Ecosystem-based Management of Pacific Tunas

by:

Lia Protopapadakis
Master of Environmental Management
Coastal Environmental Management

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Approved:

Dr. Mike Orbach, Advisor

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ABSTRACT

Ecosystem-based management is fast becoming *the* way to solve all the nation's fishery problems. It will rebuild fish stocks, eliminate bycatch, and halt habitat destruction; it will fix jurisdictional mismatches and encourage community participation; it will satisfy environmentalists and please fishermen. These are lofty expectations for a concept that few can explain. However, managers are still if it applies to all fisheries. To resolve this, I examined ecosystem-based management in the context of the United State's yellowfin and bigeye fisheries and suggested ecosystem-based approaches to managing this fishery.

EBM is *the management of human behavior in a way that maintains healthy and productive ecosystems for present and future generations*. Its main themes include: maintaining ecological integrity, matching ecological and governance boundaries, and recognizing humans as a part of the ecosystem.

Using ecosystem approaches to management offers several benefits to fisheries managers, including: a tool to address non-fishing related causes for declining fisheries, such as the dams in the Pacific Northwest that have endangered most salmon runs; an opportunity to re-furbish an aging management system; and a method for setting management and conservation priorities. Some of these benefits are not applicable to pelagic fisheries. However a large number of issues currently facing the yellowfin and bigeye fisheries can be addressed with EBM. These include: the overfishing of stocks, the definition of stock boundaries, the unintentional capture of non-target species, the contamination of tuna with mercury, and the flexibility of fishermen in response to regulation.

Because of these benefits, and in light of the fact that fisheries managers are clearly moving toward using EBM (Kalo et al. 2002, EPAP 1998, POC 2003, USCOP 2004, WPRFMC 2005), I found that EBM is worth pursuing in pelagic fisheries in the future, despite the challenges mangers will face when implementing it.

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ACRONYMS

CITES	Convention on International Trade of Endangered Species
CNMI	Commonwealth of the Northern Mariana Islands
EBM	Ecosystem-based Management
EEZ	Exclusive Economic Zone
EFH	Essential Fish Habitat
ESA	Endangered Species Act
ETP	Eastern Tropical Pacific
FAD	Fish Aggregating Device
FEP	Fishery Ecosystem Plan
FMP	Fishery Management Plan
FOB	Floating Object
IATTC	Inter-American Tropical Tuna Commission
MFMT	Maximum Fishing Mortality Threshold
MMPA	Marine Mammal Protection Act
mph	Miles Per Hour
MSA	Magnuson-Stevens Fisheries Conservation and Management Act
MSST	Minimum Stock Size Threshold
MSY	Maximum Sustainable Yield
mt	Metric Tons
nm	Nautical Miles
NMFS	National Marine Fisheries Service
OY	Optimum Yield
pFAD	Personal Fish Aggregating Device
PIRO	Pacific Islands Regional Office
PISC	Pacific Islands Fisheries Science Center
SFA	Sustainable Fisheries Act
SPTT	South Pacific Tuna Treaty
UNCLOS	United Nations Convention on the Law of the Seas
VMS	Vessel Monitoring System
WCP	Western and Central Pacific
WCPFC	Western and Central Pacific Fisheries Commission

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Chapter 1: INTRODUCTION

Poised to amend the Magnuson-Stevens Fisheries Conservation and Management Act (MSA)—the most important piece of legislation for fisheries management in the United States—Congress appears to have finally opened the policy window for ecosystem-based management (EBM). The concept is not a new one, but has recently come to the forefront for fisheries management.

EBM is *the management of human behavior in a way that maintains healthy and productive ecosystems for present and future generations*. Its main themes include: maintaining ecological integrity, matching ecological and governance boundaries, and recognizing humans as a part of the ecosystem.

Modern models of EBM began to develop in the early 1930’s. Ecosystem approaches to natural resource management gained popularity in terrestrial circles in the 70’s in conjunction with the growing environmental movement. However, it was not until the 90’s, when the amendments to the MSA added habitat protection and bycatch reduction to the list of goals of fisheries management, that the idea was first applied to fisheries management.

EBM is attractive because it gives fisheries managers tools with which they can address non-fishing related causes for declining fisheries, such as the dams in the Pacific Northwest that have endangered most salmon runs. It also gives them an opportunity to re-furbish an aging management system, and supplies them with a method for setting management and conservation priorities.

Applying EBM to inshore fisheries—where habitat loss visibly contributes to declining fish stocks—seems reasonable. But what about offshore, pelagic fisheries? Would these fisheries feel the benefits of an EBM system?

Yellowfin and bigeye tuna are commercially valuable pelagic predators. Their bodies are sleek and powerful. Their flesh is a juicy; the meat, buttery. These qualities make them delectable and therefore valuable to humans.

Over the course of their lives they will cross several international boundaries, making them difficult to manage. As a result, managing tunas require international cooperation.

Sadly, both yellowfin and bigeye tuna are currently being overfished. New fishing methods are catching a shocking number of tunas that have not yet reproduced. In addition, sea turtles, marine mammals, and sea birds are being unintentionally caught, killed, and wasted by fishing gear. Is there a place among these issues where we can apply ecosystem approaches for better results?

To answer this question, I examined whether EBM can improve the management of pelagic fisheries and how fisheries managers can incorporate ecosystem approaches into their management practices using the yellowfin and bigeye tuna fisheries as case studies. Since pelagic fisheries are international ones, I include in my discussion information on the international management regime and how the domestic management system interacts with it; however, the main focus of my paper will be domestic policy and management.

Chapter 2: METHODS

To evaluate the potential for EBM for pelagic fish in the Pacific, I contrasted it with the *current* management regime for this species. But first, I needed to understand the biophysical ecosystem of yellowfin in the tropical pacific.

I conducted a literature review of the life history and ecology of yellowfin tuna. This literature review included documents from scientific conferences, journals, and government documents.

Next, I examined the existing laws, regulations, treaties, and court cases that affect the fishery, as well as minutes from the international negotiations and statistics about the fishery.

I observed and participated in fisheries policy formation regarding tunas in the Pacific in the summer of 2005 at the Southwest Fisheries Regional Office of the National Marine Fisheries Service (NMFS) in Long Beach, California, and in the winter of 2006 at the Western Pacific Regional Fisheries Management Council in Honolulu, Hawai`i.

I studied existing theories about EBM as presented in policy reports, news articles, editorials, journal articles, fishing forums, and interviews with fishermen, environmentalists, and managers.

From the foregoing, I identified the current challenges facing the yellowfin and bigeye fisheries and key themes in EBM. Then, I matched these themes with these challenges. From this I deduced ways in which EBM could be applied to address these issues.

Chapter 3: BACKGROUND

ECOLOGY OF YELLOWFIN AND BIGEYE TUNA

Yellowfin tuna (*Thunnus albacares*) and its sister species bigeye (*T. obesus*) belong to an elite group of fish that cruise the pelagic ocean. All in this group: swordfish, marlins, tunas, bonitos, and mackerels are built for hydrodynamic speed with adaptations that make them effective predators. They are also highly sought after as food and for sport. Together they comprise the Scombroidei sub-order. Swordfish belong to the Xiphiidae family; marlins and other billfish, to Istiophoridae; and the true tunas, to Scombridae and the genus *Thunnus*. Other closely related species in the *Thunnus* genus include northern bluefin tuna (*T. thynnus*), albacore (*T. alalunga*), southern bluefin tuna (*T. maccoyii*), longtail tuna (*T. tonggol*), and blacktail tuna (*T. atlanticus*). Bluefin, albacore, yellowfin, and bigeye are all targets of commercial fishing operations around the globe. Of these, bigeye and yellowfin are the most similar in appearance, feeding behavior, and distribution. Skipjack tuna (*Katsuwonus pelamis*), another important commercial fish, is a cousin of these tunas in the same family (Joseph et al. 1980, Miyabe 1993).

An average adult yellowfin weighs around 250 pounds and measures about six feet in length (71 inches, 180 centimeters) (Hampton et al. 2005a, Nakamura and Uchiyama 1966). Bigeye are slightly larger and deeper bodied, weighing in at 380 pounds and measuring six and a half feet (79 inches, 200 centimeters) (Hampton et al. 2005b). Their sleek and powerful bodies are widest just behind the head and taper rapidly toward the tail. Their silvery-blue counter-shading perfectly camouflages them in the open ocean, except for the accents of bright yellow on their finlets, which march down the upper and under-side of their tails. Bigeye's are rimmed with black, one of the scant distinctions between them and yellowfin (Figure 1).

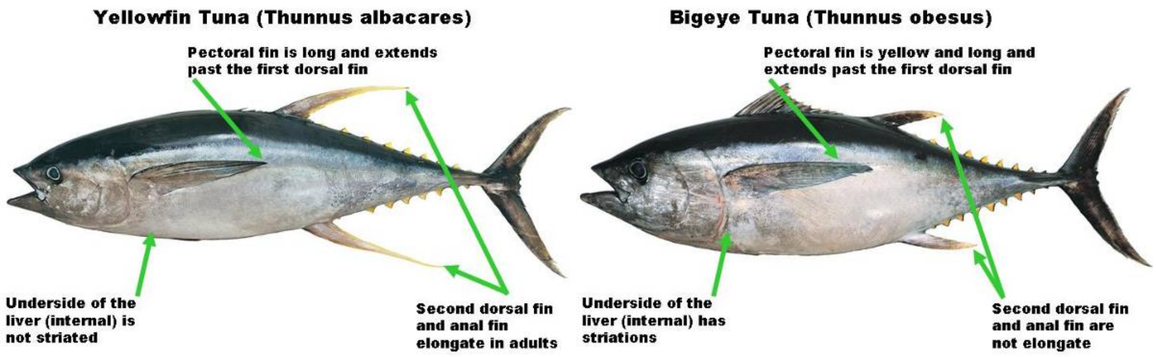

Figure 1: Yellowfin and Bigeye Tuna Compared. (www.dfw.state.or.us)

Both tunas have evolved special adaptations that make them more streamlined. For example, their first dorsal fin disappears into a slit on their back and their stiff pectoral fins fit into grooves on their sides to eliminate drag when they sprint. Their muscular tails launch these agile animals forward no *slower* than one body length per second. This cruising speed of roughly 3.4 mph allows them to travel thousands of miles across the Pacific in a matter of months (Joseph et al. 1980, Safina 1997).

Unlike all other marine fish, only the tunas regulate their body temperature. Using a complex system of intertwined blood vessels, they harvest the energy generated from swimming to heat their blood and maintain their internal temperature above that of the surrounding water. This elevated temperature allows them to rapidly convert food into energy and enables them to accelerate in one quick burst (Joseph et al. 1980, Block et al. 2001).

Their high metabolic rates help them maintain their elevated temperature, but in the process, this furnace burns a lot of oxygen. To feed their internal fire, tunas' gills have evolved to be as effective at gathering oxygen as a mammal's lungs, and their hemoglobin concentrations are as high as a human's. But nothing is perfect, and to pass enough water through their gills to get the oxygen they require, these fish must swim constantly. To sustain their eternal swimming, they have a higher proportion of red, oxygen-rich muscle than any other fish, which gives their flesh the luscious red hue it is known for (Joseph et al. 1980).

Tunas are classified as a highly migratory fish under the United Nations' Convention on the Law of the Sea (UNCLOS) and the MSA because they travel across the invisible, human-drawn boundaries, which designate national territories and resources (UN 1982, 16 *USCS* § 1802(20)). A group of researchers tracked one exceptional yellowfin 3,100 miles. Most do not travel this far, remaining within 1,000 nautical miles (nm) of one area. Recent research suggests that most of these fish will spend their lives in an even smaller area of 330 to 400 nm. Bigeye roam farther than yellowfin, traveling up to 4,000 miles, but, like yellowfin, they remain in a smaller area for long periods of time (Joseph et al. 1980, Silbert and Hampton 2003, Hampton et al. 2005a and 2005b).

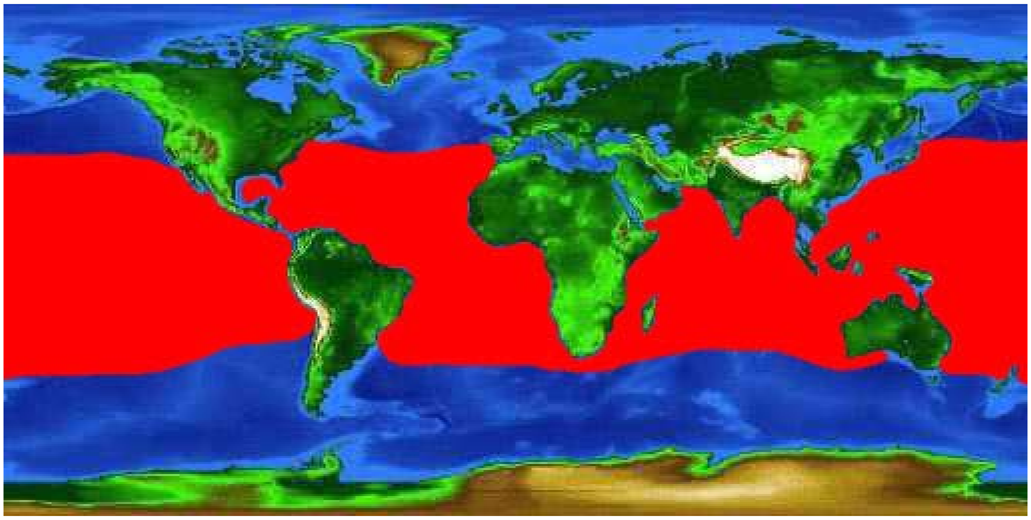

Figure 2: Global Distribution of Yellowfin and Bigeye Tuna. (Florida Museum of Natural History)

Yellowfin and bigeye have been observed as far away from the equator as 40° N and 40° S latitude but reside primarily in tropical waters, between 20°N and 20°S (Figure 2). Yellowfin prefer warmer waters than bigeye and therefore typically occupy the upper water column. Both species congregate near islands, seamounts, and temperature fronts, which have high concentrations of prey (WPRFMC 2005). In the eastern tropical Pacific (ETP), large adult yellowfin school with pods of dolphins. This occurs only in the ETP, and no one knows why.

Like all tunas, yellowfin and bigeye are upper level predators (Figure 3). Squids, flying fishes, small scombrids (mackerel, tuna, and bonito), and epipelagic and mesopelagic fishes compose the bulk of their diet. They also feed on mahi-mahi, juvenile fish (including sharks, and tunas), lance, fish nekton, and epipelagic and mesopelagic micronekton. Their only predators are sharks, billfish, toothed whales, swordfish, and humans (FAO 2003, Hinke et al. 2004, WPRFMC 2005).

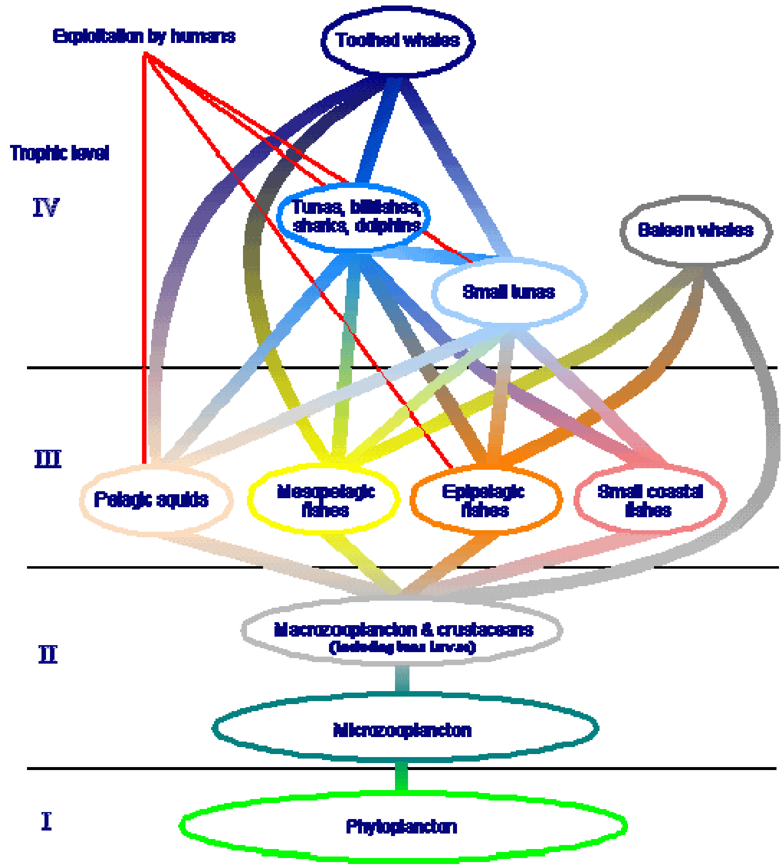

Figure 3: Pelagic Foodweb in the Pacific. (FAO 2003)

Yellowfin live shorter and grow faster than bigeye (Musick 1999), making them less vulnerable to overfishing. For example, after one year, an average yellowfin will weigh 6.6 pounds. It will double its size by year two, and triple in size again by year three. Its growth rate usually slows at this point but despite this, they still double in size again in year four (Joseph et al. 1980).

Food availability and water temperature appear to be key factors determining the age and size at which yellowfin and bigeye mature. Generally these tunas mature faster in the cooler, more productive waters of the ETP, but if they cannot find water warm enough, they will not spawn. Fortunately, this is not usually the case, so tunas mature noticeably earlier in the food-rich east. In these highly productive waters, yellowfin start spawning after two years, when they reach 80-90 centimeters or 20-30 pounds. Yellowfin growing in the less productive western and central Pacific (WCP) mature about half a year later, at 104 centimeters or 48 pounds. Bigeye—perhaps due to their love of cooler water—mature more slowly, reaching maturity between three and four years of age. Yellowfin live an average of six years, while bigeye, surprisingly, can live for eight to fifteen years, even in the face of intense fishing pressure (Itano 2006, Hampton et al. 2005a and 2005b).

Tunas are highly fecund. Adult female tunas produce roughly 100,000 eggs per kilogram (2.2 pounds) of body mass annually; an average-sized mother will produce about 16,000,000 eggs each year. When spawning, they expel between two and four million eggs, day after day. We do not know much about the spawning behavior of either yellowfin or bigeye. However, we do know that yellowfin typically spawn at night, within 10° latitude of the equator, and in waters above 24-25 °C; and that spawning bigeye are most active from April to May, north of the equator, and from February to March, south of the equator (Joseph et al. 1980, Itano 1999, Miyabe 1993).

The slightly buoyant tuna eggs and larvae drift with ocean currents in the upper 100-200 meters, where blowing wind mixes the water. While the band of tropical water stretching across the Pacific is suitable habitat for both yellowfin and bigeye, water columns above seamounts and banks, with summits shallower than 2,000 meters, are particularly important because the water above circulates and lingers. Tuna larvae are planktonic and therefore face predation by most marine animals, including their older siblings (WPRFMC 2005, Joseph et al. 1980).

Not much is known about the habitat preferences of juvenile yellowfin and bigeye, but they most likely tolerate a narrower range of temperature than their parents (WPRFMC 2005). Evidence, from commercial landing records suggests that juveniles may school with the smaller skipjack and albacore tunas in the open ocean and under floating objects (FOBs) (Schaefer and Fuller 2006, Safina 2002, Hall 1998).

We lack information about the spatial structure of their populations despite much research in this area. Either two or three semi-independent, sub-populations of yellowfin live in the Pacific. The debate centers on the central and western population. Tagging, genetic, and larval distribution studies show that there is mixing between the central and the western stocks, but morphometric studies suggest that their short life spans and rapid growth restrict large scale genetic mixing. At both the international and domestic level, we managed yellowfin as two stocks (WPRFMC 2005, Silbert and Hampton 2003, Itano 2000, Hampton et al. 2005a, 71 *FR* 57). So far, no evidence exists to suggest that the Pacific is home to *more than* one population of bigeye and we currently manage them as one stock, although this arrangement is a tenuous one (Hampton et al. 2005b, 69 *FR* 250).

HISTORY OF THE FISHERY AND ITS MANAGEMENT

Below is a timeline describing key developments in the yellowfin and bigeye tuna fisheries and efforts to manage those fish.

Before 1900 – Pelagic fisheries have long been an important resource to the Pacific Islanders and other native peoples living on the islands of the far western Pacific. Ancient Polynesians would traditionally travel to yellowfin *koa* areas—areas known to consistently congregate these fish—where they would lower a weighted handline, or *drop stone*, with a single baited hook into a hoped-for school of tuna (Itano 1999).

1917 – A Japanese immigrant introduced pelagic longlining to the Hawai`ian Islands[1]. In this fishing method, fishermen use this method o target apex pelagic predators like sharks, swordfish, and tunas by laying up to several miles of hooks in the ocean (Crowder and Myers 2001).

1920 – Fishermen with Okinawan ancestry developed the artisanal *ika-shibi* fishery (Glazier 2004). *Ika-shibi* is a night-time handline fishery that uses lights to attract squid to the boat and then target their predators, adult yellowfin and bigeye tunas. Another artisanal method of fishing, *palu-ahi,* developed from the *drop stone* technique, using modern weighting technology (Itano 1999).

[1] Longlining is described in more detail in section 3.2.2.

1920-1940 – The total production of tunas from the Pacific has still not exceeded 300,000 metric tons (mt) per year.

At this time, the Japanese dominated the fishing fleet in the WCP. Japanese longlining was confined to the Northwestern Pacific during the colder months. For the summer season these fishermen converted their vessels to bait-boats (Suzuki 1993). On bait-boats, fishermen used barbless feathered jigs and live bait to catch tunas on a pole and line (Joseph and Greenough 1979).

Japanese purse seiners typically operated in Japanese waters, but some fished in the western equatorial waters during the winter off-season (Suzuki 1993). This method involves setting a net around a school of fish, cinching the bottom of the net shut, and then hauling it, and the encircled fish, aboard[2].

Fishing primarily with bait-boats, the U.S. dominated the eastern Pacific (Wild 1993).

1940's – After the advances in boating technology made during the Second World War, fishing effort expanded and landings rapidly increased Pacific-wide (Joseph and Greenough 1979).

1949 – Anticipating this growing industry, Costa Rica and the U.S. signed an agreement creating the Inter-American Tropical Tuna Commission (IATTC). They open membership to the commission to other countries fishing in the region (IATTC 1949).

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[2] Purse seining is described in more detail in section 3.2.1.

1953 – Panama joined the IATTC (Hedley 2001).

Mid 1950's – The Japanese longline fleet expanded its fishing operations through the central Pacific and into the eastern Pacific. Taiwanese and Koreans began developing their fleets (Suzuki 1993, Wild 1993).

Late 1950's – The U.S. still dominated the ETP fishery, accounting for more than 90% of the effort. Bait boat fishermen began to switch to purse seine gear and also began to expand their fishing seaward (Wild 1993). These fishermen targeted mature yellowfin that associate with dolphins because they were easy to locate. Fishermen cast their net around pods of dolphins with a school of tuna underneath. Trapped and entangled, many of these dolphins drowned during haul-back. Three species of dolphins are involved in this interaction: spotted dolphins (*Stenella attenuata*), spinner dolphins (*S. longirostris*), and common dolphins (*Delphinus delphis*) (Hall 1998, Joseph and Greenough 1979).

1960 – U.S. purse seiners in the ETP recognized that removing dolphins from the net was a waste of time and that dead dolphins could not lead the fleet to more tuna. These fishermen developed the *backdown method* to reduce the numbers of dolphins trapped and killed in their nets. The method works like this: after one-half to two-thirds of the net has been hauled aboard, the captain shifts the vessel into reverse, relieving some tension in the corkline attached to the net at the surface, which causes this part of the net to sink. The net is then, in effect, pulled underneath the dolphins, who immediately race away (Joseph and Greenough 1979).

1963 – Delegates at this meeting of the World Conservation Union drafted the first version of the Convention on the International Trade in Endangered Species (CITES) and began negotiations.

1964 – Mexico joined the IATTC (Hedley 2001).

1966 – IATTC set the first quotas for yellowfin landings in a small area (relative to the Commission's jurisdiction) off the coast of the Americas near the equator. Management decisions required consensus and the commission did not allocate the yellowfin quota. This last feature effectively established a fish-derby, in which rich countries with the largest vessels and most advanced gear—the U.S. fleet—had an advantage (Joseph and Greenough 1979).

Congress passed the Endangered Species Conservation Act[3], a precursor to the Endangered Species Act (ESA). This act directed federal agencies to preserve endangered species habitat on their lands, and authorized the Secretary of the Interior to create a list of endangered domestic fish and wildlife (Thoreau Institute 2006).

1967 – Countries at the United Nations began to negotiate the UNCLOS agreement. Issues they discussed included shipping, marine pollution, and seaward boundaries of national jurisdiction. The U.S. opposed this last proposal until the 80's because of their military's and distant water fishing fleet's interests in the Pacific.

1969 – Congress amended the Endangered Species Conservation Act, allowing the list of endangered species to include international fish and wildlife (Thoreau Institute 2006).

1970 – Japan joined the IATTC (Hedley 2001).

The Secretary of the Interior listed leatherback (*Dermochelys coriacea*) and hawksbill sea turtles (*Eretmochelys imbricate*) as endangered under the Endangered Species Conservation Act (FWS [No Date]).

1971 – U.S. purse seiner, Captain Harold Medina replaced the upper portion of the back panel of his purse seine net with a finer mesh. This finer netting prevented flippers and flukes from snagging as the dolphins escaped during *backdown*. Realizing the value of this modification, other purse seiners followed suit (Joseph and Greenough 1979).

[3] The ESA is described in more detail in section 3.4.2.

1972 – To pacify Americans outraged at the numbers of dolphins dying in the ever-growing purse seine fishery—despite the fishermen's efforts—Congress passed the Marine Mammal Protection Act (MMPA) in 1972. This act charged the federal government with the responsibility to prevent the mortality of dolphins and other marine mammals. The requirements of this law did not apply to purse seiners until 1974.

1973 – Congress unanimously passed a completely re-written version of the Endangered Species Conservation Act entitled the Endangered Species Act. This law extended protection to species that are threatened or endangered in all or part of their range, and to plants and invertebrates (Thoreau Institute 2006).

Negotiations over CITES concluded, and a sufficient number of countries signed it, for it to entered into force in 1975.

Nicaragua and France—representing its territories in the Pacific Islands—join IATTC (Hedley 2001).

1974 – Distant water fleets fishing within 200 miles of the coast of the Americas—primarily off of Ecuador, Mexico, and Costa Rica—caught 77% of the yellowfin harvest from the ETP. The conflict at IATTC over allocation grew as the Latin American countries began to develop their fishing fleets. These, and other nations adjacent to the resource, began to argue that they each deserved more of the quota than they were getting under the current system. To make their point, they started limiting access to the waters within 200 miles from their shorelines (Joseph and Greenough 1979).

Provisions of the MMPA entered into effect, requiring U.S. purse seiners to obtain a permit, which allowed them to kill a small number of dolphins (Joseph and Greenough 1979).

Mid 1970's – The fleets of the Latin American countries grew by 80%, while the distant water fleet, including the U.S., increased by 280%. Even so, the U.S.'s share of the harvest had dropped to 73% due to the expanding Asian fleet (Joseph and Greenough 1979).

1976 – Despite arguing for the rights of U.S. fishermen to fish within 200 miles of other countries at the negotiations of UNCLOS, Congress passed the MSA, prohibiting foreign fishing within a similar zone of our coast. This act gave the authority for managing fisheries in this area to the NMFS, and established the federal council system, including the Western Pacific Regional Fisheries Management Council (16 *USCS* § 1801).

U.S. fishermen started fishing in and around the islands of the south, western, and central Pacific (Coan 1993).

1977 – A Japanese fisherman discovered that tunas often congregated underneath floating logs and the FOB fishery was borne (Suzuki 1993). Fishermen would attach radio beacons to a tangle of knotted net fragments and jettison the whole mess overboard. They would return days later to catch the fish that had found its shade. This technique gave purse seiners in the ETP another viable alternative to setting on dolphins.

1978 – Mexico leaves IATTC because of the dispute about resource allocation (Hedley 2001).

Congress listed loggerhead sea turtles (*Caretta caretta*) as endangered; breeding populations of green (*Chelonia mydas*) and olive ridley sea turtles (*Lepidochelys olivacea*) on Mexico's Pacific coast as endangered; and breeding populations of green sea turtles in Hawai`i as threatened under the ESA (FWS [No Date]). Longlinging is one of the main threats they face (WPRFMC 2005).

1979 – The disagreement within the IATTC became intractable and several other countries withdrew from the convention (Orbach and Maiolo 1989). However, the commission continued to work primarily on reducing bycatch for the next several years.

1980's – The Hawai`ian longline fleet slowly began to grow in the 1980's as albacore trawlers started longlining in the wither months (Cook 2006b, Crowder and Myers 2001).

1982 – Nations signed UNCLOS, officially settling the debate in favor of a 200 mile Exclusive Economic Zone (EEZ) (UN 1982, Hunter et al. 1998, p 682).

1988 – The island nations of the South Pacific and the United States signed the South Pacific Tuna Treaty (SPTT), an agreement that allows American fishing vessels to fish in those nation's EEZs in exchange for American assistance in developing the fisheries of the South Pacific Islands (16 *USCS* § 973).

U.S. longliners discovered swordfish around the Hawai`ian Islands. Longline operations expanded rapidly as a result, attracting new boats from the Gulf of Mexico and the east coast (Cook 2006b).

1990 – Congress amended the MSA to allow the Pacific councils to regulate fisheries for highly migratory species within the U.S. EEZ in cooperation with international management organizations (16 *USCS* § 1812).

Environmentalists succeeded in marketing a "dolphin-safe tuna" label for canned tuna in U.S. markets. In response, the U.S. fleet stopped encircling dolphin-associated yellowfin schools. They now target unassociated schools or set on FOBs (Safina 2002).

Vanuatu joined the IATTC (Hedley 2001).

1991 – The Council banned longlining within 50 nm of the Northwestern Hawai`ian Islands (NWHI) and within a seasonally shifting area around the Main Hawai`ian Islands (Heinemann et al. 2005).

1992 – The Council passed Amendment 6 to the pelagic Fishery Management Plan (FMP) adding albacore (*T. alalunga*), bigeye tuna (*T. obesus*), bluefin tuna (*T. thynnus*), skipjack tuna (*K. pelamis*), and yellowfin tuna (*T. albacares*) to the existing management unit of mahi-mahi, wahoo, billfish and oceanic sharks (WPRFMC 1992).

The members of IATTC signed the La Jolla Agreement on the Conservation of Dolphins.

Venezuela joins IATTC (Hedley 2001).

1995 – The countries at the United Nations signed the Straddling Stocks agreement, establishing an international policy to co-manage shared stocks of marine resources (UN 1995).

1996 – Congress overhauled the MSA with the Sustainable Fisheries Act (SFA). These amendments added three new fisheries management standards to the already existing seven and redefined the control and target rules by which fish stocks are managed.

The Council established a limited access system and limited access permit for the longline fisheries under their jurisdiction (Kalo et al. 2002).

1997 – Ecuador and El Salvador join IATTC (Hedley 2001).

1999 – The members of IATTC signed the Agreement of the International Dolphin Conservation Program to reduce the mortality of dolphins in the purse seine fishery that was actively setting their nets around dolphins associated with schools of yellowfin tuna.

Mexico re-joins the IATTC (Hedley 2001).

2000 – After decades of management in the ETP, the countries fishing in the WCP finally created an international management organization for the region. The Convention for the Conservation and Management of Highly Migratory Fish Stocks in the Western and Central Pacific Ocean established the Western and Central Pacific Fisheries Commission (WCPFC). Like the IATTC, its purpose is to provide a single management authority for the fisheries of highly migratory species and followed the policies set out in the United Nations' Straddling Stocks Agreement (WCPFC 2000).

Guatemala joins the IATTC (Hedley 2001).

The Center for Marine Conservation sued NMFS on the grounds that they were violating the ESA by allowing longlining to continue in spite of high sea turtle and sea bird mortality. The judge found in favor of the Center. His ruling prohibited longliners from fishing for swordfish north of the equator. It also prohibited longlining for tuna during April and May in waters south of the equator (*CMC v. NMFS* 2000).

This closure remained in effect for 4 years, causing $45 million in economic losses and shifting fishing effort away from the U.S. fleet toward less turtle-friendly, poorly regulated, and un-enforced international fisheries (Lewison et al. 2004).

2002 – The Hawai`i Longline Association sued NMFS over the 2000 ruling in the Center for Marine Conservation case on procedural grounds. This case was settled in 2004 and lead to the eventual reopening of the longline fishery.

2003 – Members of the IATTC ended their allocation war and signed the Antigua Convention, which was also based on the 1995 United Nations' Straddling Stocks Agreement. The changes included a shift from consensus to majority-rule. It used the "precautionary" language put forth in the United Nations' agreement, proposed allocating the total catch between members, and provided the legal basis for sanctions to be used against non-complying members (IATTC 2003a). This convention needs five more ratifications and has not entered into force.

The IATTC adopted a resolution calling for the prohibition of tuna purse seineing for the full month of December 2003 and for a 6-week period beginning August 1, 2004 to address overfishing of yellowfin and bigeye. This resolution also called upon members and non-members to take measures necessary to ensure that their total longline catches of bigeye tuna in the ETP during 2004 did not exceed those of 2001. For the U.S., this amounted to 150 mt (IATTC 2003b).

2004 – The IATTC recommendations from the previous year were revised to allow countries to choose between closing the purse seine fishery in the fall or in the winter. The restriction on longline catch remained (IATTC 2004b).

The Hawai'ian longline swordfish fishery re-opened with the stipulation that gear targeting swordfish would be required to only use 18 gauge circle hooks baited with mackerel (69 *FR* 64).

NMFS determined that overfishing was occurring Pacific-wide for bigeye (69 FR 250).

THE FISHERY TODAY

In 2004, fishermen caught 2,582,774 mt of tuna globally. The Pacific is the most productive of the world's oceans, accounting for 78% of tuna landed. Of this, the fisheries in the WCP bring in 51% of tuna, while those in the ETP land the remaining 8%

(Figure 4). Skipjack comprised the bulk of this catch at 80%; yellowfin, 15%; and bigeye, 5% (Figure 5) (Williams and Reid 2005).

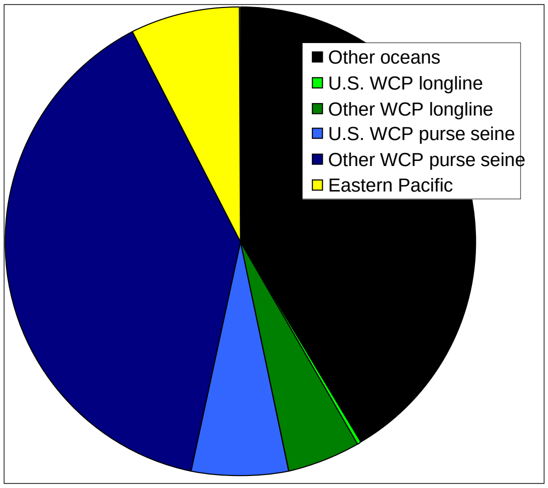

Figure 4: Global Tuna Catch by Gear and Region. (Williams and Reid 2005, IATTC 2005a)

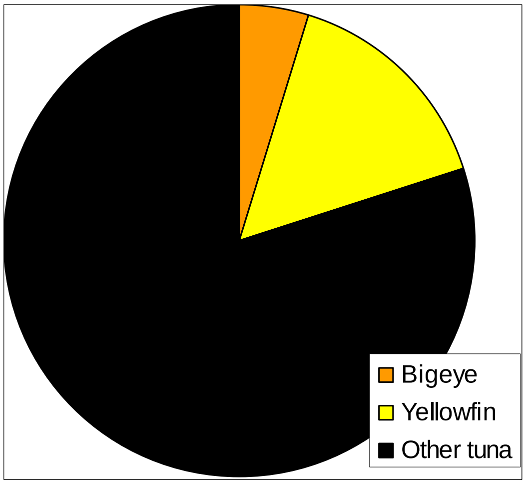

Figure 5: Pacific Tuna Catch by Species. (Williams and Reid 2005, IATTC 2005a)

The total yellowfin catch in the WCP reached 400,000 mt in 1991 and has been hovering around this number ever since (Williams and Reid 2005). The total yellowfin catch is a little lower in the eastern Pacific, ranging between 200,000 and 300,000 mt until 2001 when the catch jumped to 400,000 mt. After 2002, domestic and international regulations limited landings in the eastern tropical Pacific (Hinton 2005).

Since 1997, the total catch of Pacific bigeye has not dropped below 200,000 mt, reaching a high of almost 250,000 mt in 2000 and 2002. Catch is pretty evenly distributed between the eastern and western Pacific (Williams and Reid 2005).

The U.S. catch of tuna in the eastern Pacific was around 2% of the global catch in 2004, while in the WCP it is around 40% (IATTC 2005b, Williams and Reid 2005, WPRFMC 2005).

Purse Seine

Purse seiners fish by encircling an entire school with a large net. The net is then cinched at the bottom, and hauled in from the top (Figure 6). Fishermen make three types of sets. The first involves pods of dolphins with a school of yellowfin swimming below, them and occurs only in the ETP. In the second type, fishermen use bird behavior, surface activity, helicopters, and fish finders to locate free-swimming, or unassociated, schools of tuna. In the third type, fishermen set their nets around FOBs to capture the skipjack tuna underneath. This third method makes use of natural flotsam and jetsam or floating arrays deployed by fishermen called fish aggregating devices (FADs).

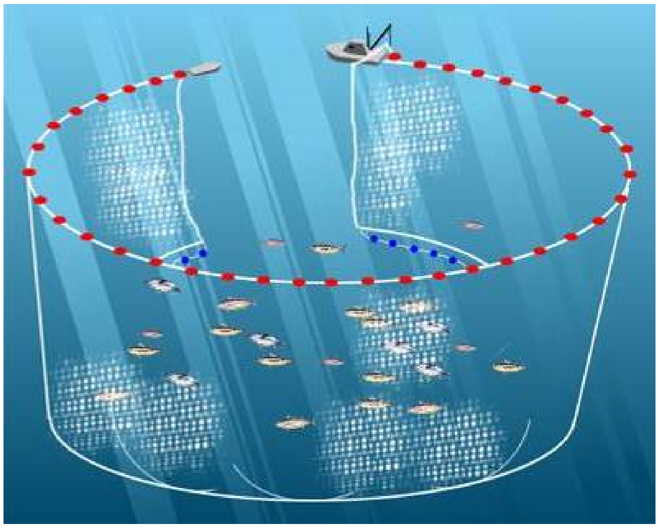

Figure 6: Purse Seine Operation. (www.fao.org)

In addition to schools of skipjack, these FOBs attract a large number of other marine species, including juvenile yellowfin and bigeye, sea turtles, marlins, sharks, other commercially valuable species like wahoo and mahi-mahi, and non-commercial species like triggerfish (Hall 1998). The higher catches of marlins, sharks, triggerfish, and sea turtles are particularly noteworthy because these animals have limited market-value and are therefore wasted. In addition, marlins, sharks, and sea turtles are slow-growing and long-lived apex predators whose populations cannot sustain these losses (Myers and Worm 2005).

The International Fleet

The international purse seine fleet fishes throughout the Pacific. They sell their relatively low-value catch to tuna canneries in Bangkok, Spain, and American Samoa, and to processors in Japan (Williams and Reid 2005).

In the west, the fleet is dominated by large, industrialized vessels fishing far from home. The nations with the largest distant water fleets in the area are the U.S., Japan, Taiwan, Korea, and China. The Philippines, Australia, and New Zealand also have distant water fleets that are much smaller (WPRFMC [no date]).

Purse seiners in the WCP target skipjack, which account for 70-75% of their catch. Yellowfin are the next largest component of their catch at 20-25%. However, in 2004, that 25% of purse seine landings explained 43% of all yellowfin removed from the region. The amount of bigeye caught in this fishery is nominal compared to the other species. Most of the tuna caught in the WCP come from underneath FOBs (Williams and Reid 2005).

Purse seining is even more important in the ETP. In 2002, this gear caught almost 95% of the yellowfin catch (Hinton 2005), and in 2004—after the increased restrictions on both purse seiners and longliners—purse seiners accounted for 98% of all yellowfin caught in the eastern Pacific (IATTC 2005b, IATTC 2003b). More bigeye are caught in with this gear in the ETP than in the WCP (Williams and Reid 2005).

Over half of the purse seine catch in the ETP catch comes from dolphin-sets, roughly 25% comes from unassociated-sets, and about 12% comes from FOB-sets (IATTC 2005).

Domestic

Less than 27 U.S. fishing vessels use purse seines to harvest Pacific tuna. Fourteen vessels fish in the WCP, including the area governed by the SPTT. These vessels operate out of American Samoa, and sell their fish to the canneries in Pago Pago (WPRFMC [No Date], Coan 1993). Five Hawai`i-based purse seiners currently are large enough—greater than 350 mt capacity—to fish in the ETP, but a resolution agreed on at IATTC allots them only one trip per year (IATTC 2002).

Three U.S. vessels operate out of Ecuador and fish in the ETP (Cook 2006). This fleet does not set on dolphins because of the MMPA and the dolphin-safe label. Instead, they target schools of yellowfin and skipjack tuna associated with drifting FADs. In 2004, roughly 25% of sets were on unassociated schools of tuna, another 25% were on schools associated with FOBs, and 50% were on FADs.

In addition to these dedicated tuna fishermen, fishermen in the coastal pelagic purse seine fishery for sardines, mackerel, and squid off the west coast of California will opportunistically switch to targeting bigeye as these tropical tuna become available in the warmer part of the year (PFMC 2003).

Longline

Longline gear consists of miles of mainline, which is set horizontally near the surface. Branch lines (*gangions*) are clipped to it at regular intervals, each with a single baited hook (Figure 7). One set can include thousands of hooks clipped to a single mainline extending across several miles of ocean, buoyed by plastic or glass floats. Fishermen leave the line to soak for about half the day while the crew removes hooked fish as they are caught. The depth of the mainline and the spacing of the gangions change depending on the species the vessel is targeting. For example, fishermen targeting swordfish set the mainline shallower than for bigeye, and they set the gangions closer together than for both bigeye and yellowfin tuna. Fishermen also attach chemical light sticks near the baited hook when targeting swordfish to attract these nocturnal predators (WPRFMC [No Date]).

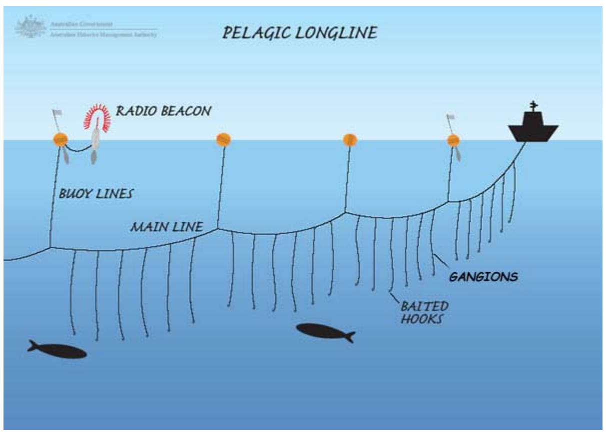

Figure 7: Longline Operation. (Australian Fisheries Management Authority)

Compared to purse seining, the tuna caught on longline gear are higher quality. The fish are large, mature and fat; the capture method does not damage their flesh; and the time between capture and sale is relatively short. For these reasons, fish caught with longline gear are generally sashimi grade and garner a higher price from Japanese and local wholesalers.

Not surprising given the vastness of the ocean, longline fishing effort is inefficient: fishermen consider catch rates of 2% to be good (WPRFMC [No Date]). However, the higher value of the catch makes the lower catching efficiency more than tolerable (Cook 2006a).

Because it is and catches anything that is attracted to the bait, some environmentalists considered it to be one of the more wasteful fisheries. Animals that are unintentionally caught with longline gear include: mahi-mahi, wahoo, barracuda, moonfish, pomfrets, sharks, billfish, seals, dolphins, sea turtles, and sea birds (WPRFMC 2005). The bycaught fish often have a market value and fishermen either sell or consume them. However, marine mammals, sea turtles, and sea birds are all protected by U.S. law and environmentalists continue to push regulators to reduce the numbers of these animals killed with longline gear.

Sea turtles are highly endangered due to indirect takes in fishing gear, as well as egg harvests, habitat destruction, light pollution, and direct harvest. Regardless, several activists are focusing on bycatch in the longline fishery as the solution to the declining turtle populations. Some environmental organizations are calling for a moratorium of longline fishing altogether, while others are pushing for technological gear changes, 100% observer coverage, and enforcement.

International

The longline fleet in the WCP is much smaller than the purse seine fleet. In 2004 it took 11% of all tuna from the region. Longliners target bigeye, not yellowfin, and for this reason accounts for much more of bigeye fishing mortality. Longliners bring in about 65% of all bigeye in the region, while they catch only 17% of all yellowfin (Williams and Reid 2005).

Just as purse seining is more important in the ETP, longlining is less so. In 2002 ETP longliners hooked about 5% of all tuna from that region, and in 2004 (after the quotas were in place) their portion of the fishery, bait-boats, and other gear *combined* fell to less than 2% (IATTC 2005).

Domestic

While a small segment of the domestic tuna fisheries, and a minute segment of the global tuna fisheries, longlining is the largest segment of the Hawai`i-based fishing fleet. Because of the high quality of the fish, they sell 70% of their catch—destined for sushi restaurants—for higher prices to Japanese and local wholesalers (Cook 2005a). In 2004, 77% of the total fishing income in Hawai`i came from longline caught tuna (WPRFMC 2005). Longlining is also the principal type of gear used in American Samoa, accounting for 99% of tuna caught. However, the U.S. pelagic longline fleet comprises *just 3% of all longline vessels fishing in the Pacific Ocean* and accounts for *less than 5% of the total fishing effort* (WPRFMC 1992, Cook 2006b).

Longliners fishing out of Hawai`i and American Samoa operate under a limited access system, which permits vessels to fish in these regions. There are 30 permits in

American Samoa, ten of which are vessels greater than 50.1 ft in length. The smaller vessels average 350 hooks per set, while the larger vessels can put up to five or six times more (WPRFMC 2005). There are 163 permits for the Hawai`ian fleet. Of these, roughly 130 are active (Cook 2006a).

Other

In addition to the large commercial fishing operations in the Pacific, smaller, locally-based, artisanal fleets also fish commercially in the region. In the WCP, domestic fisheries of the Philippines and eastern Indonesia take 37% of yellowfin, using a variety of gears that include ring nets, bargnets, gillnets, handlines, and seine nets (Williams and Reid 2005).

Hawai`ians are increasingly using FADs to fish for tuna in and around the Hawai`ian Islands. In addition to the distant water purse seine FAD fishery, there are two types that target tunas near the Hawai`ian Islands: the offshore FOB fishery and the inshore personal FAD (pFAD) fishery. The Hawai`ian offshore FOB fishery is a handline fishery derived from *ika-shibi* and *palu-ahi* methods. They take advantage of tuna's aggregating behavior, but instead of a separate FOB, they use their vessel.

The State of Hawai`i regulates the pFAD fishery, which operates within 3 miles of the coast. While the State has deployed 55 FADs for public use, unknown numbers of pFADs are secretly and illegally placed in state waters for personal use. The pFAD fishery targets yellowfin, which run inshore in the summer, and bigeye, which run inshore in the winter (Itano 2006).

Artisanal fishing for tuna also occurs in American Samoa, the Commonwealth of the Northern Mariana Islands (CNMI), and Guam. Locals use various methods including vertical longlining, trolling, and handlining. Traditional methods include *ika-shibi*, *palu-ahi*, and *aku boat*. Fishermen in *aku boats* use a pole and line and live bait, like the bait-boats (WPRFMC 2005).

Recreation

Scant information is available on the recreational fishing industry in Hawai`i. According to the Fisheries of the United States 2004 report, more than 407, 000 marine recreational participants took 2.9 million trips and caught a total of about 4.5 million fish in Hawai`i in 2004 (Pritchard 2005). Yellowfin tuna were the third most commonly caught non-bait fish. At a cost of around $800 per trip for a charter boat, recreational fishermen spent more than $2.32 billion in 2004 (Prichard 20054). This figure does not include money spent on gear, bait, and travel (lodging, food, and transportation).

FISHERY MANAGEMENT TODAY

[4] I estimated the cost of a fishing trip based on the price quotes on a few charter boat websites in the area including: http://www.chupu.com/chupa.html, http://www.konabiggamefishing.com/

International Management Organizations

Inter-American Tropical Tuna Commission

The purposes of the IATTC are 1) to study the "abundance, biology, biometry, and ecology of yellowfin and skipjack tuna,"[5] to monitor "the effects of natural factors and human activities on the abundance of the populations of fishes supporting all these fisheries," and 3) to "maintain the populations of yellowfin and skipjack tuna and of other kinds of fish taken by tuna fishing vessels" within the convention area.

The waters under the purview of IATTC are those which are bounded by the coast of the Americas, 50°N latitude, 50°S latitude, and 150°W longitude (Figure 8). This area covers most of the ETP (IATTC 1949).

Figure 8: The IATTC Convention Area. (www.iattc.org)

Fourteen countries are party to the IATTC: Costa Rica, Ecuador, El Salvador, France, Guatemala, Japan, Mexico, Nicaragua, Panama, Peru, Republic of Korea, Spain, United States, Vanuatu, and Venezuela. Six other fishing communities cooperate with

[5] All quotes in this paragraph are taken from Article II(1) of the Convention for the Establishment of an Inter-American Tropical Tuna Commission (IATTC 1949).

the convention as *fishing non-parties* or *cooperating fishing entities*. They are: Canada, China, the European Union, Honduras, Korea, and Chinese Taipei. The secretariat is headquartered in La Jolla, California, and conducts research into two main areas: reducing dolphin mortality in the purse seine fishery and reducing billfish mortality in the longline and FOB fisheries. In addition, the convention allows each country to establish an advisory committee. The IATTC conducts research on yellowfin tuna and runs the Achotines Lab in Panama that studies larval development.

South Pacific Tuna Treaty

The SPTT is an agreement between the U.S. and the nations of the South Pacific, the South Pacific Community. In it the South Pacific Community, grants U.S. fishermen the privilege of fishing in their EEZ (Figure 9) in exchange for assistance in building the capacity of their fleet (16 *USCS* § 973).

Figure 9: EEZs of the South Pacific Community. (www.spc.int)

U.S. fishermen who want to fish in this area must obtain a permit. Primarily U.S. purse seiners are the fishermen who take the advantage of this access and the majority of the U.S. purse seine catch comes from this region (Wild 1993).

Western and Central Pacific Fisheries Commission

The convention establishing the WCPFC convened after the United Nations' Straddling Stocks agreement in 1995 and entered into force in 2004 after thirteen countries ratified it. The nations that have signed the agreement are Australia, Canada, China, the Cook Islands, Micronesia, Fiji, France, Indonesia, Japan, Kiribati, the Marshall Islands, Nauru, New Zealand, Niue, Palau, Papua New Guinea, the Philippines, South Korea, Samoa, the Solomon Islands, Tonga, Tuvalu, Great Britain, the U.S., and Vanuatu (WCPFC 2000).

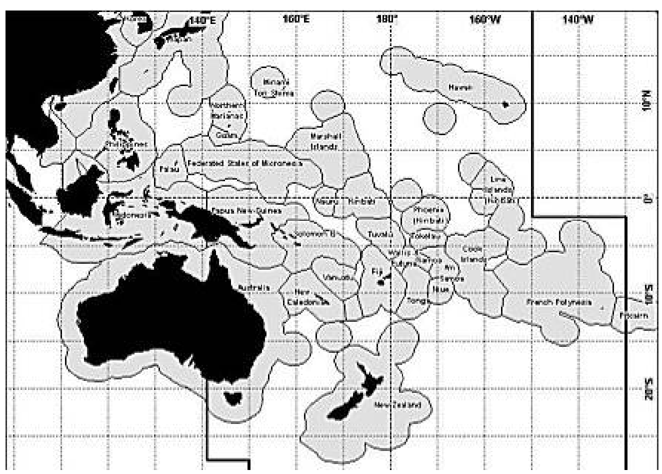

Figure 10: The WCPFC Convention Area. The bold line on the right that travels south along 150°W longitude until it reaches 5°S latitude at which point it heads east to 130°W longitude and then south from there along that line marks the eastern boundary of the Council's jurisdiction. The region between 130°W and 150°W to the left of the boundary is also under the jurisdiction of the IATTC. The shaded areas represent the EEZs of countries in the WCP region. (Oceanic Fisheries Programme, Secretariat of the Pacific Community)

The area under the jurisdiction of the WCPFC includes the waters of the Pacific west of 150°W (Figure 10). The areas under the jurisdiction of the IATTC and the WCPFC overlap slightly near the equator. While not formally stated in the convention itself, members of both organizations have agreed to try to collaborate. Canada, China, France, Japan, Great Britain, USA, and Vanuatu are all parties to both organizations, with representatives on of their negotiating teams who attend both commissions' meetings, so coordination, or at least mutual awareness, is possible.

Similar to the stratification of nations along economic lines that resulted from the allocation disagreement in the IATTC, the island nations in the WCP banned together to form a voting block so that their interests would not be overruled by the powerful Japanese and U.S. negotiating teams. One result of this is that the headquarters for the commission are in Micronesia (Routt 2005).

Domestic Legislation

Tuna Conventions Act

The Tuna Conventions Act (TCA) of 1950, implements the requirements of the IATTC. It designates four commissioners, appointed by the President, to represent the U.S. at the annual IATTC meetings. At least three of the four must reside in a state whose vessels maintain a substantial fishery in the convention area; at least one must not be a State or Federal Government employee; at least one must be from NMFS; and at least one must represent a nongovernmental conservation organization – Congress added this last requirement in the 1992 amendment (16 *USCS* § 952). The Act gives the Secretary of Commerce, in consultation with the commissioners, the authority to appoint a General Advisory Committee and a Scientific Advisory Subcommittee. The Committee attends the international meetings at the request of the IATTC. The Subcommittee advises the Committee and the commissioners on biological and conservation matters, recommends research programs, and reviews data received from the IATTC (16 *USCS* § 953).

This Act authorizes the Secretary of State to agree to bylaws and rules or amendments adopted by the IATTC, circumventing the customary approval of Congress. The Secretary of State, in consultation with the Secretary of Commerce, is also authorized to agree to the management recommendations made by the IATTC and to take appropriate action either directly or through NMFS (16 *USCS* § 955). However, any regulation that is promulgated under this act and at the recommendation of IATTC must occur in conjunction with other nations and can be suspended should foreign fishing operations in the Convention area threaten the achievement of the objectives of the IATTC's recommendations.

This act also requires the Secretary of Commerce to restrict U.S. companies that import "fish in any form of those species", which IATTC manages from nations and their vessels not party to IATTC or not fishing in accordance with it (16 *USCS* § 955).

Eastern Pacific Tuna Licensing Act

This Act establishes the permit system required by the SPTT (16 *USCS* § 972)

Western and Central Pacific

As of this writing, the Government Printing Office has not published the legislation that implements the WCPFC.

Magnuson-Stevens Fisheries Conservation and Management Act

The MSA installed a co-management system between the Fisheries Management Councils and NMFS. The Councils are responsible for writing fisheries management plans (FMPs) that contain conservation and management measures for the fisheries under their control. NMFS is responsible for approving the FMPs and implementing them through regulations. When Congress passed the MSA, they exempted the fisheries for tunas and other highly migratory species from its requirements because international management was already in place.

The general tenor regarding international fishery agreements in the act was that the U.S. would allow only reciprocal access to fisheries within its EEZ and that any agreement reached through negotiations must meet the requirements of the MSA, as in the TCA. It authorizes the Secretary of State in cooperation with the Secretary of Commerce to negotiate at international fishery management organizations (16 *USCS* § 1821(f), 16 *USCS* § 1822).

The purpose, national standards, and "contents of FMP" sections of the MSA, and the SFA after it, provide guidelines and guiding principles for the councils to follow when managing the fisheries under their jurisdiction. Congress' purpose was to conserve and manage the fisheries of the U.S. for the fishermen of the U.S. in perpetuity. As stated earlier, Congress initially intended this law to promote American fleets at the expense of foreign ones. Later, overfishing and the unintended consequences of fishing became more of a problem. The requirements set forth in the SFA and MSA that are important to the discussion about fisheries management in an ecosystem context are described below.

National Standard 1 (16 *USCS* § 1851(1)) requires the councils to manage fish stocks in such a way that they produce optimum yield (OY). The OY means "the amount of fish which will provide the greatest overall benefit to the Nation" and is based on the maximum sustainable yield (MSY) of the fishery, but sets aside some amount required to protect the marine ecosystem. MSY is the maximum amount of fish that can be removed while maintaining a population at the size at which its growth rate is the fastest. It is founded on the principle that there is surplus production that humans can harvest (16 *USCS* § 1802 (28)). National Standard 1 also requires that the councils prevent overfishing. This means that they are to prevent fishing mortality at a level that jeopardizes the capacity of the fishery to produce the MSY on a continuing basis (16 *USCS* § 1802 (29)).

Congress endeavored to reduce the negative impact fishing can have on the marine environment by requiring in National Standard 8 that the unintended capture and killing of non-target marine species should be minimized. However, they included a caveat which allows fishing activities to continue even if this bycatch cannot be minimized (16 *USCS* § 1851).

The amendments found in the SFA recognize that loss of habitat is one of the greatest long-term threats to the health of most commercial and recreational fisheries. Therefore, the SFA requires that the councils define habitat essential to fish stocks (EFH), minimize the impact fishing activities have on it, and promote its conservation and enhancement (16 *USCS* § 1853 (7)). It also requires other federal agencies to consult with the Secretary of Commerce when they intend to engage in activities that may adversely affect EFH (16 *USCS* § 1855 (b)).

In National Standard 3, Congress recognizes that it is important to manage a stock throughout its range (16 *USCS* § 1851).

Congress also qualifies every National Standard in the MSA and the SFA with the requirement that the councils consider the economic and social impact of the management measures taken in the FMPs (16 *USCS* § 1851).

Marine Mammal Protection Act

The principal goal of the MMPA is to maintain stocks of marine mammals "as functioning element[s] in the ecosystem" and "at their optimal sustainable population levels."(16 *USCS* § 1361) To accomplish this, it prohibits the harassing, hunting, capturing, killing of marine mammals and any attempts at the preceding.

The MMPA gives the authority for managing sea otters, walruses, polar bears, and manatees to the Fish and Wildlife Service in the Department of the Interior, and the authority for managing cetaceans and pinnipeds to the Office of Protected Resources within NMFS in the Department of Commerce. For the purposes of holding live animals for research or public display, the Department of Agriculture and the Department of Commerce share the authority; the Department of Commerce takes the lead on tracking captives; and the Department of Agriculture takes the lead on handling and health-and-safety (16 *USCS* § 1361).

Endangered Species Act

The ESA, passed in 1973, is similar but less strict than the MMPA. It protects any endangered or threatened species by prohibiting U.S. citizens from harassing, harming, pursuing, hunting, shooting, wounding, killing, trapping, capturing, or collecting designated animals, or attempting to engage in such conduct (16 *USCS* § 1531). The terms *threatened* and *endangered* are not quantitatively defined in the Act, which makes it difficult to prove that a species needs to be protected.

Any agency that could potentially harm an endangered species has the responsibility and authority to implement the tenets of this law. However, the Fish and Wildlife Service has the authority to monitor all species listed as threatened or endangered, their habitats, and any activities that might affect them. The Office of Protected Resources within NMFS provides oversight and guidance for the NMFS and the FMCs on meeting the requirements of the ESA (NMFS [No Date]).

Domestic Management Organizations

The Western Pacific Regional Fisheries Management Council

The Western Pacific Regional Fisheries Management Council is located in Honolulu, Hawai`i. The Council has authority over the fisheries based in and surrounding the State of Hawai`i; the territories of American Samoa, Guam, and the CNMI; Baker, Howland, Jarvis, and Wake Islands; Johnston, Palmyra, and Midway Atoll; and Kingman Reef from three miles off the shoreline to two hundred miles out to sea. The Council also has jurisdiction over the waters from the shoreline of CNMI to three miles. This amounts to an area of nearly 1.5 million square miles[6] (Figure 11). However, the fishing effort in the U.S. EEZ accounts for less than 10% of the total pressure on the wide-ranging yellowfin population (WPRFMC 1992).

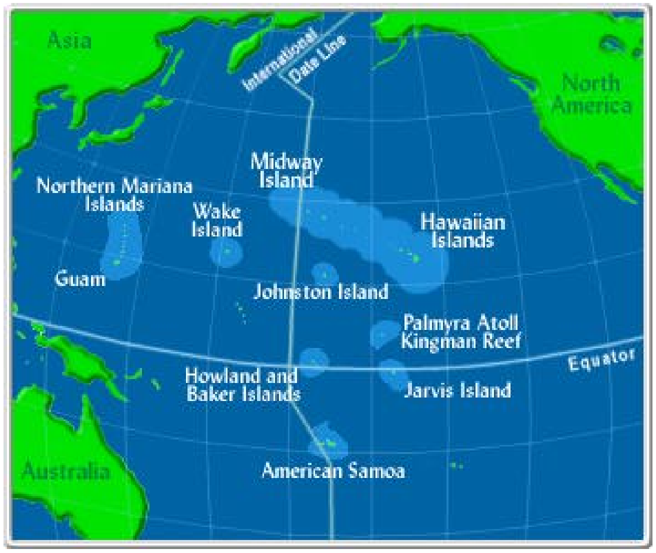

Figure 11: The U.S. Offshore EEZ in the Pacific Ocean.
(www.wpcouncil.org)

The Council's structure is a mixture of bottom-up and top-down management. It has thirteen voting members. The Secretary of Commerce appoints eight, while the Governors of American Samoa, Guam, CNMI, and Hawai`i appoint one member each. The last member is the Regional Administrator of NMFS. Of the Secretary of Commerce appointees, two must be from American Samoa, one from Guam, four from Hawai`i, and one from CNMI. There are also three non-voting members from the Department of State, the U.S. Fish and Wildlife Service, and the U.S. Coast Guard to ensure coordination between these agencies (16 *USCS* § 1851).

[6] http://www.wpcouncil.org/about.htm

The Council has fifteen permanent staffers who provide information to its members, coordinate its activities with other statutes, and perform other functions such as education and outreach[7]. The Council has five active FMPs and has created Plan Teams, Standing Committees, Advisory Panels, and other committees to advise the development and amendment of these plans.

The National Marine Fisheries Service, the Pacific Island Regional Office, and the Pacific Island Fisheries Science Center

The Pacific Island Regional Office (PIRO) of NMFS, located in Honolulu, HI, became a Regional Office in April of 2003 (WPRFMC 2004). It is responsible and accountable for the management of fisheries in the U.S. EEZ in the jurisdiction of the Council. This office approves or disapproves FMPs and passes approved plans along to the NMFS national office for final endorsement.

NMFS has two laboratories that perform scientific and technical support to the Council, which assists the plan writing process: the Pacific Island Fisheries Science Center (PISC) in Honolulu, Hawai'i; and the South West Fisheries Science Center in La Jolla, California.

[7] http://www.wpcouncil.org/contact.htm

Other Management Authorities

The State and Territories with authority in the waters adjacent to the waters under the jurisdiction of the Council include: Hawai`i, American Samoa, and Guam. The CNMI does not have authority over any of its surrounding waters[8].

There are a few other domestic entities with some shared authority in the management of yellowfin tuna. In addition to sitting in on the Council's meetings, the State Department works with the Department of Commerce at international meetings of the IATTC and the WCPFC; the Coast Guard works in conjunction with the Department of Commerce to enforce fishing regulations; the National Ocean Service (also in the Department of Commerce's National Oceanic and Atmospheric Administration) regulates fishing activities within marine protected areas in consultation with NMFS, Fish and Wildlife Service, and the Department of Fish and Game (16 *USCS* § 1431).

The Management Process

The IATTC monitors the status of the eastern yellowfin stock, while PISC monitors the status of the western and central stock (PFMC 2005, IATTC 2004a). These bodies conduct stock assessments for yellowfin and bigeye annually due to the importance of the fishery and the level of concern about their population (Itano 2006). Frequent assessments allow management to adapt to changing environmental conditions.

The Council identifies three types of control rules needed to attain the goal of maintaining OY from the fishery, as established by the MSA. The first is a control rule,

[8] http://www.doi.gov/oia/Islandpages/cnmipage.htm, Follow the *Political Status* link.

which serves to identify overfished stocks and is based on MSY. The second is a target rule based on OY. The target rule effectively sets a harvest goal for the fishery as long as it remains in good health. The third is a rebuilding rule, which sets the harvest goal while the fishery is being rebuilt (WPRFMC 2002).

The control rule establishes an upper limit on the rate of fishing (maximum fishing mortality threshold, MFMT) and a lower limit on the stock size (minimum stock size threshold, MSST). If fishermen remove too many fish in one year (MFMT) or the stock falls below the level that can produce MSY (MSST) than the stock is being overfished (Restrepo et al. 1998). The Council adopted the default MFMT and MSST proposed by Restrepo in the NMFS guidelines for implementing National Standard 1 (WPRFMC 2002).

If the stock's current biomass is less than its biomass at MSY, then MFMT is the ratio of the number of fish removed by fishermen in one year to the number of fish that would have died of natural causes in that year if the population was at MSY. If the stock's current biomass is more than its biomass at MSY, then MFMT is the rate of fishing mortality the population can sustain if its biomass is at MSY[9]. MSST is the remaining stock biomass after the natural mortality in the fisher has been subtracted from the stock's biomass at MSY.

Additionally, the Council has established a warning reference point that warns them when the stock approaches unhealthy levels. This occurs when the stocks biomass reaches the predicted biomass at MSY. The Council has not officially defined EFH for the pelagic fish in their jurisdiction, even though the MSA and SFA requires it (16 *USCS* § 1855).

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[9] See the Council's Pelagic FMP for the formula (WPRFMC 1992).

To be approved by NMFS, any FMP proposed by the Council must not jeopardize endangered species or marine mammals. As mentioned earlier, the MMPA allows purse seiners in the ETP yellowfin fishery to incidentally take marine mammals, but its goal of reducing mortality and serious injury rates remains zero. Therefore, fisheries managers must keep the tenets of this law in mind when they write FMPs and regulations.

Species protected under the ESA that the yellowfin fishery interact with are: Hawai`ian monk seals (*Monachus schauinslandi*), green sea turtles (*Chelonia mydas*), hawksbill turtles (*Eretmochelys imbricate*), Kemp's ridley turtles (*Lepidochelys kempii*), leatherback turtles (*Caretta caretta*), and olive ridley turtles (*L. olivacea*). The white marlin (*Tetrapturus albidus*) might be listed in the near future[10] and also interacts with this fishery.

Regulations

As of this writing, the only pelagic fishery that the Council regulates is the longline fleet. Regulations require all fishing or transshipping activities around or from Hawai`i and American Samoa to have the local limited access permit. The Council also requires longliners fishing or transshipping around Guam, CNMI, or the other remote Pacific Island areas, except for Midway, to have a general longline permit. The requirements for the Hawai`i limited access permit are the most extensive, and in the interest of space, will be the only one I discuss below (WPRFMC 2002).

[10] www.nmfs.noaa.gov

The limited access permit system was established to limit the capacity of the longline fleet and to limit the effort of the shallow-set swordfishery, which has higher bycatch rates of endangered sea turtles (Crowder and Myers 2001). As noted earlier, there are 163 permits in the Hawai`ian Islands, and 30 in American Samoa. Each year, NMFS evenly distributes 2,120 shallow-set certificates among the permit holders who apply. These certificates can then be traded or sold and currently cost $50,000 each (Cook 2006a). Each certificate allows a boat to make one shallow-set north of the Equator.

Vessels must notify PIRO when they are leaving on a shallow-set trip, and *cannot* have any deep-set gear on board. If they do not notify PIRO, they can land only ten swordfish per trip. NMFS requires 100% observer coverage on shallow-set trips and 20-25% observer coverage on deep-set trips. If the shallow-set sector of the longline fleet catches 17 loggerhead turtles or 16 leatherbacks, the Council shuts the fishery down (WPRFMC 2002).

To reduce the numbers of turtles and sea birds harmed or killed in the longline fishery, the Council requires owners and operators of permitted vessels to annually attend a protected species workshop given by NMFS. In addition, the Council approved specific bycatch mitigation gear that they require each vessel to have and to use. The Council also specified handling and resuscitation guidelines for sea turtles and sea birds that each vessel is required to follow (WPRFMC 2002).

To further protect sea turtles, shallow-sets made north of the equator must use eighteen-gauge (18/0) circle hooks with a ten degree offset and mackerel-type bait (Figure 12). Longliners fishing north of 23°N must also follow a series of procedures designed to prevent sea bird bycatch. These requirements include fishing only at night, and discarding offal (used bait and other discarded fish parts) on the side of the boat opposite from the line (WPRFMC 2002).

Figure 12: Different Types of Longline Hooks. Pictured here are a J-Hook, an 18/0 Circle Hook with an offset, and an 18/0 Circle Hook without and offset. (www.nmfs.noaa.gov)

Permit owners must participate in the Vessel Monitoring System (VMS), which allows the vessel's owner, NMFS, and the Coast Guard to track the location of the vessel as it is fishing. Among other things, this allows NMFS and the Coast Guard to monitor and enforce compliance with the various closed areas in the region. NMFS pays for the VMS system and the vessel is responsible for keeping it operational (WPRFMC 2002).

In addition to these measures, the Council has prohibited longlining within fifty nm of the NWHIs and around the MHIs as delineated annually in the Federal Register between February 1 and September 30 in part to protect the Hawai`ian monk seal and to reduce conflicts between fishermen using different gears. (WPRFMC 2005, WPRFMC 2002)

CHALLENGES FACING THE FISHERY

On December 30, 2004, NMFS determined that overfishing for bigeye tuna was occurring in all parts of the Pacific (69 *FR* 250). In March of 2006, NMFS found the same was true of the WCP stock of yellowfin tuna (71 *FR* 57). These findings simply mean that the numbers of fish being removed from the ocean cannot be sustained, and resulted from the mortality of yellowfin and bigeye exceeding the maximum fishing rate that maintains a population size capable of producing the MSY. To prevent overfishing, managers must reduce fishing effort. The biggest obstacle managers face when doing this is the gap between their long-term goals for the fishery and the short-term needs of the fishermen.

Questions about the population structure of both yellowfin and bigeye still remain. Scientists believe that there is one population of bigeye in the Pacific, but two international organizations are managing it. These same two international organizations manage yellowfin even though researchers are unsure whether the WCP population is one or are really two. Both of these potential mismatches could be detrimental for the health of the fishery.

Purse seine fishing off of FOBs has become an increasingly important component of the fishery in both the ETP as fishermen move away from dolphin-sets, and the WCP as fishermen recognize the efficiency of this method. Setting around FODs has dramatically decreased dolphin mortality in the ETP purse seine fishery, but has increased the capture of other marine life throughout the Pacific (Figure 13).

How much is one dolphin worth?

Differential costs of fishing with dolphin sets versus sets on floating objects

1 DOLPHIN =	25,824	small tuna
	382	mahi-mahi
	188	wahoo
	82	yellowtail and other large fish
	27	sharks and rays
	1	billfish
	1,193	triggerfish and other small fish
	0.06	sea turtles

Figure 13: Bycatch from Dolphin-sets *vs.* Bycatch from FOB-sets. (Taken from Safina 2002, data from Hall 1998)

The high numbers of juvenile tuna, sea turtles, marlins, sharks, and triggerfish caught in this fishery are particularly concerning, because these animals either do not have market value and are therefore wasted or they are slow-growing and long-lived apex predators whose populations cannot sustain these losses. The significantly higher catch of juvenile bigeye and yellowfin means that fishermen are removing more and more fish from the population *before* they have a chance to spawn. This is one of the major reasons bigeye populations are declining (68 *FR* 232)

Longlines continue to be a key factor threatening the survival of three of the six species of sea turtles (leatherbacks (*Dermochelys coriacea*), loggerheads (*Caretta caretta*), and greens (*Chelonia mydas*)) and at least one species of sea bird, the short-tailed Albatross (*Phoebastria immutabilis*) (WPRFMC 2005). The shallow-set swordfishery is the only sector of the longline fishery subject to sea turtle regulations because it catches more sea turtles than the deep-set tuna fishery. However, more vessels operate in the tuna fishery and this higher effort might negate their lower sea turtle catch rate

(Crowder and Myers 2001). In addition, sea birds are attracted to the bait as it enters the water so these animals are caught on both deep and shallow-sets.

Another problem facing the fishery is mercury contamination of tuna. While it is unclear whether the source of mercury comes from power plants or natural sources such as hydro-thermal vents in the sea-floor (_____ 2002, Kraepiel et al. 2003) and whether the levels of mercury in tuna will cause human health problems (Myers et al. 1999, Waldman 2005), consumers are afraid that they might be poisoned by eating tuna. This fear is driving U.S. demand for tuna downward (Rodgers 2005).

Finally, an issue rarely considered by fisheries managers, but one that often faces enforcement officials, is the ease with which fishermen move around, in, and out of different fisheries. When the longline fleet reaches their quota in the ETP, then can move to the WCP, which has a larger quota; when a judge closed the Hawai`ian longline fishery in 2001 to protect sea turtles, most of the fleet relocated to California but continued to fish on the same grounds. Now, managers just close down the swordfish fishery, but when they do, these fishermen spend one day in port replacing their line, and floats, and then head back out to start fishing for tuna (Cook 2005a). This adaptability presents managers with challenges to creating effective management plans.

Chapter 4: ECOSYSTEM-BASED MANAGEMENT

DEFINITION AND HISTORY OF THE IDEA

Definitions

Campbell (2004, p 1145) defines ecosystems as *all the organisms and abiotic factors that interact within a particular area*. The Council, hitting the key points, defines it as "the interdependence of species and communities with each other and with their non-living environment."(WCPFMC 2005, p xiii) I agree with Campbell—an ecosystem is the things that interact, not the interaction itself. However, I prefer the Council's way of allowing the species and communities to define the non-living environment over Campbell's apparently arbitrarily defined area. So for the purposes of this paper, an ecosystem will be *all the organisms including humans and the abiotic factors that potentially interact with each other*.

Abiotic factors—such as temperature, salinity, and oxygen levels—distinguish one ecosystem from another. In the terrestrial world, geographical location dictates the properties of these factors. For example, within 23.5° latitude of the equator, the day length and temperature do not change much throughout the year, and it is very wet. The plants and animals that live in this region have adapted to this climate, and as a group, they form a tropical rain forest (Campbell 1996).

The ocean is different. The defining abiotic factors (temperature, salinity, light levels, oxygen, and nutrients) and the floating marine creatures that live there, move with the currents. The only factor that is fixed in space is depth. As a result, defining ecosystems by their geographical location in the ocean is imprecise. Luckily, a water mass will retain its character even as it roams the ocean basin, making the habitat mobile, yet stable. So scientists must use the abiotic characteristics themselves to define habitat for ocean-going species (Castro and Huber 2000, Angel 1993).

The interaction between living and non-living things takes different forms; non-living things interact with living things and living-things interact with other living-things. When we talk about habitat we are talking about the two-way relationship between the non-living environment and a living thing—such as plants or coral. Habitat can also be the non-nutritional relationship between plants and animals. Foodwebs describe the circulation of nutrients between different types of organisms, and trophic pyramids demonstrate the correlation between the size of a species population and its place in the foodweb (Campbell 1996).

Ecology tells us that because living things require specific mixes of abiotic factors, and each plant and animal at each life stage plays a unique role in the ecosystem, disrupting or altering the non-living environment, or removing vast amounts of one creature, will result in a cascade of changes to the entire ecosystem (Campbell 1996).

These predictions appear to be coming true in some areas; cod stocks in New England are failing to recover despite fishing closures. In response to these crises and in accordance with the developing fields of ecology, conservation biology, and environmental science, people began to discuss managing the negative consequences society's expansion and development has on the environment using ecosystem approaches (Grumbine 1994). Based on the literature, I define EBM as *the management of* *human behavior in a way that maintains healthy and productive ecosystems for present and future generations* (Campbell et al. 1996, EPAP 1998, Grumbine 1994, POC 2003, Primack 2000, USCOP 2004, WPRFMC 2005, WPRFMC 2006).

The main themes in EBM are[11]:

- **Ecological Integrity:** managing for sustained ecosystem health and function by protecting species, populations, ecosystems, and the ecological patterns and processes that maintain biodiversity.
- **Ecological Boundaries and Governance:** working across administrative and political boundaries to define ecological boundaries at appropriate scales, even if this requires management agencies to cooperate, or that the organizational structure of government must change.
- **Humans and the Ecosystem:** separating people from nature is impossible; humans are fundamental influences on ecological patterns and processes and are in turn affected by them.

Ahupua`a system

EBM has a long history in the Hawai`ian Islands. Perhaps because of the nature of island life, the native Hawai`ians understood the impact activities on land can have on the ocean. Under the traditional *ahupu`a* system, the land was divided among chiefs on watershed boundaries. Each chief managed the entire watershed *mauka makai* (from the mountain to the sea). In the *ahupua`a*, the *kanaka* (the common Hawai`ian) grew mangos, yams, and bananas near the forested mountain peaks. Theses plots of land were often terraced to prevent erosion and runoff during tropical rainstorms. They grew taro on the low, well-watered land nearer the ocean. Fish ponds along the shore utilized and

[11] The sources I used to develop this are: Grumbine 1994 and Primack 2000.

captured any nutrients running off the land before they entered the sea, keeping the ocean, and the offshore resources unpolluted (Figure 14) (Weaver 1898). In addition to this, Pacific Islanders based decisions about when to fish, on environmental cues such as moon and spawning cycles (WPRFMC 2006).

Figure 14: Drawing of an Ahupua`a. The terraced plots where the *kanaka* grew fruit and yams can be seen at the top of the picture, the taro fields are the squares in the middle, the village is on the shore, and the fish ponds are on the bottom left. (www.saveourseas.org)

Modest Beginnings

The idea of EBM has been around since the early 1930's. In a paper published in 1932 discussing the merits of a national nature sanctuary system, the Ecological Society of America proposed protecting ecosystems and species and noted that for this to be successful, cooperation across agencies would be essential (Grumbine 1994[12]).

In a paper evaluating the National Park System published in 1935, biologists George Wright and Ben Thompson introduced the concept that for resource management to be successful, managers must define management boundaries based on ecological and

[12] Taken from Shelford 1933 as cited in Grumbine 1994.

biological information (Grumbine 1994[13]). And as the Ecological Society of America previously noted, to do this requires cooperation among agencies.

The environmental movement of the 60's and 70's brought EBM out of the shadows and into the political limelight. Mandates to protect the habitat of marine mammals and endangered species were included in the MMPA and the ESA. (16 *USCS* § 1361, 16 *USCS* § 1531). However, managers had not yet applied EBM to the ocean and Congress did not include any ecosystem provisions in the MSA, which passed after both the MMPA and the ESA. One reason for this is that, at the time, protecting ecosystems appears to be more suited for animal-protection laws, such as the MMPA and ESA, and less suited for a resource-extraction law, such as the MSA.

In 1979 Frank and John Craighead seconded Wright and Thompson's conclusions from the 30's after studying the grizzly bears of Yellowstone National Park for twelve years. The Craigheads recognized that the area of grizzly habitat protected by the park was not enough to support the current population of bears (Grumbine 1994[14]).

Meanwhile, the field of ecology was perusing ideas about non-equilibrium ecology. The new theory came into its own in the 80's (Wallington et al. 2005) and was incorporated into the developing idea of EBM in a book-length piece by Jim Agee and Darryll Johnson in 1988 (Grumbine 1994). The melding of EBM with non-equilibrium ecology emphasizes the malleable nature of ecosystems.

By this time, many scientists and managers had begun to support EBM and were finally beginning to experiment with it. Yellowstone almost became the first region to gain an ecosystem management plan in 1990, but political debate stalled the plan.

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[13] Taken from Wright and Thompson 1935 as cited in Grumbine 1994.
[14] Taken from Craighead 1979 as cited in Grumbine 1994.

Instead, a year later, California became the first region to adopt an ecosystem approach to protecting biodiversity (CA 1991). In 1992 the forest service adopted an ecosystem model for managing the resources under their jurisdiction (Grumbine 1994[15]). This might be the first application of EBM to *resource* management.

SFA Amendments

As EBM gained popularity in terrestrial resource management circles, people began thinking about applying it to fisheries management. By 1996, frustrated with the failures of the old system, Congress overhauled the MSA and passed the SFA. While the MSA still remains a resource use act, the SFA increased the conservation undertones. Among other things, the amendments required fisheries managers to address the ecological impacts of fisheries. The impacts Congress was concerned about were bycatch, altered foodwebs, and damaged habitat. The methods of addressing these issues required by the new act were monitoring and reducing bycatch, identifying and setting aside quota for the ecosystem, and designating and considering EFH (Kalo et al. 2002).

The SFA also required NMFS to establish a panel of experts to review the extent to which ecosystem principles were being used in the current management systems and assess how these principles could be applied under the current management regime (16 *USCS* § 1882, Kalo et al. 2002). The panel reported its findings to congress in 1998 (EPAP 1998).

[15] Taken from USDA Forest Service 1992 as cited in Grumbine 1994.

The Pew Commission on Ocean Policy and the U.S. Commission on Ocean Policy

A few years later, two independent commissions established to review U.S. ocean policy reported their findings. Both the Pew Oceans Commission (POC 2003) and the U.S. Commission on Ocean Policy (USCOP 2004) recommend moving toward EBM of our oceans. Their recommendations included fisheries management but encompassed the management of other ocean-based activities as well.

These reports—as the Ecological Society of America, Wright and Thompson, Craighead and Craighead, and Agee and Johnson before them—call for the complete restructuring of our ocean governance system. They urge for what I will call *pure* EBM. This *pure* approach asks managers to regulate fishing to restore the health of the ecosystem. “However, when fishing is examined in an ecosystem context the rational for harvesting surplus production is unclear”(EPAP 1998, p 9) because “Very little, if any of this biomass, is truly ‘surplus’ to an ecosystem.”(EPAP 1998, p 9) The question then becomes “What level of fishing… can a ‘healthy’ ecosystem support?”(EPAP 1998, p 18) And the answer is roughly, the amount and pattern of fishing that *does not* cause irreversible changes to the ecosystem. This practice will undoubtedly result in reductions in fishing effort, but those reductions will be more pronounced for keystone species—species critical to the ecosystem.

The *pure* approach differs from the more anthropocentric approach, which employs ecosystem principles as a method of restoring the health of fisheries. The U.S. Commission on Ocean Policy report embeds an anthropocentric approach to fisheries management within their *pure* approach to ocean management (USCOP 2004). Both of these approaches differ from fisheries management today, even after the SFA amendments.

Given the current legislated authority and ocean governance structure, this second, fisheries-centric approach is more feasible. Although a more modest step, it can still address problems like the collapse of the Monterey sardine fishery, which was caused by a combination of environmental variability and high fishing pressure, more readily than traditional management (Johnston and Sutinen 1996).

APPLICATION OF ECOSYSTEM-BASED MANAGEMENT TO THE YELLOWFIN AND BIGEYE FISHERY

EBM is still a new concept and managers are still struggling to understand what it means. Suggestions for how to apply EBM to fisheries range from an updated version of "the best science... available"(16 *USCS* § 1851(2)) principle to the *pure* EBM approach to ocean management, discussed above (EPAP 1998, USCOP 2004, POC 2003, Essington et al. 2005, Hall 1998, WPRFMC 2006). EBM can be applied to the following areas of fisheries management: management unit definitions, harvest goals, habitat, bycatch, and fishing communities. The benefits of EBM include: managing species by area, maintaining OY, protecting habitat, minimizing bycatch, and including fishing communities in management.

Because pelagic fisheries are so different from inshore fisheries, some have argued that the benefits gained from EBM will not be realized in pelagic fisheries and therefore using ecosystem principles when managing these fisheries would not be worth the expense. While this argument is true for *some* of the benefits of EBM—managing species by area and protecting habitat—EBM bequeaths other benefits to tuna fisheries. Using ecosystem approaches will allow pelagic fisheries managers to addresses the major issues in the fishery, discussed earlier: overfishing, stock boundaries, bycatch, mercury contamination, and fishermen flexibility. It can also be used to address other potential challenges in the fishery, such as prey availability and environmental availability. Below, I discuss these challenges and how they relate to EBM.

Ecological Integrity

In order to protect the ecological integrity of a system, the human activities that affect it need to be cataloged. Non-fishing activities can impact the marine ecosystem. Coastal development destroys coastal habitat and dumps polluted water into near-shore areas. Oil and gas development raises the risk of oil spills and increases the level of marine noise. Fishing activities can also damage habitat either directly, as bottom trawling does, or indirectly, as abandoned and drifting fishing gear snags on coral reefs. While important considerations in other fisheries, none of these matter much in the bigeye and yellowfin fisheries.

However, fishing can also directly alter marine foodwebs by removing fish at multiple levels of the food-chain, by unintentionally removing other species, and by selectively targeting one group of fish over another (Essington et al. 2005, Hall 1998, Worm et al. 2005).

Longliners remove large quantities of higher order predators: adult tunas, billfishes, sharks (Worm et al. 2005). These fish hunt higher up in the food-chain, are productive breeders, and are nearer to the end of their lives. Their removal will relieve pressure on squids. Their larger numbers will then apply more pressure on their food sources—small mesopelagic and epipelagic fishes. These populations will have fewer numbers with which to apply pressure on their source of nutrition—zooplankton and phytoplankton. The entire system reconfigures itself.

Tuna purse-seiners remove even larger quantities of skipjack, and small yellowfin and juvenile bigeye. These fish hunt lower in the food-chain, so while the effect downward is similar, the fish that hunt juvenile tuna will go hungry.

Squid, one of the main forage species for yellowfin and bigeye are caught Pacific-wide (SAUP 2005, Hinke et al. 2004). Declines in the populations of these species could mean less food available to support tuna populations. However, fisheries managers do not monitor the squid fishery, or the squid population.

Unfortunately, no fishing method is so precise as to capture only the fish we target. In addition to the tunas and swordfish that longliners target, longlines hook sea birds, sea turtles, and marine mammals, as well as other marketable fish, such as sharks, billfish, wahoo, mahi-mahi, and opah. The diets of the most frequently caught species, sharks and billfish, are much more varied than tuna's, so the impact their removal has on the entire system is felt much more widely (Hinke et al. 2004).

Finally, fishing pressure can exasperate natural fluctuations in the marine environment, which cause fluctuations in predator and prey populations. The collapse of fish populations due to a combination of fishing pressure and natural environmental variability is well documented for wetfish, such as sardines and anchovettas (Johnston and Sutinen 1996). Scientists know that landings of bigeye and ETP yellowfin also fluctuate with the El Niño/La Niña cycles in the ETP (Miyabe 1993, Wild 1993), responding, perhaps, to changes in prey population sizes. Scientists have not observed the same fluctuation in the WCP (Suzuki 1993), but this might be an artifact of the data[16].

Ecological Boundaries and Governance

As stated earlier, managing a resource throughout its range is a prerequisite of EBM and is already included as National Standard 3 in the MSA. Why is this important?

Suppose, for a moment, that there is one population of tuna in the Pacific, not two, as we currently believe. And suppose that Pacific-wide, the population is unhealthfully small. Now, let's assume that the population is being managed as two stocks. The recovery of the entire population would be dependent on both rates of fishing: those allowed in the east and those in the west. Any effort to rebuild the stock by cutting back on fishing in one region would be, at best, diluted by unreduced fishing pressure in the other, and, at worst, nullified by increased fishing pressure in the other.

Now suppose that instead of one population there are really two. And this time the population is being managed as one. And suppose that fishing pressure in the west is greater than fishing pressure in the east, and as a result, the population in the west is overfished, while the population in the east is not. Because managers believe there is only one population in this case, the stock assessments would not reveal that the western population is unhealthfully low, so managers would not recommend measures to rebuild that stock. Fishing would continue at the same rate, and the population in the west would continue to decline.

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[16] Suzuki (1993) relied on bigeye landings in the Japanese longline fleet for his comparison between years, the longline fleet in the WCP represents 10-12% (Williams and Reid 2005) so it is possible that the tuna's response to environmental variations will not be visible in this fishery.

The above situations demonstrate the importance of managing along ecological boundaries. These boundaries need to be understood and governance systems need to adhere to them. Unfortunately, questions about the population structure of both yellowfin and bigeye still remain. The problem with bigeye follows the first example, where we believe that there is one population but that population is being managed as two. For yellowfin, the problem could be that of the second example, where the western and central populations are being managed as one.

Placing Humans in the System

Humans are a part of the marine ecosystem, in that fishermen act as predators on multiple species (Hinke et al. 2004). Regulations managing their behavior are bound to have impacts on these communities. However, a common complaint with traditional fisheries management is that, while managers are required to "minimize adverse economic impacts on such [fishing] communities"(16 *USCS* § 1851(8)) they do not consider fishermen to be part of the ecosystem when promulgating regulations (USCOP 2004, Grumbine 1994). Examples of this include: the increase in the amount of bycatch in the ETP due to that purse seine fleet's switch from dolphin-sets to FOB-sets, and the increase in the number of deep-sets made by the longline fleet after sea turtle bycatch closes the shallow-set component of the longline fleet.

EBM gives managers tools to place fishermen in the system and more accurately examine the effects that proposed management measures are likely to have on the ecosystem *and* the fishing community, the ecosystem's and fishing community's responses, and the resulting effect each of these response will have on the fishing community and the ecosystem respectively.

Finally, some environmentalists hope that the fear of mercury poisoning in tuna, which is causing a decline in demand and the subsequent decline in dock-side value, will lead to decreasing fishing effort and will help save the sea turtles[17]. This is not a foregone conclusion, however, and the decline in price might actually lead to increased effort as fishermen attempt to pay their bills by catching more fish.

Even if the levels of mercury in tuna are not harmful and the source of that mercury is not anthropogenic, the perception remains. Addressing the human sources of atmospheric pollution might adequately mollify consumer concern. Because this is one instance where human activities external to fishing are affecting a fishery, it is a prime candidate for approaching with EBM.

Other Issues

One of the attractions of a new management system is in the design. Creating a new system presents an opportunity to correct prior, perceived-to-be inept management processes. EBM gives us the opportunity to modernize our fisheries management system. Some of these other, new ideas in fisheries management that can be conveniently wrapped into EBM include: community-based management, adaptive management, and economic approaches to management.

Community-based management recognizes that different communities living at different times value resources and the environment differently. To address this,

[17] www.seaturtles.org

management should be constructed in a way that allows for diverse opinions. For this reason, fishermen are an essential component of the management team. In managing yellowfin and bigeye, the Council must address this diversity, exemplified by the variety of cultures and communities under their jurisdiction—ranging from European to Polynesian and from the U.S. to Japan—and the multiple uses of this resource—from recreational to subsistence.

Adaptive management acknowledges the complexity of trying to manage human behavior in a changing environment and the uncertainty it breeds, and concludes that effective management needs to be adaptable to be effective. Because EBM accepts and attempts to respond to environmental variability, an adaptive system of management will be essential. But this runs two serious risks: management objectives might be so flexible that there would effectively be none, and constant adjustments to ever changing rules about where and when fishing can occur will cost fishermen in time, money, and energy as they attempt to alter their behavior. In addition, this unstable management environment will prevent them from being able to plan ahead and make effective investments.

The outcome of the Cold War demonstrated that a free-market system was much better at providing for the wants and needs of the people, than a command-economy. Applying economic approaches to these problems will be useful in any EBM endeavor, if for no other reason than to decrease its data requirements and increase its flexibility and adaptability.

Chapter 5: THE COUNCIL AND ECOSYSTEM-BASED MANAGEMENT

ECOSYSTEM-BASED MANAGEMENT CURRENTLY: THEIR FIRST STEP

Recognizing the potential of EBM and anticipating federal action on the subject, the Council has started to write Fishery Ecosystem Plans (FEPs) for all the fisheries under their jurisdiction, including yellowfin and bigeye tuna. To do this they have shuffled the fisheries in the existing management plans from species complexes, such as *crustaceans* and *bottomfish*, to areas such as the Mariana Archipelago. The Mariana Archipelago FEP vertically integrates *crustaceans* and *bottomfish* in one plan. While reorganizing the managed species, the Council restructured their advisory panels in the same way, to mimic the FEPs (WPRFMC 2005). Because of the nature of pelagic fisheries, the pelagics plan is the only plan that cannot be restructured by area.

The Council based their FEP largely on the recommendations of the Ecosystem Principles Advisory Panel (WPRFMC 2005), defining the fisheries that are managed by the plan, the ecosystem that they belong to, and the foodweb interactions that take place; and identifying fishing and non-fishing related impacts on the fishery *via* impacts on the ecosystem (EPAP 1998).

The Council intends the draft FEP to be the first step in an eventual switch to EBM (WPRFMC 2005). The council states that the draft FEP "establishes the framework"(WPRFMC 2005, p iii) only, and that does not "establish any new fishery management regulations"(WPRFMC 2005, p iii) at this time.

While the foremost goal in traditional fisheries management is to prevent overfishing and achieve OY (16 *USCS* § 1851), the aim with EBM will be to "maintain ecosystem health and sustainability."(EPAP 1998, p 1) The Council's principal objective is to maintain the ecosystem, which pelagic fisheries are a part of, in a healthy and productive state (WPRFMC 2005). As in the existing FMP, the Council still manages yellowfin as two stocks, and the targets for management under the current system are still based on the ideas of MSY and OY.

The council does take a small step toward EBM in these fisheries by adding the available information about the pelagic ecosystem into the plan. They designate EFH and "habitat of particular concern" for yellowfin eggs and larvae as the epipelagic zone down to a depth of 200m in all waters under its jurisdiction, and for juveniles and adults this habitat is designated as the water column down to a depth of 1,000m. They based this definition on the assumption that because squids and mesopelagic fishes aggregate in these places, tunas will too (WPRFMC 2005).

Hopefully with an eye toward future ecosystem-based regulations and management measures, the Council described marine food chains, trophic levels, and foodwebs. They did not place fishermen in the marine foodweb, but in a different section, they provided the description of the fishery from the previous plan (WPRFMC 2005).

To a similar end, the Council included a much more detailed description of affected protected species (five species of sea turtles, five species of marine mammals, and three species of sea birds) than the original FMP, as well as these species' habitat preferences, known behaviors, and the top explanations for their waning populations (WPRFMC 2005, 1986, 1992, 1994, and 2002).

INTERNATIONAL CHALLENGES

International law is a *tenuous* agreement among nations. Short of war, there is no method for forcing a nation to participate, and to go to war over an agreement on fishing, while not unheard of, is probably unsound foreign policy. Therefore, trust, bargaining, and skillful debate are the stuff international law is made of.

However, there are a few customs and general principles that keep the whole thing from devolving into complete anarchy. After a treaty is signed, each nation must ratify the document. In a democratic nation like the U.S., this requires a positive vote in the Senate and the signature of the President.

Each treaty specifies how many ratifications are required before the agreement will become effective. Once the required number has been reached and the document *enters into force*, all signatories—not just those that have ratified—are expected to follow it unless they officially object.

Nations party to an agreement are allowed to impose trade sanctions on incompliant nations if the violation is against an established principle. However, these sanctions are only indisputable under the General Agreement on Tariffs and Trade at the World Trade Organization if they are made against a product—not the production or disposal of a product. There are compelling arguments supporting the use of retaliatory trade sanctions to enforce compliance with international environmental agreements, but they have yet to be tested (Hunter et al. 1998).

All of these international treaties and their resulting management organizations manage their fisheries in different ways with different procedures. To effectively manage migratory species, such as yellowfin and bigeye, the management system needs to be more coordinated. For example, when U.S. citizens demand that the U.S. fleet catch fewer turtles and managers respond by shutting down the U.S. fishery after it catches a certain number of turtles—as they did in 2001—the proportion of the tuna caught by U.S. vessels declines. When international managers set rebuilding quotas based on historical landings data—as they did in 2003, using 2001 landings of bigeye—then the conservation-induced smaller U.S. share of the fishery becomes permanent. This does not just harm U.S. fishermen; it also harms sea turtles, as fishing effort shifts to less conservation-oriented fleets.

Furthermore, recall that the U.S. segment of the international fishery is at most, less that 10%. This means that U.S. measures to reduce overfishing or eliminate bycatch are less meaningful without international fishing fleets doing the same thing. The Council has an obligation to push for international measures that are consistent with U.S. law (16 *USCS* § 1822). To this end, a working model of EBM might be an easier sell than an un-solidified idea.

Chapter 6: RECOMMENDATIONS

Below I suggest issues that EBM of yellowfin and bigeye should address, and how it might be applied.

Ecological Integrity

The basic assumption of EBM is that *protecting ecosystems is essential for protecting species*. If managers and fishermen accept this assumption, then they can bridge the gap between short and long-term economic goals, and can set more precautionary harvest goals. Recognizing the increased importance of long-term health of the fishery under an EBM regime, managers should:

- Instate a harvest goal based on OY.
- Identify commercial species that play a keystone role in the pelagic ecosystem, such as swordfish, and give them a higher priority for conservation.
- Monitor the mortality and population sizes of important prey species, such as squid, to ensure the long-term health of the tuna's food base. This might also benefit protected species that also rely on these species for food.

Relating ecosystem health to population health increases the incentives for fishermen to decrease the amount of non-target species they remove from the ocean. The purse seine fishery catches more juvenile bigeye and smaller yellowfin than the longline fishery (Hampton et al. 2005a). The FOB fishery catches juvenile yellowfin while other methods obtain adults. By applying ecosystem principles, management should:

- Target those fisheries that land juveniles as a priority for regulations.
- Reduce the incidental mortality of non-discriminating apex predators like sharks and billfish that consume a wide variety of marine species and therefore have broader ecosystem impacts.

Scientists have observed that yellowfin and bigeye populations respond to El Niño cycles and climate change. However, the interaction between fishing pressure and natural cycles in their population size due to environmental variability is poorly understood. If it were known, it might be a useful guide for setting and adjusting harvest quotas to forestall overexploiting a population in an environmentally bad year. Therefore managers should

- Commission more research in this area. This is also an area where managers should apply *adaptive management*.

Ecological Boundaries and Governance

Aligning management jurisdictions with the ecological boundaries of the resource is an important part of EBM. To do this and determine the appropriate level of cooperation between national and international management organizations, managers should:

- Fund more research into the population structure of bigeye and yellowfin in the Pacific.

Humans and the Ecosystem

Understanding the place humans have in the pelagic ecosystem is another fundamental principle of EBM. Ecologists use Ecopath and Ecosim to model the interactions within an ecosystem and how changes in one sector with alter the rest of the system. Hinke et al. (2004) have expanded the use of these modeling programs to include fishing as predators in marine systems. Meanwhile, social scientists have developed similar programs that model fishermen response to weather, and regulation (Johnson et al. 2001). Managers should:

- Include a map of all the agencies that have responsibility and authority over activities impacting the pelagic ecosystem in the management plan. This map should depict what part of the system is affected by what activity. Since there are few activities other than fishing-related ones, this map is expected to be small.
- Link the Ecopath and Ecosim models to social network models to predict the fluid behavior of fishermen. Managers should use the resulting meta-model to analyze the potential outcomes of various management measures.

Concerns about mercury contamination in tuna effect consumer behavior and are driving markets for canned and fresh tuna. Since the perceived source of this contamination is non-fishery related, since consumer perception of the fishery affects demand, and since fishermen affected by decreasing demand might alter their behavior to mitigate these effects, such as increasing fishing effort to pay their bills, managers should:

- Publicly comment on coal burning power plant re-licensing proposals and other federal agency activities perceived to contribute to mercury levels in tuna.

Chapter 7: CONCLUSION

EBM is relatively new and therefore controversial topic in fisheries management. Drawbacks to this system include the incredible amount of data it might require, the lack of any kind of definition for a healthy ecosystem, and the difficulty of identifying measurable indicators of ecosystem health once it is defined (EPAP 1998, WPRFMC 2006).

However, in light of the SFA; the reports of the Ecosystem Principles Advisory Panel, the Pew Ocean Commission, and the U.S. Commission on Ocean Policy; and the Council's draft FEPs, fisheries managers are clearly moving toward using EBM (Kalo et al. 2002, EPAP 1998, POC 2003, USCOP 2004, WPRFMC 2005).

Using ecosystem approaches to management offers several benefits to fisheries managers, some of which would not be realized when managing pelagic fisheries, such as yellowfin and bigeye tuna. However a large number of issues currently facing this fishery can be addressed with EBM. These include: the overfishing of stocks, the definition of stock boundaries, the unintentional capture of non-target species, the contamination of tuna with mercury, and the flexibility of fishermen in response to regulation. Because of these benefits, EBM is worth pursuing in pelagic fisheries in the future, despite the challenges mangers will face when implementing it.

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