and billfishes. II. A preliminary assessment of the trophic impacts of fishing and effects on tuna dynamics. Canadian Journal of Fisheries and Aquatic Sciences **59**:1724-1747.

Cramer, K.L., Perryman, W.L., Gerrodette, T. 2008. Declines in reproductive output in two dolphin populations depleted by the yellowfin tuna purse-seine fishery. Marine Ecology Progress Series 369:273-285.

De Anda-Montanez, J. A., A. Amador-Buenrostro, S. Martinez-Aguilar, and A. Muhlia-Almazan. 2004. Spatial analysis of yellowfin tuna (*Thunnus albacares*) catch rate and its relation to El Nino and La Nina events in the eastern tropical Pacific. Deep-Sea Research II **51**:575-586.

Denham, J. 2000. *Sphyrna mokarran.* In: 2004 IUCN Red List of Threatened Species. The World Conservation Union. Accessed October 15, 2005. Available at: http://www.redlist.org.

Desurmont, A., and L. Chapman. 2000. The use of anchored FADs in the area served by the Secretariat of the Pacific Community (SPC): regional synthesis. Pages 108-140 *in* J. Y. Le Gall, P. Cayre, and M. Taquet, editors. Tuna Fishing and Fish Aggregating Devices. IFREMER/ENSAR, 15-19 October 1999, Martinique, Lesser Antilles.

Diaz, G. A., and J. Serafy. 2005. Longline-caught blue shark (*Prionace glauca*): factors affecting the numbers available for live release. Fishery Bulletin **103**:720-724.

Dickson, J. O., and A. C. Natividad. 2000. Tuna fishing and a review of payaos in the Philippines. Pages 141-158 *in* J. Y. Le Gall, P. Cayre, and M. Taquet, editors. Tuna Fishing and Fish Aggregating Devices. IFREMER/ENSAR, 15-19 October 1999, Martinique, Lesser Antilles.

Dunn, J., and B. A. Block. 2001. Advances in acoustic, archival, and satellite tagging of tunas. Pages 167-224 *in* B. A. Block and E. D. Stevens, editors. Tuna physiology, ecology, and evolution. Academic Press, San Diego, CA.

Edwards, E. F. 2006. Duration of unassisted swimming activity for spotted dolphin (Stenella attenuata) calves: implications for mother-calf separation during tuna purse seine sets. Fishery Bulletin **104**:125-135.

Edwards, E. F. 1992. Energetics of associated tunas and dolphins in the eastern tropical Pacific Ocean: a basis for the bond. Fishery Bulletin **90**:678-690.

Essington, T. E., D. E. Schindler, R. J. Olson, J. F. Kitchell, C. Boggs, and R. Hilborn. 2002. Alternative fisheries and the predation rate of yellowfin tuna in the eastern Pacific Ocean. Ecological Applications **12**:724-734.

Eurofish. 2005. FISH INFOnetwork market report on tuna. Accessed August 30, 2005. Available at: http://www.eurofish.dk/indexSub.php?id=3060.

FAO. 2003. Globefish commodity update - tuna. Food and Agriculture Organization of the United Nations.

FAO. 2006. Fishery country profile: Republic of Indonesia. Food and Agriculture Organization of the United Nations. Accessed July 10, 2007. Available at: http://www.fao.org/fi/fcp/en/IDN/profile.htm.

Ferraroli, S., J.-Y. Georges, P. Gaspar, and Y. L. Maho. 2004. Where leatherback turtles meet fisheries. Nature **429**:521-522.

Fisheries Agency. undated. New image for Taiwan's far seas tuna longline fishery. Taiwan Fisheries Agency. Accessed July 5, 2007. Available at: http://www.fa.gov.tw/eng/media/text/nitfstuna.txt.

FFA. 2005. Pacific Islands Forum Fisheries Agency. Accessed 2005. Available at: http://www.ffa.int/.

Fonteneau, A. IRD - Unité de Recherche n° 109 (THETIS), Centre de Recherche Halieutique Méditerranéenne et Tropicale. Personal communication, 2006.

Fonteneau, A. 2003. Biological overview of tuna stocks and overfishing. *in* J. Swan and D. Greboval, editors. Report and Documentation of the International Workshop on the Implementation of International Fisheries Instruments and Factors of Unsustainability and Overexploitation in Fisheries, Mauritius, 3 -7 February 2003. FAO Fisheries Report No. 700, Rome.

Fonteneau, A., P. Pallares, J. Sibert, and Z. Suzuki. 2001. The effect of tuna fisheries on tuna resources and offshore pelagic ecosystems ocean yearbook. University of Chicago Press, Volume 16.

Fonteneau, A., P. Pallares, and R. Pianet. 2000. A worldwide review of purse seine fisheries on FADs. Pages 15-35 *in* J. Y. Le Gall, P. Cayre, and M. Taquet, editors. Tuna Fishing and Fish Aggregating Devices. IFREMER/ENSAR, 15-19 October 1999, Martinique, Lesser Antilles.

Freon, P., and L. Dagorn. 2000. Review of fish associative behavior: toward a generalisation of the meeting point hypothesis. Reviews in Fish Biology and Fisheries **10**:183-207.

Froese, R., and D. Pauly. 2005. FishBase. Accessed July 26, 2005. Available at: http://www.fishbase.org/Summary/SpeciesSummary.php?id=143.

Gaertner, D., J. Ariz, and V. Nordstrom-Fonteneau. 1998. Spatial changes in the purse-seiners' activities in the eastern Atlantic Ocean from 1991 to 1995. SCRS/1997/101 Rev., Col. Vol. Sci. Pap. ICCAT, 48 (3):322-330. International Commission for the Conservation of Atlantic Tunas.

Gaertner, D., F. Menard, C. Develter, J. Ariz, and A. Delgado de Molina. 2002. Bycatch of billfishes by the European tuna purse-seine fishery in the Atlantic Ocean. Fishery Bulletin **100**:683-689.

Garcia, M. A., and M. A. Hall. 1997. Spatial and seasonal distribution of bycatch in the purse seine tuna fishery in the eastern Pacific Ocean. *in* Fisheries Bycatch: Consequences and Management. Alaska Sea Grant Program Report No. 97-02, University of Alaska Fairbanks.

Gascuel, D., A. Fonteneau, and C. Caprisano. 1992. Modélisation d'une croissance en deux stances chez l'albacore (Thunnus albacares) de l'Atlantique. Aquatic Living Resources **5**:155-172.

Gerrodette, T., and J. Forcada. 2005. Non-recovery of two spotted and spinner dolphin populations in the eastern tropical Pacific Ocean. Marine Ecology Progress Series **291**:1-21.

Gilman, E., S. Clarke, N. Brothers, J. Alfaro-Shigueto, J. Mandelman, J. Mangel, and et al. 2007. Shark depredation and unwanted bycatch in pelagic longline fisheries: industry practices and attitudes, and shark avoidance strategies. Western Pacific Fishery Management Council, Honolulu, Hawaii.

Girard, C., S. Benhamou, and L. Dagorn. 2004. FAD: fish aggregating device or attracting device? A new analysis of yellowfin tuna movements around floating objects. Animal Behaviouir **67**:319-326.

Gonzales-Ania, L. V., C. A. Brown, and E. Corte. 2001. Standardized catch rates for yellowfin tuna (*Thunnus albacares*) in the 1992 - 1999 Gulf of Mexico longline fishery based upon observer. ICCAT Coll. Vol. Sci. Pap. 52:222-237.

Goodyear, C. P. 2000. Atlantic blue marlin and yellowfin tuna: comparative vulnerability to fishing. SCRS/1999/102 Col. Vol. Sci. Pap. ICCAT, 51(3): 968-974. International Commission for the Conservation of Atlantic Tunas.

Gosliner, M. L. 1999. The tuna-dolphin controversy. *in* J. R. Twiss, Jr. and R. R. Reeves, editors. Conservation and Management of Marine Mammals. Smithsonian Institution Press, Washington DC.

Graham, J. B., and K. A. Dickson. 2001. Anatomical and physiological specializations for endothermy. Pages 121-166 *in* B. A. Block and E. D. Stevens, editors. Tuna physiology, ecology, and evolution. Academic Press, San Diego, CA.

Guzman, R. A., H. Salazar, and L. Astudillo. 1994. Analasis de la captura y el esfuerzo de la pesqueria atunera de pequenos palangreros en el Caribe venezolano:1983-1991. ICCAT Coll. Vol. Sci. Pap. 41(2):232-236.

Hall, M. A. 1997. Dolphins and other bycatch in the eastern Pacific Ocean tuna purse seine fishery. *in* Fisheries Bycatch: Consequences and Management. Alaska Sea Grant Program Report No. 97-02, University of Alaska Fairbanks.

Hall, M. A. 1998. An ecological view of the tuna-dolphin problem: impacts and trade-offs. Reviews in Fish Biology and Fisheries **8**:1-34.

Hampton, J., and D. A. Fournier. 2001. A spatially disaggregated, length-based, age-structured population model of yellowfin tuna (*Thunnus albacares*) in the western and central Pacific Ocean. Marine and Freshwater Research **52**:937-963.

Hampton, J., P. Kleiber, A. Langley, and K. Hiramitsu. 2004. Stock assessment of yellowfin tuna in the western and central Pacific Ocean. SCTB17 Working Paper SA-1. 17th Meeting of the Standing Committee on Tuna and Billfish, Majuro, Marshall Islands.

Hampton, J., P. Kleiber, A. Langley, Y. Takeuchi, and M. Ichinokawa. 2005a. Stock assessment of yellowfin tuna in the western and central Pacific Ocean. WCPFC-SC1 SA WP-1. 1st Meeting of the Scientific Committee of the Western and Central Pacific Fisheries Commission WCPFC-SC1, Noumea, New Caledonia.

Hampton, J., J. R. Sibert, P. Kleiber, M. N. Maunder, and S. J. Harley. 2005b. Decline of Pacific tuna populations exaggerated? Nature **434**:E1.

Hareide, N. R., J. Carlson, M. Clarke, S. Clarke, J. Ellis, S. Fordham, and et al. 2007. European shark fisheries: a preliminary investigation into fisheries, conversion factors, trade products, markets and management measures. European Elasmobranch Association. Accessed July 9, 2007. Available at: http://lenfestocean.org/publications/SharkFinning_underlying_report.pdf.

Harley, S., S. Hoyle, et al. (2010). Stock Assessment of bigeye tuna in the western and central Pacific Ocean, Western and Central Pacific Fisheries Commission.

Hays, G. C., A. C. Broderick, B. J. Godley, P. Luschi, and W. J. Nichols. 2004a. Tracking turtles to their death. Marine Ecology Progress Series **283**:299-300.

Hays, G. C., J. D. R. Houghton, and A. E. Myers. 2004b. Pan-Atlantic leatherback turtle movements. Nature **429**:522.

Hobday, A., I. Stobutzki, and H. Webb. 2004. Draft ecological risk assessment of effects of fishing: eastern tuna and billfish fishery (V7). *in* A. Hobday, A. D. M. Smith, and I. Stobutzki, editors. Ecological risk assessment for Australian commonwealth fisheries. Final report stage 1-Hazard identification and preliminary risk assessment, Report to the Australian Fisheries Management Authority, Canberra, Australia.

Hoenig, J. M., and S. H. Gruber. 1990. Life-history patterns in the elasmobranches: implications or fisheries management. *in* H. L. Pratt, Jr., S. H. Gruber, and T. Taniuchi, editors. Elasmobranches as living resources: advances in the biology, ecology, systematics, and the status of fisheries, NOAA Tech Rep NMFS 90.

Holland, K. N., A. Jaffe, and W. Cortez. 2000. The Fish Aggregating Device (FAD) system of Hawaii. Pages 55-62 *in* J. Y. Le Gall, P. Cayre, and M. Taquet, editors. Tuna Fishing and Fish Aggregating Devices. IFREMER/ENSAR, 15-19 October 1999, Martinique, Lesser Antilles.

Hospido, A., and P. Tyedmers. 2005. Life cycle environmental impacts of Spanish tuna fisheries. Fisheries Research **76**:174-186.

Hoyle, S. D., and M. N. Maunder. 2005. Status of yellowfin tuna in the eastern Pacific Ocean in 2004 and outlook for 2005. Inter-American Tropical Tuna Commission. Accessed February 16, 2006. Available at: http://www.iattc.org/PDFFiles2/SAR6-YFT-ENG.pdf.

Hoyle, S., P. Kleiber, et al. (2010). Stock Assessment of skipjack tuna in the western and central Pacific Ocean. Rev.1, Western and Central Pacific Fisheries Commission.

IATTC. 2002. Scientific report on the status of dolphin stocks in the eastern Pacific Ocean. Inter-

American Tropical Tuna Commission.

IATTC. 2004a. Annual report of the Inter-American Tropical Tuna Commission 2003. Available at: http://www.iattc.org/PDFFiles2/IATTC_Annual_Report_2003ENG.pdf. La Jolla, CA.

IATTC. 2004b. Working group on bycatch 4th meeting: interactions of sea turtles with tuna fisheries, and other impacts on turtle populations. Document BYC-4-05a. Inter-American Tropical Tuna Commission, Kobe, Japan.

IATTC. 2005. Estimated total catch by species, flag, and gear for the eastern Pacific Ocean. Inter-American Tropical Tuna Commission.

IATTC. 2006. Annual report of the Inter-American Tropical Tuna Commission. Accessed June 23, 2006. Available at: http://www.iattc.org/PDFFiles2/IATTC-Annual-Report2004ENG.pdf.

IATTC. 2008. Fishery Status Report No. 6: Tunas and Billfishes in the Eastern Pacific Ocean in 2007. IATTC. La Jolla, California.

IATTC (2010). Fishery Status Report No 7: Tunas and Billfishes in the Eastern Pacific Ocean in 2008. La Jolla, CA, IATTC: 145.

ICCAT. 2001. Report of the fourth ICCAT billfish workshop. Col. Vol. Sci. Pap. 53: 1-130. Miami, FL.

ICCAT. 2004. 2003 ICCAT Atlantic yellowfin tuna stock assessment session. SCRS/2003/016: Collective Volume of Scientific Papers 56(2): 443-527. International Commission for the Conservation of Atlantic Tunas, Merida, Mexico 21-26 July 2003.

ICCAT. 2005. Report of the 2004 inter-sessional meeting of the ICCAT sub-committee on by-catches: shark stock assessment. Col. Vol. Sci. Pap. 57. International Commission for the Conservation of Atlantic Tunas, Tokyo, Japan.

ICCAT (2008). Report of the 2008 ICCAT Yellowfin and Skipjack Stock Assessments Meeting. Accessed June 19, 2009. Available at: http://www.iccat.int/en/assess.htm.

IOTC. 2002. Recommendation 02/07 Concerning measures to prevent the laundering of catches by IUU large-scale tuna longline fishing vessels. Indian Ocean Tuna Commission. Accessed October 17, 2005. Available at: http://www.iotc.org.

IOTC. 2003. Report of the sixth session of the Scientific Committee of the IOTC. IOTC-SC-06-03R[E]. Indian Ocean Tuna Commission, Victoria, Seychelles 3-6 December 2003.

IOTC. 2004. Report of the sixth session of the IOTC working party on tropical tunas. IOTC-2004-WPTT-R[EN]. Indian Ocean Tuna Commission, Victoria, Seychelles.

IOTC. 2005. Report of the eighth session of the Scientific Committee. IOTC-2005-SC-R[EN]. Indian Ocean Tuna Commission, Victoria, Seychelles.

IOTC. 2009. Report of the Twelfth Session of the Scientific Committee. Indian Ocean Tuna Commission. 30 Nov- 4 Dec 2009. IOTC-2009-SC-R[E]

Ishihara, H., and et al. 2002. *Manta birostris.* In: 2004 IUCN Red List of Threatened Species. The World Conservation Union. Accessed October 15, 2005. Available at: http://www.redlist.org.

Itano, D. 2000. The reproductive biology of yellowfin tuna (*Thunnus albacares*) in Hawaiian waters and the western tropical Pacific Ocean: project summary. SOEST 00-01 JIMAR contribution 00-328. Pelagic Fisheries Research Program, JIMAR, University of Hawaii.

Itano, D., and K. Holland. 2000. Movement and vulnerability of bigeye (*Thunnus obesus*) and yellowfin tuna (*T. albacares*) in relation to FADs and natural aggregation points. Aquatic Living Resources **13**:213-223.

IUCN. 2004. The IUCN Red List of Threatened Species. International Union for Conservation of Nature and Natural Resources. Accessed 2005. Available at: http://www.redlist.org/.

Johnson, H. M. 2004. 2004 annual report of the United States seafood industry. HM Johnson & Associates, Jacksonville, OR.

Kakuma, S. 2000. Synthesis on moored FADs in the North West Pacific region. Pages 15-35 *in* J. Y. Le Gall, P. Cayre, and M. Taquet, editors. Tuna Fishing and Fish Aggregating Devices. IFREMER/ENSAR, 15-19 October 1999, Martinique, Lesser Antilles.

Kamezaki et al. 2003. Loggerhead turtles nesting in Japan. Pages 210-217 *in* A. B. Bolten and B. E. Witherington, editors. Loggerhead sea turtles. Smithsonian Institution Press, Washington DC.

Kaplan, I. C., S. P. Cox, and J. F. Kitchell. 2007. Circle hooks for Pacific longliners: not a panacea for marlin and shark bycatch, but part of the solution. Transactions of the American Fisheries Society **136**:392-401.

Kelleher, K. 2004. Discards in the world's marine fisheries - an update. FAO Fisheries Technical Paper No. 470. FAO, Rome.

Kerstetter, D. W., and J. E. Graves. 2006. Effects of circle versus J-style hooks on target and non-target species in a pelagic longline fishery. Fisheries Research **80**:239-250.

Kinan, I. Western Pacific Regional Fishery Management Council. Personal communication, 2006.

Kitchell, J. F., T. E. Essington, C. Boggs, D. E. Schindler, and C. J. Walters. 2002. The role of sharks and longline fisheries in a pelagic ecosystem of the central Pacific. Ecosystems **5**:202-216.

Korsemeyer, K. E., and H. Dewar. 2001. Tuna metabolism and energetics. Pages 36-78 *in* B. A. Block and E. D. Stevens, editors. Tuna physiology, ecology, and evolution. Academic Press, San Diego, CA.

Kotas, J. E. 2000. *Sphyrna lewini*. In: 2004 IUCN Red List of Threatened Species. The World Conservation Union. Accessed October 15, 2005. Available at: http://www.redlist.org.

Kraepiel, A. M. L., K. Keller, H. B. Chin, E. G. Malcolm, and F. M. M. Morel. 2003. Sources and variations of mercury in tuna. Environmental Science and Technology **37**:5551-5558.

Langley, A., B. Molony, D. Bromhead, K. Yokawa, and B. Wise. 2006. Stock assessment of striped marlin (Tetrapturus audax) in the Southwest Pacific Ocean. WCPFC-SC2-2006/SA Wp-6. Western and Central Pacific Fisheries Commission, Manila, Philippines.

Langley, A., J. Hampton, P. Kleiber, and S. Hoyle. 2007. Stock assessment of yellowfin tuna in the western and central Pacific Ocean, including an analysis of management options. WCPFC, Honolulu, HI, USA.

Langley, A., S. Harley, et al. (2009). Stock assessment of yellowfin tuna in the western and central Pacific Ocean. Western and Central Pacific Fisheries Commission. 10-21 August 2009. WCPFC-SC5-2009/SA-WP-03

Largacha, E., M. Parrales, L. Rendon, V. Velasquez, M. Orozco, and M. Hall. 2005. Working with the Ecuadorian fishing community to reduce the mortality of sea turtles in longlines: the first year March 2004 - March 2005. Accessed November 10, 2005. Available at: http://www.panda.org/downloads/ecuadorcirclehooks.pdf.

Lawson, T. 2004a. Estimates of annual catches of tuna in the western and central Pacific Ocean. SCTB Working Paper SWG-2. 17th Meeting of the Standing Committee on Tuna and Billfish.

Lawson, T. A. 2004b. Secretariat of the Pacific Community tuna fishery yearbook. Available at: http://www.spc.int/oceanfish/Docs/Statistics/YB_2003.pdf. SPC, Noumea, New Caledonia.

Lawson, T. 2004c. Availability of observer data for estimating catches of non-target species by longliners in the western and central Pacific Ocean, with catch estimates for offshore fleets in tropical waters. SCTB17 Working Paper SWG-5. Secretariat of the Pacific Community, Oceanic Fisheries Programme, Noumea, New Caledonia.

Lehodey, P., and B. Leroy. 1999. Age and growth of yellowfin tuna (*Thunnus albacares*) from the western and central Pacific Ocean as indicated by daily growth increments and tagging data. WP YFT-2, SCTB 12. Papeete, French Polynesia 16 - 23 June 1999.

Lennert-Cody, C. E., and M. A. Hall. 2000. The development of the purse seine fishery on drifting Fish Aggregating Devices in the eastern Pacific Ocean: 1992-1998. Pages 78-107 *in* J. Y. Le Gall, P. Cayre, and M. Taquet, editors. Tuna Fishing and Fish Aggregating Devices. IFREMER/ENSAR, 15-19 October 1999, Martinique, Lesser Antilles.

Lewison, R. L., and L. B. Crowder. 2003. Estimating fishery bycatch and effects on a vulnerable seabird population. Ecological Applications **13**:743-753.

Lewison, R. L., L. B. Crowder, A. J. Read, and S. A. Freeman. 2004a. Understanding impacts of fisheries bycatch on marine megafauna. Trends in Ecology and Evolution **19**:598-604.

Lewison, R. L., S. A. Freeman, and L. B. Crowder. 2004b. Quantifying the effects of fisheries on threatened species: the impact of pelagic longlines on loggerhead and leatherback sea turtles. Ecology Letters **7**:221-231.

Ma, C. T., and C. C. Hsul. 1997. Standardization of CPUE for yellowfin tuna caught by Taiwanese longline fishery in the Atlantic. SCRS/1996/089, Col. Vol. Sci. Pap. ICCAT, 46(4):197-204. International Commission for the Conservation of Atlantic Tunas.

Majkowski, J. 2004. Tuna resources, fisheries, and their management. Marine Resources Service, Fishery Resource Division, FAO, Rome, Italy.

Marcano, J. S., A. Larez, X. Gutierrez, J. J. Alio, H. Salazar, and M. Marquez. 2004. Incidental catch of billfish and other species by Venezuelan longline vessels in the Caribbean Sea and western Atlantic Ocean: period 1986-2000. Ciencas Marinas **30**:210-217.

Marsac, F., A. Fonteneau, and F. Menard. 2000. Drifting FADs used in tuna fisheries: an ecological trap? Pages 537-552 *in* J. Y. Le Gall, P. Cayre, and M. Taquet, editors. Tuna Fishing and Fish Aggregating Devices. IFREMER/ENSAR, 15-19 October 1999, Martinique, Lesser Antilles.

Maunder, M. N., and S. J. Harley. 2005. Status of yellowfin tuna in the eastern Pacific Ocean in 2003 and outlook for 2004. Inter-American Tropical Tuna Commission.

Maunder, M.N., and Aires-Da-Silva, A. 2008. Status of yellowfin tuna in the eastern Pacific Ocean in 2007 and outlook for the future. Inter-American Tropical Tuna Commission. La Jolla, California. May 12-16 2008.

Maunder, M. and A. Aires-da-Silva (2009). Status of yellowfin tuna in the eastern Pacific Ocean in 2008 and outlook for the future. Inter-American Tropical Tuna Commission. 12-15 May 2009.

Maunder, M. (2009). Updated indicators of stock status for skipjack tuna in the eastern Pacific Ocean. Stock Assessment Report 10, Inter-American Tropical Tuna Commission.

Miyake, P. M. 2005b. A review of the fishing capacity of the longline fleets of the world. *in* W. H. Bayliff, J. I. d. Leiva Moreno, and J. Majkowski, editors. Management of tuna fishing capacity: conservation and socio-economics. Second Meeting of the Technical Advisory Committee of the FAO Project, Madrid Spain 15 - 18 March 2004.

Molony, B. 2005. Estimates of the mortality of non-target species with an initial focus on seabirds, turtles, and sharks. WCPFC-SC1 EB WP-1. Western and Central Pacific Fisheries Commission, Nouemea, New Caledonia.

Moore, P. 2004. Examining dolphin hydrodynamics provides clues to calf-loss during tuna fishing. Journal of Biology **3**.

Musick, J. A., G. Burgess, G. Cailliet, M. Camhi, and S. Fordham. 2000. Management of sharks and their relatives (Elasmobranchii). Fisheries **25**:9-13.

Mycock, S. G. 2004. *Sphyrna corona*. In: 2004 IUCN Red List of Threatened Species. The World Conservation Union. Accessed October 15, 2005. Available at: http://www.redlist.org.

Myers, R. A., and C. A. Ottensmeyer. 2005. Extinction risk in marine species. Pages 58-79 *in* E. A. Norse and L. B. Crowder, editors. Marine Conservation Biology: the Science of Maintaining the Sea's Biodiversity. Island Press,, Washington, DC.

Myers, R. A., and B. Worm. 2003. Rapid worldwide depletion of predatory fish communities. Nature **423**:280-283.

Nakano, H., and W. Bayliff. 1992. A review of the Japanese longline fishery for tunas and billfishes in the eastern Pacific Ocean, 1981-1987. Inter-Am Trop Tuna Comm. Bull. 20(5): 183-355.

NMFS. 2004a. Stock assessment and fishery evaluation (SAFE) report for Atlantic highly migratory species. National Marine Fisheries Service, Office of Sustainable Fisheries.

NMFS. 2004b. Fisheries of the United States - 2003. National Marine Fisheries Service. Available at: http://www.st.nmfs.gov/st1/fus/fus03/index.html.

NMFS. 2004c. Canned tuna industry update. National Marine Fisheries Service. Accessed November 8, 2005. Available at: http://swr.nmfs.noaa.gov/fmd/04_12.pdf.

NMFS. 2004d. Final supplemental environmental impact statement - reduction of sea turtle bycatch and bycatch mortality in the Atlantic pelagic longline fishery. Available at: http://www.nmfs.noaa.gov/sfa/hms/hmsdocuments.html#feis. National Marine Fisheries Service, Office of Sustainable Fisheries, Highly Migratory Species Division, Silver Spring, MD.

NMFS. 2005a. Fisheries statistics division: commercial fisheries and foreign trade information.

National Marine Fisheries Service. Accessed November 14, 2005. Available at: http://www.st.nmfs.gov/st1/index.html.

NMFS. 2005b. 2004 status of U.S. fisheries. Available at: http://www.nmfs.noaa.gov/sfa/reports.htm. National Marine Fisheries Service.

NMFS. 2005c. Biological opinion on the Hawaii-based pelagic, deep-set longline fishery, October 4, 2005. National Marine Fisheries Service, Pacific Islands Region, Sustainable Fisheries Division.

NMFS. 2005d. Summary of stock status determination changes - update through September 30, 2005. National Marine Fisheries Service.

NMFS. 2005e. 2005 guide for complying with the regulations for Atlantic tunas, swordfish, sharks, and billfish. National Marine Fisheries Service. Accessed 2005. Available at: http://www.nmfs.noaa.gov/sfa/hms/brochures/FINAL%20Compliance%20Guide%203-7-05.pdf.

NOAA (2009). Stock Assessment and Fishery Evaluation (SAFE) report for Atlantic Highly Migratory Species. NOAA, Silver Spring MD.

Nootmorn, P., S. Panjarat, W. Singtongyam, S. Roopradit, K. Kawises, and T. Intharasuwan. 2002. Tuna longline landings in Phuket, Thailand, from 1994 to 2002. IOTC Proceedings no. 5 pages 440-449. Indian Ocean Tuna Commission.

Oceana. 2007. Hunted for fins. Oceana. Accessed July 9, 2007. Available at: http://www.sharkalliance.org/.

Pauly, D., and M.-L. Palomares. 2005. Fishing down marine food web: is it far more pervasive than we thought. Bulletin of Marine Science **76**:197-211.

Peel, E., R. Nelson, and C. P. Goodyear. 2003. Managing Atlantic marlin as bycatch under ICCAT. The fork in the road: recovery or collapse. Marine and Freshwater Research **54**:575-584.

PIRO. 2007a. Hawaii Longline Deep Set Quarterly and Annual Status Reports. Pacific Islands Regional Office. Accessed July 5, 2007. Available at: http://www.fpir.noaa.gov/OBS/obs_hi_ll_ds_rprts.html.

PIRO. 2007b. Hawaii Longline Shallow Set Quarterly and Annual Status Reports. Pacific Islands Regional Office. Accessed July 5, 2007. Available at: http://www.fpir.noaa.gov/OBS/obs_hi_ll_ss_rprts.html.

PFMC. 2003. HMS Fishery Management Plan. Pacific Fishery Management Plan. Accessed 2005. Available at: http://www.pcouncil.org/hms/hmsfmp.html.

PFMC. 2005. HMS Information and FAQs. Pacific Fishery Management Council. Accessed

August 3, 2005. Available at: http://www.pcouncil.org/hms/hmsfaqs.html#Q8.

PFMC. 2005. HMS stock status in Pacific Council News. Pacific Fishery Management Council.

PFMC. 2008. Status of the US West Coast Fisheries for highly migratory species through 2007. September 2008. Portland, Oregon.

Reilly, S. B., M. A. Donahue, T. Gerrodette, K. Forney, P. Wade, L. Ballance, and et al. 2005. Report of the scientific research program under the International Dolphin Conservation Program Act. NOAA-TM-NMFS-SWFSC-372. National Marine Fisheries Service Southwest Fisheries Science Center.

Retnowati, W. D. 2006. Indonesian tuna fisheries in Sulawesi Sea and western Pacific Ocean waters. Annual Report, Part I - Information on Fisheries, Research, and Statistics: Indonesia. WCPFC Scientific Committee 2nd Regular Session, Manila, Philippines.

Romanov, E. V. 2002. Bycatch in the tuna fisheries of the western Indian Ocean. Fishery Bulletin **100**:90-105.

Rose, C., and K. McLaughlin. 2001. Review of shark finning in Australian fisheries. Bureau of Rural Sciences, Canberra, Australia.

Safina, C. 2001. Tuna conservation. Pages 414-460 *in* B. A. Block and E. D. Stevens, editors. Tuna physiology, ecology, and evolution. Academic Press, San Diego, CA.

Sakagawa, G. T. 2000. The impact of FAD innovation on the performance of US tuna purse seine operations in the Pacific Ocean. Pages 371-388 *in* J. Y. Le Gall, P. Cayre, and M. Taquet, editors. Tuna Fishing and Fish Aggregating Devices. IFREMER/ENSAR, 15-19 October 1999, Martinique, Lesser Antilles.

Salazar, H., and J. S. Marcano. 1994. Analisis de los muestreos realizados en la pesqueria de atun con palangre en Venezuela entre 1988 y 1990. ICCAT Coll. Vol. Sci. Pap. 41:490-498.

Schaefer, K. M., Inter-American Tropical Tuna Commission. Personal communication, 2006.

Schaefer, K. M. 1996. Spawning time, frequency, and batch fecundity of yellowfin tuna, *Thunnus albacares*, near Clipperton Atoll in the eastern Pacific Ocean. Fishery Bulletin **94**:98-112.

Schaefer, K. M. 1998. Reproductive biology of yellowfin tuna (*Thunnus albacares*) in the eastern Pacific Ocean. Bull. 21 (5): 205-221. IATTC.

Schaefer, K. M. 2001. Reproductive biology of tunas. Pages 225-271 *in* B. A. Block and E. D. Stevens, editors. Tuna physiology, ecology, and evolution. Academic Press, San Diego, CA.

Schaefer, K. M., and D. W. Fuller. 2006. Estimates of age and growth of bigeye tuna (Thunnus obesus) in the eastern Pacific Ocean, based on otolith increments and tagging data. Bulletin Vol. 23 No. 2. Inter-American Tropical Tuna Commission, La Jolla, CA.

SCRS (2008c). Report of the 2008 ICCAT yellowfin and skipjack Stock Assessment Session. ICCAT, Madrid, Spain.

Seminoff, J. A. 2004. Marine Turtle Specialist Group Review: 2004 Global Status Assessment, Green Turtle (*Chelonia mydas*). Marine Turtle Specialist Group, The World Conservation Union (IUCN), Species Survival Commission Red List Programme. Available at: http://www.iucnmtsg.org/red_list/cm/MTSG_Chelonia_mydas_assessment_expanded-format.pdf.

Shark Specialist Group. 2000a. *Carcharhinus limbatus* In: 2004 IUCN Red List of Threatened Species. The World Conservation Union. Accessed October 15, 2005. Available at: http://www.redlist.org.

Shark Specialist Group. 2000b. *Carcharhinus obscurus.* In: 2004 IUCN Red List of Threatened Species. The World Conservation Union. Accessed October 15, 2005. Available at: http://www.redlist.org.

Sharp, G. D. 2001. Tuna oceanography - an applied science. Pages 345-390 *in* B. A. Block and E. D. Stevens, editors. Tuna physiology, ecology, and evolution. Academic Press, San Diego, CA.

Sibert, J. R., J. Hampton, P. Kleiber, and M. N. Maunder. 2006. Biomass, size, and trophic status of top predators in the Pacific Ocean. Science **314**:1773-1776.

Simpfendorfer, C. 2000. *Galeocerdo cuvier*. In: 2004 IUCN Red List of Threatened Species. The World Conservation Union. Accessed October 15, 2005. Available at: http://www.redlist.org.

Smale, M. J. 2000. *Carcharhinus longimanus.* In: 2004 IUCN Red List of Threatened Species. The World Conservation Union. Accessed October 15, 2005. Available at: http://www.redlist.org.

Smith, S. E., D. W. Au , and C. Show. 1998. Intrinsic rebound potentials of 26 species of Pacific sharks. Marine and Freshwater Research **41**:663-678.

Solana-Sansores, R. 2001. Spatial patterns of the epipelagic species caught incidentally in the tuna fishery on floating objects, in the eastern Pacific Ocean. Ciencas Marinas **27**:445-479.

Spotila, J. R., R. R. Reina, A. C. Steyermark, P. T. Plotkin, and F. V. Paladino. 2000. Pacific leatherback turtles face extinction. Nature **405**:529-530.

Stevens, J. 1996. The population status of highly migratory oceanic sharks in the Pacific Ocean. Symposium on Managing Highly Migratory Fish of the Pacific Ocean, Monterey, CA.

Stevens, J. 2000a. *Prionace glauca.* In: 2004 IUCN Red List of Threatened Species. The World Conservation Union. Accessed October 15, 2005. Available at: http://www.redlist.org.

Stevens, J. 2000b. *Isurus oxyrinchus.* In: 2004 IUCN Red List of Threatened Species. The World Conservation Union. Accessed October 15, 2005. Available at: http://www.redlist.org.

Sun, C.-L., W.-R. Wang, and S. Yeh. 2005. Reproductive biology of yellowfin tuna in the central and western Pacific Ocean. WCPFC-SC1, BI WP-1. 1st Meeting of the Scientific Committee of the Western and Central Pacific Fisheries Commission, Noumea, New Caledonia.

Tuck, G. N., T. Polacheck, and C. M. Bulman. 2003. Spatio-temporal trends of longline fishing effort in the Southern Ocean and implications for seabird bycatch. Biological Conservation **114**:1-27.

Uozumi, Y. 2003. Historical perspective of global billfish stock assessment. Marine and Freshwater Research **54**:555-565.

Vaca-Rodriguez, J. G., and R. R. Enriquez-Andrade. 2002. Multicriteria analysis of log-set strata closures to reduce the Mexican tuna fishery incidental catch. Ciencas Marinas **28**:257-271.

Walsh, C. F., and L. P. Garrison. 2006. Estimated bycatch of marine mammals and turtles in the U.S. Atlantic pelagic longline fleet during 2005. NOAA Technical Memorandum NMFS-SEFSC-539. Southeast Fisheries Science Center, NOAA Fisheries, Miami, FL.

Walters, C. J. 2003. Folly and fantasy in the analysis of spatial catch rate data. Canadian Journal of Fisheries and Aquatic Sciences **60**:1433-1436.

Ward, P., and R. A. Myers. 2005. Shifts in open-ocean fish communities coinciding with the commencement of commercial fishing. Ecology **86**:835-847.

Ward, R. D., N. G. Elliott, and P. M. Grewe. 1994. Allozyme and mitochondrial DNA variation in yellowfin tuna (*Thunnus albacares*) from the Pacific Ocean. Marine Biology **118**:531-539.

Weihs, D. 2004. The hydrodynamics of dolphin drafting. Journal of Biology **3**.

Western and Central Pacific Fisheries Commission. 2010. Tuna Fishery Yearbook 2009. Oceanic Fisheries Programme, Noumea, New Caledonia. 113 pages. Available at: http://www.wcpfc.int/system/files/documents/statistics-and-data/statistical-bulletins/YB_2009.pdf

White, W. T. 2003. *Mobula japanica.* In: 2004 IUCN Red List of Threatened Species. The World Conservation Union. Accessed October 15, 2005. Available at: http://www.redlist.org.

Wild, A. 1986. Growth of yellowfin tuna, *Thunnus albacares*, in the eastern Pacific Ocean based on otolith increments. IATTC Bulletin **18**:421-482.

Williams, P. 2004. Preliminary review of data collection forms used in the Philippines tuna fishery. Oceanic Fisheries Programme, Secretariat of the Pacific Community. 17th Meeting of the Standing Committee on Tuna and Billfish. Accessed July 10, 2007. Available at: http://www.spc.int/OceanFish/Html/SCTB/SCTB17/SWG-7.pdf.

Williams, P., and C. Reid. 2004. Overview of the western and central Pacific Ocean (WCPO) tuna fisheries - 2003. SCTB17 Working Paper GEN-1. 17th Meeting of the Standing Committee on Tuna and Billfish.

Williams, P. G. 1997. Shark and related species catch in tuna fisheries of the tropical western and central Pacific Ocean. Case study produced for the FAO Technical Working Group meeting on the Conservation and Management of Sharks, held in Tokyo Japan, 23 - 27 April 1998. Secretariat of the Pacific Community, Oceanic Fisheries Programme.

Worm, B., M. Sandow, A. Oschlies, H. K. Lotze, and R. A. Myers. 2005. Global pattern of predator diversity in the open oceans. Science **309**:1365-1369.

Yamashita, H. 2000. Problems of export-oriented yellowfin tuna industry - Indonesia and Philippines. Microbehavior and Macroresults: International Institute of Fisheries Economics and Trade (Oregon State University). Accessed July 10, 2007. Available at: http://oregonstate.edu/dept/IIFET/2000/papers/yamashita.pdf.

VI. Appendices

Appendix I. Capture Fisheries Evaluation

CRITERION 1: INHERENT VULNERABILITY TO FISHING PRESSURE

Guiding Principle: Sustainable wild-caught species have a low vulnerability to fishing pressure, and hence a low probability of being overfished, because of their inherent life history characteristics.

Primary Factors[16] to evaluate

Intrinsic rate of increase ('r')

- High (> 0.16) **0.20**
- Medium (0.05 - 0.16)
- Low (< 0.05)
- Unavailable/Unknown

Age at 1st maturity

- Low (< 5 years) **2 yrs**
- Medium (5 - 10 years)
- High (> 10 years)
- Unavailable/Unknown

Von Bertalanffy growth coefficient ('k')

- High (> 0.16) **0.72**
- Medium (0.05 - 0.15)
- Low (< 0.05)
- Unavailable/Unknown

Maximum age

- Low (< 11 years) **8 yrs**
- Medium (11 - 30 years)
- High (> 30 years)
- Unavailable/Unknown

[16] These primary factors and evaluation guidelines follow the recommendations of Musick et al. (2000). Marine, estuarine, and diadromous fish stocks at risk of extinction in North America (exclusive of Pacific salmonids). Fisheries 25:6-30.

Reproductive potential (fecundity)

- High (> 100 inds./year)
- Moderate (10 – 100 inds./year)
- Low (< 10 inds./year)
- Unavailable/Unknown

Secondary Factors to evaluate

Species range

- Broad (e.g. species exists in multiple ocean basins, has multiple intermixing stocks or is highly migratory)
- Limited (e.g. species exists in one ocean basin)
- Narrow (e.g. endemism or numerous evolutionary significant units or restricted to one coastline)

Special Behaviors or Requirements: Existence of special behaviors that increase ease or population consequences of capture (e.g. migratory bottlenecks, spawning aggregations, site fidelity, unusual attraction to gear, sequential hermaphrodites, segregation by sex, etc., OR specific and limited habitat requirements within the species' range).

- No known behaviors or requirements OR behaviors that decrease vulnerability (e.g. widely dispersed during spawning)
- Some (i.e. 1 - 2) behaviors or requirements **aggregating around FADs, schooling**
- Many (i.e. > 2) behaviors or requirements

Quality of Habitat: Degradation from non-fishery impacts

- Habitat is robust
- Habitat has been moderately altered by non-fishery impacts
- Habitat has been substantially compromised from non-fishery impacts and thus has reduced capacity to support this species (e.g. from dams, pollution, or coastal development)

Evaluation Guidelines

1) Primary Factors
   a) If 'r' is known, use it as the basis for the rank of the Primary Factors.
   b) If 'r' is unknown, then the rank from the remaining Primary Factors (in order of importance, as listed) is the basis for the rank.

2) Secondary Factors
   a) If a majority (2 out of 3) of the Secondary Factors rank as Red, reclassify the species into the next lower rank (i.e. Green becomes Yellow, Yellow becomes Red). No other combination of Secondary Factors can modify the rank from the Primary Factors.
   b) No combination of primary and secondary factors can result in a Critical Conservation Concern for this criterion.

Conservation Concern: Inherent Vulnerability

- Low (Inherently Resilient) (selected: green)
- Moderate (Inherently Neutral) (yellow)
- High (Inherently Vulnerable) (red)

CRITERION 2: STATUS OF WILD STOCKS

Guiding Principle: Sustainable wild-caught species have stock structure and abundance sufficient to maintain or enhance long-term fishery productivity.

Primary Factors to evaluate

Management classification status

- Underutilized OR close to virgin biomass
- Fully fished OR recovering from overfished OR unknown **ALL**
- Recruitment or growth overfished, overexploited, depleted or "threatened"

Current population abundance relative to B_{MSY}

- At or above B_{MSY} (> 100%) **WCPO**
- Moderately Below B_{MSY} (50 – 100%) OR unknown **EPO, ATL, IO**
- Substantially below B_{MSY} (< 50%)

Occurrence of overfishing (current level of fishing mortality relative to overfishing threshold)

- Overfishing not occurring ($F_{curr}/F_{msy} < 1.0$) **EPO, WCPO**
- Overfishing is likely/probable OR fishing effort is increasing with poor understanding of stock status OR Unknown **ATL**
- Overfishing occurring ($F_{curr}/F_{msy} > 1.0$) **IO**

Overall degree of uncertainty in status of stock

- Low (i.e. current stock assessment and other fishery-independent data are robust OR reliable long-term fishery-dependent data available)
- Medium (i.e. only limited, fishery-dependent data on stock status are available) **EPO, ATL, WCPO**
- High (i.e. little or no current fishery-dependent or independent information on stock status OR models/estimates broadly disputed or otherwise out-of-date) **IO**

Long-term trend (relative to species' generation time) in population abundance as measured by either fishery-independent (stock assessment) or fishery-dependent (standardized CPUE) measures

- ➢ Trend is up
- ➢ Trend is flat or variable (among areas, over time or among methods) OR Unknown **EPO**
- ➢ Trend is down **IO, WCPO, ATL**

Short-term trend in population abundance as measured by either fishery-independent (stock assessment) or fishery-dependent (standardized CPUE) measures

- ➢ Trend is up
- ➢ Trend is flat or variable (among areas, over time or among methods) OR Unknown **EPO**
- ➢ Trend is down **ATL, IO, WCPO**

Current age, size or sex distribution of the stock relative to natural condition

- ➢ Distribution(s) is(are) functionally normal
- ➢ Distribution(s) unknown **ALL**
- ➢ Distribution(s) is(are) skewed

Evaluation Guidelines

A "Healthy" Stock:

1) Is underutilized (near virgin biomass)
2) Has a biomass at or above BMSY AND overfishing is not occurring AND distribution parameters are functionally normal AND stock uncertainty is not high

A "Moderate" Stock:

1) Has a biomass at 50-100% of BMSY AND overfishing is not occurring
2) Is recovering from overfishing AND short-term trend in abundance is up AND overfishing not occurring AND stock uncertainty is low
3) Has an Unknown status because the majority of primary factors are unknown.

A "Poor" Stock:

1) Is fully fished AND trend in abundance is down AND distribution parameters are skewed
2) Is overfished, overexploited or depleted AND trends in abundance and CPUE are up.
3) Overfishing is occurring AND stock is not currently overfished.

A stock is considered a **Critical Conservation Concern** and the species is ranked "Avoid", regardless of other criteria, if it is:

1) Overfished, overexploited or depleted AND trend in abundance is flat or down
2) Overfished AND overfishing is occurring
3) Listed as a "threatened species" or similar proxy by national or international bodies

Conservation Concern: Status of Stocks

- Low (Stock Healthy) **WCPO**
- Moderate (Stock Moderate or Unknown) **EPO, ATL**
- High (Stock Poor) **IO**
- Stock Critical

CRITERION 3: NATURE AND EXTENT OF DISCARDED BYCATCH[17]

Guiding Principle: A sustainable wild-caught species is captured using techniques that minimize the catch of unwanted and/or unmarketable species.

Primary Factors to evaluate

Quantity of bycatch, including any species of "special concern" (i.e. those identified as "endangered", "threatened" or "protected" under state, federal or international law)

- Quantity of bycatch is low (< 10% of targeted landings on a per number basis) AND does not regularly include species of special concern **T/P**
- Quantity of bycatch is moderate (10 – 100% of targeted landings on a per number basis) AND does not regularly include species of special concern OR Unknown

  PS (unass. set)
- Quantity of bycatch is high (> 100% of targeted landings on a per number basis) OR bycatch regularly includes threatened, endangered or protected species

  LL, PS (FAD, dolphin)

[17] Bycatch is defined as species that are caught but subsequently discarded because they are of undesirable size, sex or species composition. Unobserved fishing mortality associated with fishing gear (e.g. animals passing through nets, breaking free of hooks or lines, ghost fishing, illegal harvest and under or misreporting) is also considered bycatch. Bycatch does not include incidental catch (non-targeted catch) if it is utilized, is accounted for, and is managed in some way.

Population consequences of bycatch

- Low: Evidence indicates quantity of bycatch has little or no impact on population levels

  T/P

- Moderate: Conflicting evidence of population consequences of bycatch OR Unknown

  PS (dolphin sets)

- Severe: Evidence indicates quantity of bycatch is a contributing factor in driving one or more bycatch species toward extinction OR is a contributing factor in limiting the recovery of a species of "special concern" **PS (FADs), LL**

Trend in bycatch interaction rates (adjusting for changes in abundance of bycatch species) as a result of management measures (including fishing seasons, protected areas and gear innovations):

- Trend in bycatch interaction rates is down **PS, LL (HI, US Atl)**
- Trend in bycatch interaction rates is flat OR Unknown **ALL OTHER LL**
- Trend in bycatch interaction rates is up
- Not applicable because quantity of bycatch is low **T/P**

Secondary Factor to evaluate

Evidence that the ecosystem has been or likely will be substantially altered (relative to natural variability) in response to the continued discard of the bycatch species

- Studies show no evidence of ecosystem impacts
- Conflicting evidence of ecosystem impacts OR Unknown
- Studies show evidence of substantial ecosystem impacts

  Removal of large predators (sharks/FADs)

Evaluation Guidelines

Bycatch is "**Minimal**" if:

1) Quantity of bycatch is <10% of targeted landings AND bycatch has little or no impact on population levels.

Bycatch is "**Moderate**" if:

1) Quantity of bycatch is 10 - 100% of targeted landings
2) Bycatch regularly includes species of "special concern" AND bycatch has little or no impact on the bycatch population levels AND the trend in bycatch interaction rates is not up.

Bycatch is "Severe" if:

1) Quantity of bycatch is > 100% of targeted landings
2) Bycatch regularly includes species of "special concern" AND evidence indicates bycatch rate is a contributing factor toward extinction or limiting recovery AND trend in bycatch is down.

Bycatch is considered a **Critical Conservation Concern** and the species is ranked "Avoid", regardless of other criteria, if:

1) Bycatch regularly includes species of special concern AND evidence indicates bycatch rate is a factor contributing to extinction or limiting recovery AND trend in bycatch interaction rates is not down.
2) Quantity of bycatch is high AND studies show evidence of substantial ecosystem impacts.

Conservation Concern: Nature and Extent of Discarded Bycatch

- Low (Bycatch Minimal) **T/P**
- Moderate (Bycatch Moderate) **PS (dolphin, unassociated)**
- High (Bycatch Severe) **LL (HI, US Atl)**
- Bycatch Critical **LL (All Others); PS (FAD)**

CRITERION 4: EFFECT OF FISHING PRACTICES ON HABITATS AND ECOSYSTEMS

Guiding Principle: Capture of a sustainable wild-caught species maintains natural functional relationships among species in the ecosystem, conserves the diversity and productivity of the surrounding ecosystem, and does not result in irreversible ecosystem state changes.

Primary Habitat Factors to evaluate

Known (or inferred from other studies) effect of fishing gear on physical and biogenic habitats

- Minimal damage (i.e. pelagic longline, midwater gillnet, midwater trawl, purse seine, hook and line, or spear/harpoon) **PS, TP, LL**
- Moderate damage (i.e. bottom gillnet, bottom longline or some pots/ traps)
- Great damage (i.e. bottom trawl or dredge)

For specific fishery being evaluated, resilience of physical and biogenic habitats to disturbance by fishing method

- High (e.g. shallow water, sandy habitats)
- Moderate (e.g. shallow or deep water mud bottoms, or deep water sandy habitats)
- Low (e.g. shallow or deep water corals, shallow or deep water rocky bottoms)
- Not applicable because gear damage is minimal

If gear impacts are moderate or great, spatial scale of the impact

- Small scale (e.g. small, artisanal fishery or sensitive habitats are strongly protected)
- Moderate scale (e.g. modern fishery but of limited geographic scope)
- Large scale (e.g. industrialized fishery over large geographic areas)
- Not applicable because gear damage is minimal

Primary Ecosystem Factors to evaluate

Evidence that the removal of the targeted species or the removal/deployment of baitfish has or will likely substantially disrupt the food web

- The fishery and its ecosystem have been thoroughly studied, and studies show no evidence of substantial ecosystem impacts
- Conflicting evidence of ecosystem impacts OR **Unknown** **T/P**
- Ecosystem impacts of targeted species removal demonstrated **LL**

Evidence that the fishing method has caused or is likely to cause substantial ecosystem state changes, including alternate stable states

- The fishery and its ecosystem have been thoroughly studied, and studies show no evidence of substantial ecosystem impacts
- Conflicting evidence of ecosystem impacts OR **Unknown** **all other gear**
- Ecosystem impacts from fishing method demonstrated **PS (FAD)**

Evaluation Guidelines

The effect of fishing practices is **"Benign"** if:

1) Damage from gear is minimal AND resilience to disturbance is high AND neither Ecosystem Factor is red.

The effect of fishing practices is **"Moderate"** if:

1) Gear effects are moderate AND resilience to disturbance is moderate or high AND neither Ecosystem Factor is red.
2) Gear results in great damage AND resilience to disturbance is high OR impacts are small scale AND neither Ecosystem Factor is red.
3) Damage from gear is minimal and one Ecosystem factor is red.

The effect of fishing practices **is "Severe"** if:

1) Gear results in great damage AND the resilience of physical and biogenic habitats to disturbance is moderate or low.
2) Both Ecosystem Factors are red.

Habitat effects are considered a **Critical Conservation Concern** and a species receives a recommendation of "**Avoid"**, regardless of other criteria if:

- Four or more of the Habitat and Ecosystem factors rank red.

Conservation Concern: Effect of Fishing Practices on Habitats and Ecosystems

- Low (Fishing Effects Benign) **T/P; PS (except FAD)**
- Moderate (Fishing Effects Moderate) **LL; PS (FAD)**
- High (Fishing Effects Severe)
- Critical Fishing Effects

CRITERION 5: EFFECTIVENESS OF THE MANAGEMENT REGIME

Guiding Principle: The management regime of a sustainable wild-caught species implements and enforces all local, national and international laws and utilizes a precautionary approach to ensure the long-term productivity of the resource and integrity of the ecosystem.

Primary Factors to evaluate

Stock Status: Management process utilizes an independent scientific stock assessment that seeks knowledge related to the status of the stock

- Stock assessment complete and robust **PAC, ATL**
- Stock assessment is planned or underway but is incomplete OR stock assessment complete but out-of-date or otherwise uncertain **IO**
- No stock assessment available now and none is planned in the near future

Scientific Monitoring: Management process involves regular collection and analysis of data with respect to the short and long-term abundance of the stock

- Regular collection and assessment of both fishery-dependent and independent data
- Regular collection of fishery-dependent data only **ALL**
- No regular collection or analysis of data

Scientific Advice: Management has a well-known track record of consistently setting or exceeding catch quotas beyond those recommended by its scientific advisors and other external scientists:

- No
- Yes
- Not enough information available to evaluate OR not applicable because little or no scientific information is collected

Bycatch: Management implements an effective bycatch reduction plan

- Bycatch plan in place and reaching its conservation goals (deemed effective) **LL: HI, US Atl**
- Bycatch plan in place but effectiveness is not yet demonstrated or is under debate **PS (unass. and dolphin set); ATL (PS FAD)**
- No bycatch plan implemented or bycatch plan implemented but not meeting its conservation goals (deemed ineffective) **Int'l LL; PS (FAD all other)**
- Not applicable because bycatch is "low" **T/P**

Fishing practices: Management addresses the effect of the fishing method(s) on habitats and ecosystems

- Mitigative measures in place and deemed effective
- Mitigative measures in place but effectiveness is not yet demonstrated or is under debate **(LL; purse seine FAD)**
- No mitigative measures in place or measures in place but deemed ineffective
- Not applicable because fishing method is moderate or benign

(T/P; unassoc. PS; dolphin set PS)

Enforcement: Management and appropriate government bodies enforce fishery regulations

- Regulations regularly enforced by independent bodies, including logbook reports, observer coverage, dockside monitoring and similar measures **US; EPO PS**
- Regulations enforced by fishing industry or by voluntary/honor system
- Regulations not regularly and consistently enforced

INT'L T/P, LL; INT'L PS (WCPO, ATL, IO)

Management Track Record: Conservation measures enacted by management have resulted in the long-term maintenance of stock abundance and ecosystem integrity

- Management has maintained stock productivity over time OR has fully recovered the stock from an overfished condition
- Stock productivity has varied and management has responded quickly OR stock has not varied but management has not been in place long enough to evaluate its effectiveness OR Unknown **WCPO, EPO, ATL**
- Measures have not maintained stock productivity OR were implemented only after significant declines and stock has not yet fully recovered **IO**

Evaluation Guidelines

Management is deemed to be "**Highly Effective**" if the majority of management factors are green AND the remaining factors are not red.

Management is deemed to be "**Moderately Effective**" if:
1) Management factors "average" to yellow
2) Management factors include one or two red factors

Management is deemed to be "**Ineffective**" if three individual management factors are red, including especially those for Stock Status and Bycatch.

Management is considered a **Critical Conservation Concern** and a species receives a recommendation of "**Avoid**", regardless of other criteria if:
1) There is no management in place
2) The majority of the management factors rank red.

Conservation Concern: Effectiveness of Management

- Low (Management Highly Effective) **US T/P; LL (HI & US ATL)**
- Moderate (Management Moderately Effective)

PS (WCPO, EPO, ATL, and IO unassoc.),LL (EPO, INT'L ATL, INT'L WCPO), Int'l T/P

- High (Management Ineffective) **IO (FAD PS, LL)**
- Critical (Management Critically Ineffective)

Appendix II

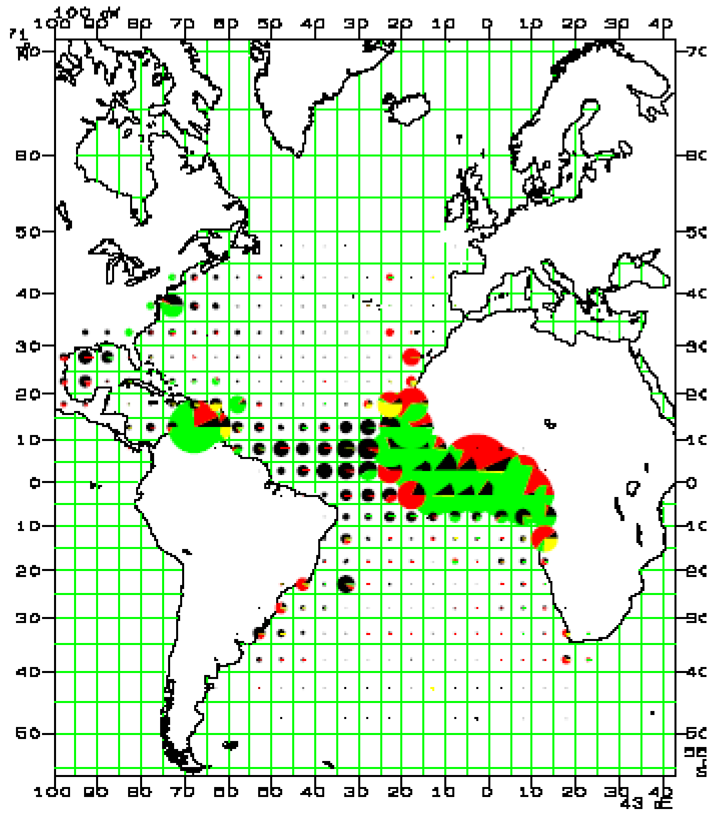

Figure A1. Distribution of Atlantic yellowfin catch by fishing gear, 1950 – 2000. Yellow, green, red, and black colors correspond to catches by other fisheries, purse seine, pole and line, and longline fisheries, respectively. Bubble size is proportional to total catches (Figure from ICCAT 2004).

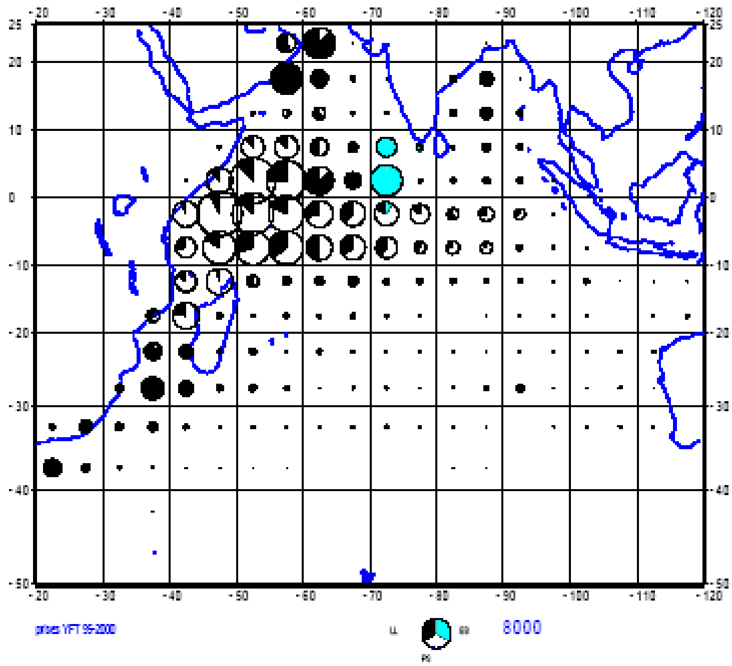

Figure A2. Distribution of yellowfin catches in the Indian Ocean, 1995 – 2000. Aqua represents pole and line catches, white represents purse seine catches, and black represents longline catches (Figure from IOTC 2003).

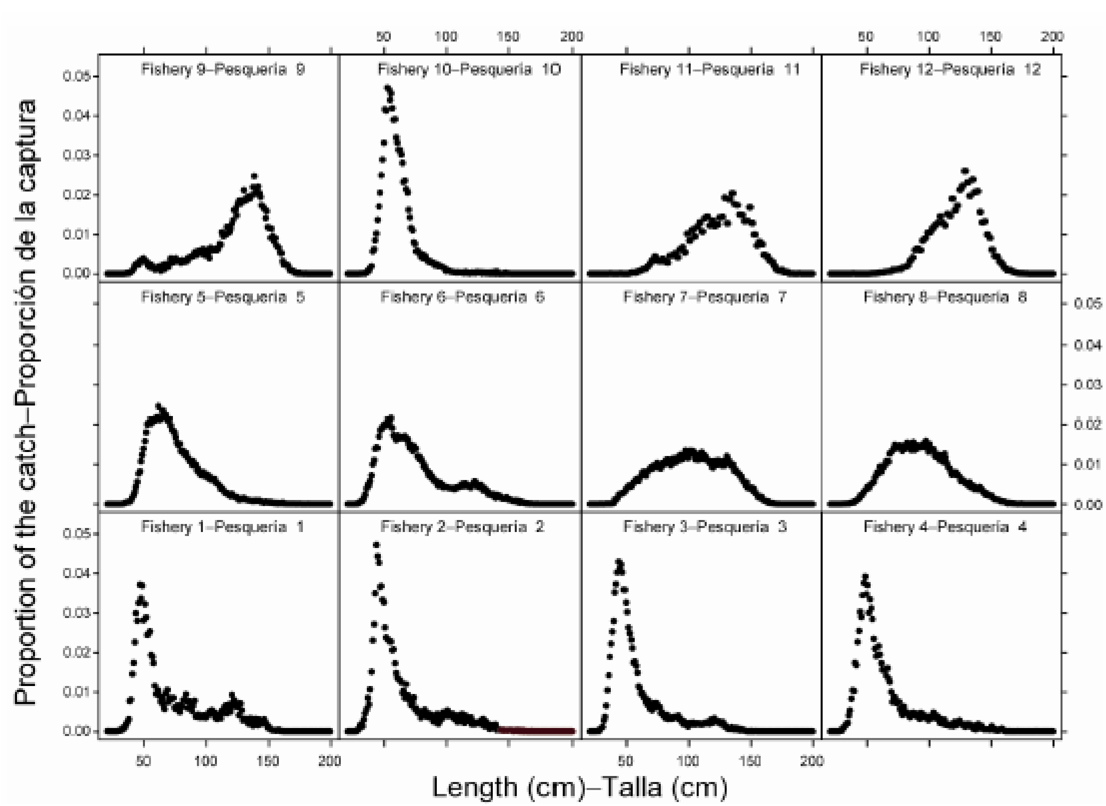

Figure A3. Average size composition of yellowfin catch by the various fisheries (as defined for the yellowfin stock assessment) in the EPO, 1975 – 2002. Fisheries 1 – 4 are purse seine sets on floating objects, fisheries 5 – 6 are purse seine sets on unassociated fish, fisheries 7 – 9 are purse seine sets on dolphin-associated schools, fishery 10 is pole and line, and fisheries 11 – 12 are longlines (Figure from Maunder and Harley 2005).

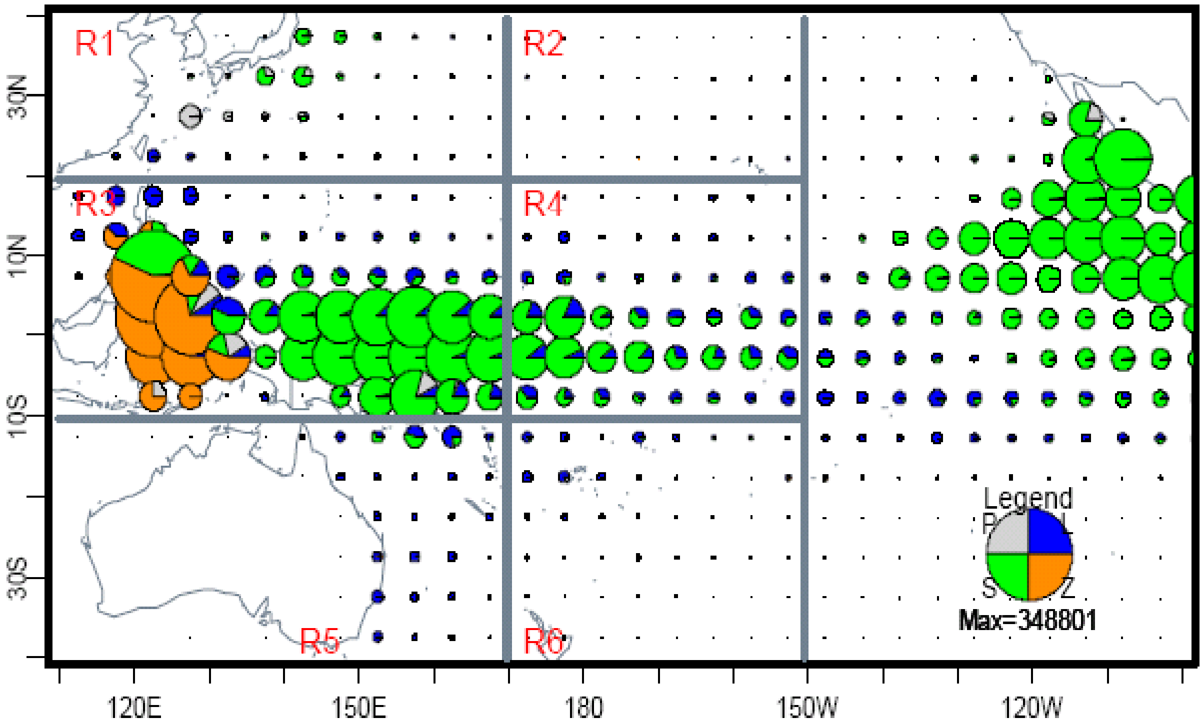

Figure A4. Distribution of yellowfin catch in the WCPO, 1992 – 2005. The heavy lines indicate the regions (1 – 6) used in the stock assessment (Figure from Langley et al. 2007).

Appendix III

Prior to the 2007 WCPO stock assessment, yellowfin tuna in the WCPO were considered not to be overfished (B/B_{MSY} =1.16-1.32), but was undergoing overfishing (F/F_{MSY} =1.22-1.35) According to the most recent stock assessment, yellowfin tuna have a B/B_{MSY} of between 1.1 and 1.4 and a F/F_{MSY} of 0.95. While fishing mortality data may suggest that the WCPO yellowfin stock is no longer undergoing overfishing, these data are highly uncertain and the likelihood that the stock continues to undergo overfishing is high. As a result, no changes in stock status ranking or overall Seafood Watch® recommendation were made.

Appendix IV

Prior to the 2007 assessment reviewed above, yellowfin in the EPO was last assessed in 2004/2005 using the same age-structured, catch-at-length analysis. As in the current assessment, the 2004/2005 stock assessment defined 16 different fisheries based on gear type, type of purse seine set, and length-frequency sampling area or latitude, with catch and effort data stratified according to these fishery definitions (Hoyle and Maunder 2005).

The stock was assessed based on several measures, including spawning biomass, yield per recruit, and average maximum sustainable yield (AMSY).[18]

- 2004/2005 spawning biomass ratio (SBR) for yellowfin in the EPO was slightly below SBR_{AMSY} = 0.44.
- 2004/2005 yield per recruit indicated that the average weight of yellowfin caught in all of the fisheries in the EPO was 9 kg at the end of 2004; this weight was far less than the critical weight of 35.2 kg estimated for yellowfin in the EPO (Hoyle and Maunder 2005). As in the current assessment, yield per recruit was generally not being maximized in these fisheries, with only the longline and dolphin-associated fisheries catching yellowfin larger than the critical weight (Hoyle and Maunder 2005).

2004/2005 AMSY indicated that the biomass of yellowfin in the beginning of 2004 in the EPO was estimated at slightly below the AMSY level (Hoyle and Maunder 2005).

Appendix V

Due to data that Seafood Watch® has collected regarding which tuna species are used in canned tuna and what gear types are predominately used to catch those species, Seafood Watch® has changed its canned tuna recommendations. The pocket guide recommendation for canned light tuna that is troll/pole-caught is recommended as a **Best Choice** due to the moderately healthy stocks, low bycatch concerns, and effective management. All other canned light tuna is recommended as **Avoid** because the majority is caught with gear types that have critical bycatch concerns. The Executive Summary has been updated to reflect this change.

Appendix VI – October 2010

Stock update.

The latest assessments indicate that stock status of yellowfin in the EPO and WCPO has improved. Stock status is the EPO is now a moderate conservation concern and stock status in

[18] AMSY is defined as "the maximum long-term yield that can be achieved under average conditions, using the current, age-specific selectivity pattern of all fisheries combined" (Hoyle and Maunder 2005, p. 19).

the WCPO is now a low conservation concern. Overall, this moves U.S. EPO troll/pole- caught yellowfin, all WCPO troll/pole-caught yellowfin, and WCPO unassociated purse seine caught yellowfin from Good Alternative to Best Choice, and moves Hawaiian longline-caught yellowfin from Avoid to Good Alternative. Stock status for Atlantic and Indian Ocean stocks was also updated, but the ranking for each remains unchanged. For the Atlantic stock, different assessment models provide different results as to whether the stock is overfished or not, so the stock status remains a moderate concern. The Indian Ocean stock remains a high concern due to continued overfishing. These changes are reflected in the Stock Section (Criterion 2), and the Executive Summary.

Bycatch addendum.

In this report, the only longline fisheries that receive a high conservation concern rating for bycatch (as opposed to a critical rating) are the US Atlantic and Hawaii fisheries. This is due to these fisheries having observer programs (and associated analyses) that demonstrate declining bycatch trends or otherwise providing evidence that they are not contributing to the decline of a species. However, several recent developments suggest the need for an updated and comprehensive analysis of the bycatch in these fisheries. These developments are provided below for interested readers. Seafood Watch fully intends to conduct this updated analysis once the current process to revise the fisheries assessment criteria is complete.

Sea turtles

A recent Endangered Species Act (ESA) status of loggerhead sea turtles indicates a far more complicated stock structure than assumed at the time of the most recent Biological Opinions (BiOps) for the US longline fisheries (NOAA/USFWS 2009). There is now evidence that the global population is composed of at least nine subpopulations (Distinct Population Segments or DPS in ESA parlance). Each DPS is genetically unique and represents a unique ecosystem; the loss of any one DPS would represent a significant loss of genetic diversity and would result in a significant gap in the species' range (NOAA/USFWS 2009). Seven of the DPS meet the criteria for listing as 'Endangered;' the remaining two still meet the criteria for listing as 'Threatened' (all loggerheads are currently listed as Threatened). The DPS' with which US longline fisheries interact (primarily the North Pacific Ocean DPS and the Northwest Atlantic Ocean DPS, though also possibly the Northeast Atlantic Ocean DPS) both meet the criteria for listing as endangered. Both continue to decline, and declines are driven primarily by fisheries bycatch. Fisheries bycatch is also the primary threat to most of the other DPS' (and a major threat to all DPS') (NOAA/USFWS 2009). The nesting loggerheads in the US are one of the two aggregations that compose the majority of nesting populations worldwide, and are thus of paramount importance to the survival of the species (NOAA/USFWS 2009). Furthermore, recent work estimating loggerhead fecundity on US beaches using satellite telemetry suggests that current estimates of population size may be considerable overestimates (by 32%) (Tucker 2010).

The bycatch rate of loggerheads in the US Atlantic fishery increased from 2005 (one of the lowest rates in the last two decades) to 2008 and there was relatively high uncertainty in the estimates (as shown by a considerable 95% CI range, especially in 2008). The most recent observer data however indicates a decline in 2009 to the lowest rate since 1992 (when the observer program began) and a much higher certainty (Garrison and Stokes 2010). Although this is a positive sign, the most recent BiOp (2004) needs review in light of the new information on stock structure and status outlined above. Specifically, current loggerhead bycatch limits may need to be modified considerably to ensure the fishery does not jeopardize the continued existence of this species. The same applies to the Hawaiian longline fishery, in which the take limit for loggerheads was recently increased in the Hawaiian shallow-set pelagic longline fishery to allow for expansion of the fishery (the most recent BiOp found no jeopardy from this action, but again did not consider the new information on stock structure and status - NOAA 2008).

Marine mammals
In the US Atlantic pelagic longline fishery, bycatch rates for Risso's dolphins and pilot whales are generally down over a longer time series and takes are below PBRs. According to observer data, bycatch rates increased in 2008 (2007-2008 for Risso's dolphins), but decreased again in 2009 (Garrison and Stokes 2010). This decrease may reflect measures implemented in 2009 to reduce the number of interactions (fishing effort increased in 2009), but it is too early to make that determine yet (especially as the timeline for reducing interactions thorugh these measures is five years).

Until recently, the Hawaiian pelagic longline fishery was listed as Category I in the List of Fisheries (LoF). In 2009, the fishery was split into two separate fisheries. The deep-set fishery for tuna remained Category I due to the continued exceedance of the false killer whale PBR (the fishery remains Category I in the 2010 LoF). The shallow-set fishery was (and continues to be in the 2010 LoF) re-listed as Category II due primarily to the bycatch of humpback whales. Based on inference and limited data, the pelagic longline fisheries targeting tuna and swordfish out of American Samoa are listed as Category II. As required under the MMPA, a Take Reduction Team (TRT) was convened in January 2010 with the goal of reducing the bycatch of false killer whales to levels less than the PBR within six months of implementation of the plan (FKWTRT 2010). Recommendations in the current draft report include closure of the area north of the main Hawaiian islands year round (it is currently a seasonal closure), the use of circle hooks, and the use of 'weak' hooks should experiments provide evidence that the cetaceans can straighten the hook out and thus escape (FKWTRT 2010). Recommendations in the report will also apply to the shallow-set fishery.

Bluefin Tuna
Bluefin tuna is a species of particular concern in the Atlantic, as all stocks are overfished with overfishing still occurring. The species is currently managed as separate eastern and western stocks, which reach age at maturity at different ages and have isolated spawning grounds in the Gulf of Mexico and Mediterranean Sea (SCRS 2008). Recent tagging and genetic research suggests stock structure is likely more complex, with multiple breeding stocks in the Mediterranean (Reeb 2010; Riccioni, Landi et al. 2010), and possibly additional population structure in the Gulf of Mexico (S Miller, Tag A Giant, pers. comm.). This and other factors (e.g. growth curve, past and future recruitment, degree of stock mixing, age at maturity) result in significant uncertainty in the status of Atlantic bluefin tuna (SCRS 2008). Current assessments suggest a strong likelihood that both the eastern and western stocks have a biomass lower than 15% of unfished biomass (SCRS 2008). Declining catch rates by the major fisheries in the Western Atlantic (US, Canada, and Japan) suggest past projections have been overly optimistic, at least for the western stock (Restrepo 2009). Various authors have predicted the collapse of

Atlantic bluefin tuna both in the west Safina and Klinger 2008 and the east MacKenzie, Mosegaard et al. 2009, and concerns have been great enough over failed management that petitions have been made to get the species listed under CITES (Buck 1995; CITES 2009) and the US Endangered Species Act (CBD 2010).

According to logbook data, bluefin tuna discards in the US Atlantic longline fishery targeting tunas have generally been increasing since 2001 (Figure A-VI) (HMS logbook data, 1992-2008). The data suggest bluefin discards were less than two times the retained catch in 2001-2005, but have been closer to three times the retained catch since then (2006-2008). Moreover, observer data in the fishery suggest that logbook data may underestimate the number of discards of bluefin (relative to retained), indicating that discards of bluefin for 2001-2005 outnumbered retained fish by over four times (Pelagic Observer Program data).

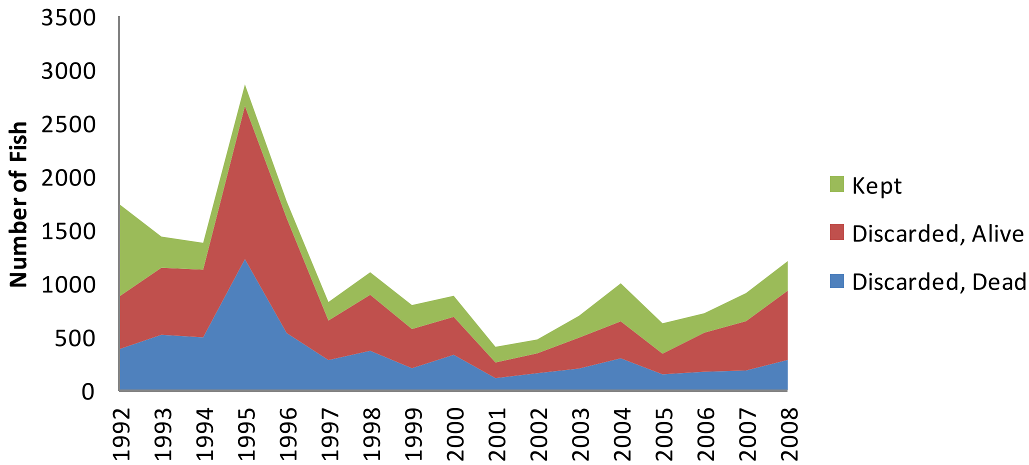

Figure A-VI : Trend in disposition of bluefin tuna caught by US Atlantic pelagic longline vessels targeting yellowfin, bigeye, or mixed tunas (HMS logbook data, 1992-2008).

Billfish

The pelagic longline fisheries targeting yellowfin and bigeye tuna and swordfish account for the majority of mortality of Atlantic blue marlin, white marlin (only found in the Atlantic) and Atlantic sailfish (Peel, Nelson et al. 2003; SCRS 2009). All remain overfished with overfishing occurring. US mortality of Atlantic marlins and sailfish for the time period 2000-2008 (average) was about 3%, 1%, and 0.2% for white marlin, blue marlin, and Atlantic sailfish respectively (data from SCRS 2009).

White marlin in particular has been considered as among the most overexploited species under ICCAT management (Beerkircher, Arocha et al. 2010). Concern over the future of the species has been high enough that a petition to list the species as endangered under the US Endangered Species Act was filed in 2001. NOAA recently concluded that listing was not warranted NOAA 2007. However, concerns now exist over the longstanding misidentification of the recently discovered roundscale spearfish (Tetrapturus georgii) as white marlin, throwing considerable doubt on scientists' understanding of the life history of white marlin (e.g., age and growth, reproduction, feeding habits, migratory patterns, and habitat utilization). Recent population assessments (in lieu of full stock assessments) suggest white marlin have been overfished since at least the early 1990s and perhaps as far back as the mid-1960s, and is still showing declining biomass despite decades of international management (Beerkircher, Arocha et al. 2010). The majority of simulations suggest the species was overfished in 2001 and that overfishing is still occuring (Beerkircher, Arocha et al. 2010). While early data on the proportion of misidentified roundscale spearfish landed was included in the ESA review noted above, the more recent findings suggest further review is necessary.

Baum, J. K., R. Myers, et al. (2003). "Collapse and conservation of shark populations in the Northwest Atlantic." Science 299: 389-392.

Beerkircher, L., F. Arocha, et al. (2010). "Effects of species misidentification on population assessment of overfished white marlin Tetrapturus albidus and roundscale spearfish T. georgii." Endangered Species Research 9(2): 81-89.

Buck, E. (1995). Atlantic bluefin tuna: international management of a shared resource. Washington, DC, The National Council for Science and the Environment.

Carretta, J. V., M. M. Muto, et al. (2002). False Killer Whale (Pseudorca crassidens): Hawaiian stock. US Pacific Marine Mammal Stock Assessments: 2002. La Jolla, CA, NOAA/NMFS/SWFSC: 286 pp.

CBD (2010). Petition to list the Atlantic bluefin tuna (Thunnus thynnus) as Endangered under the United States Endangered Species Act, Center for Biological Diversity.

CITES (2009). Proposal to include Atlantic Bluefin Tuna (Thunnus thynnus (Linnaeus, 1758)) on Appendix I of CITES in accordance with Article II 1 of the Convention.

Crowder, L. and R. Myers (2001). A Comprehensive Study of the Ecological Impacts of the Worldwide Pelagic Longline Industry. Philadelphia, PA, The Pew Charitable Trusts: 143.

FKWTRT (2010). Draft False Killer Whale Take Reduction Plan: 199.

Garrison, L. P. and L. Stokes (2010). Estimated bycatch of marine mammals and sea turtles in the U.S. Atlantic pelagic longline fleet during 2009. : 65.

Hoyle, S. and N. Davies (2009). Stock assessment of albacore tuna in the south Pacific Ocean (Rev.), Western and Central Pacific Fisheries Commission.

IOTC (2008). Report of the Second Session of the IOTC Working Party on Temperate Tunas.

Lewison, R., S. Freeman, et al. (2004). "Quantifying the effects of global fisheries on threatened species: the impact of pelagic longlines on loggerhead and leatherback sea turtles." Ecology Letters 7: 221-231.

MacKenzie, B. R., H. Mosegaard, et al. (2009). "Impending collapse of bluefin tuna in the northeast Atlantic and Mediterranean." Conservation Letters 2(1): 26-35.

NMFS (2001). Final Environmental Impact Statement: Pelagic Fisheries of the Western Pacific Region, Southwest Fisheries Science Center, NMFS/NOAA.

NMFS (2003). 2001 Pelagic Annual Report. Honolulu, National Marine Fisheries Service.

NOAA (2007). Leatherback Sea Turtle (Dermochelys coriacea). 5-year review: Summary and Evaluation. N. OPR. Silver Spring, MD, NOAA: 81.

NOAA (2008). Endangered Species Act - Section 7 Consultation, Biological Opinion: Management Modifications for the Hawaii-based Shallow-set Longline Swordfish Fishery - Implementation of Amendment 18 to the Fishery Management Plan for Pelagic Fisheries of the Western Pacific Region.

NOAA (2009a). Stock Assessment and Fishery Evaluation (SAFE) report for Atlantic Highly Migratory Species. Silver Spring MD, NOAA.

NOAA (2009b). NOAA Summary of the 21st Regular Meeting of the International Commission for the Conservation of Atlantic Tunas (ICCAT), November 2009. Accessed at http://theabta.com/11-09ICCATmeet.pdf.

NOAA/USFWS (2009). Loggerhead Sea Turtle (Caretta caretta) 2009 Status Review Under the US Endangered Species Act.

NOAA/USFWS (2009). Recovery Plan for the Northwest Atlantic Population of the Loggerhead Sea Turtle (Caretta caretta) Second Revision.

Peel, E., R. Nelson, et al. (2003). "Managing Atlantic marlin as bycatch under ICCAT. The fork in the road: Recovery or collapse." Marine and Freshwater Research 54(4): 575-584.

Restrepo, V. (2009). "On the possible current status of the western Atlantic bluefin tuna stock, had the main fisheries caught their 2003-2007 quota. ." Col. Vol. Sci. Pap. ICCAT 64(2): 657-661.

Safina, C. and D. H. Klinger (2008). "Collapse of bluefin tuna in the Western Atlantic." Conservation Biology 22(2): 243-246.

SCRS (2008). Report of the 2008 Atlantic Bluefin Tuna Stock Assessment Session. Madrid, Spain: 247pp.

SCRS (2009). Report for the biennial period, 2008-09 PART II (2009) - Vol. 2. Madrid, Spain, ICCAT.

SCRS (2009). Report of the 2009 ICCAT Albacore Stock Assessment Session. Madrid, Spain, ICCAT: 100pp.

Stevens, J. (1996). The population status of highly migratory oceanic sharks in the Pacific Ocean. Symposium on Managing Highly Migratory Fish of the Pacific Ocean, Monterey, California.

Tucker, A. D. (2010). "Nest site fidelity and clutch frequency of loggerhead turtles are better elucidated by satellite telemetry than by nocturnal tagging efforts: Implications for stock estimation." Journal of Experimental Marine Biology and Ecology 383(1): 48-55.