NOAA Technical Memorandum NMFS-PIFSC-30

January 2012

Spillover Effects of Environmental Regulation for Sea Turtle Protection: The Case of the Hawaii Shallow-set Longline Fishery

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Chan, H. L., and M. Pan.
2012. Spillover effects of environmental regulation for sea turtle protection: the case of the Hawaii shallow-set longline fishery. U.S. Dep. Commer., NOAA Tech. Memo., NOAA-TM-NMFS-PIFSC-30, 38 p. + Appendices.

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Spillover Effects of Environmental Regulation for Sea Turtle Protection: The Case of the Hawaii Shallow-set Longline Fishery

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EXECUTIVE SUMMARY

The study examines whether, and to what extent, U.S. fishing limits instituted to protect endangered species can cause changes in foreign fleet activity that ultimately have adverse effects on the very species intended for protection. To protect sea turtles, federal fishery managers established a regulatory regime that resulted in a temporary closure of the Hawaii swordfish (shallow-set longline) fishery during 2001-2004 and the establishment of annual fishing effort limits and annual sea turtles interaction caps when the fishery was reopened. The globalized (pelagic) resources of swordfish and sea turtles allow for "spillover effects": when one fishery reduces activity, other fisheries may increase activity to satisfy the unmet demand, and vice versa. This study provides a quantified estimate of the possible spillover effects resulting from the aforementioned regulations based on 2 perspectives. First, this study estimates the spillover effect resulting from market replacement as U.S. swordfish consumption shifts from domestic production to foreign imports as a result of the domestic fishery closure. Because U.S. swordfish imports are harvested in different oceans by different countries, the spillover effects are estimated on a global scale (the sum across all oceans). Subsequently, this study estimates the spillover effects resulting from the displacement of production by the competitors in the specific ocean area where the Hawaii shallow-set longline fishery for swordfish operates. The study found strong spillover (market transfer) effects from regulation of the Hawaii shallow-set longline fishery for swordfish, resulting in more sea turtle bycatch as Hawaii swordfish production declined.

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INTRODUCTION

This report presents a study on the spillover effects, also termed “transfer effects”, resulting from proposed regulatory changes for the Hawaii longline fishery specifically for swordfish. In the economics literature, spillover effects are externalities of economic activities that affect other entities; they may be positive, i.e., generating spillover benefits or negative, i.e., generating costs. This study evaluates whether, and to what extent, spillover effects may occur when regulatory changes decrease or increase the allowable fishing activities in the Hawaii shallow-set longline fishery for swordfish.

Several studies, including Sarmiento (2006), Rausser et al. (2009), and Bartram et al. (2010), have investigated the spillover effects of the closure of the Hawaii shallow-set longline swordfish fishery closure over the 2001-2004[1] period. These studies concluded that Hawaii shallow-set longline fishery regulations are likely to cause more turtle interactions on a global scale. However, Sarmiento (2006) and Bartram et al. (2010) did not quantify the spillover effects in terms of the net change in number of sea turtle interactions caused by regulation of this fishery. Rausser et al. (2009) quantified the spillover effects in terms of the net change in total number of sea turtle interactions caused by regulation in this fishery, but they assumed the same bycatch rate (the average bycatch rate from 17 studies) across all the non-U.S. fisheries from which the United States imported swordfish to calculate the total number of sea turtle interactions. In addition, while spillover effects can be generated by both market flows (imports and exports) and production displacements, Rausser et al. (2009) only examined the spillover effects resulting from the transferred swordfish imports associated with sea turtle protection regulations.

This study estimates the possible spillover effects from two aspects: 1) the spillover effect associated with market replacement as U.S. swordfish consumption shifts from domestic production to foreign imports; and 2) the spillover effects in the specific ocean area where the Hawaii shallow-set longline swordfish fishery shares the same fish stock with foreign fleets and interacts with the same sea turtle stock as the foreign fleets. Also, this study identifies the most current studies on sea turtle bycatch rates and uses the catch rate reported from each individual fleet/country whenever they are available.

This report is presented as follows:

1) Provides background information on: the trends in world swordfish production, both worldwide and by ocean; the trends in U.S. swordfish production and consumption; and the contribution of Hawaii swordfish production to worldwide and U.S. production;

2) Discusses the necessary conditions that allow spillover effects to occur, presents a literature review on this topic, and defines the method used in the study to measure

[1] We classify 2001-2004 as the closure period even though the Hawaii swordfish reopened in April 2004. The reopening had little effect initially because the swordfish season was almost over by the time the fishery formally opened and only minimal fishing activity occurred in the rest of 2004.

3) the spillover effects associated with the Hawaii shallow-set longline swordfish fishery;

4) Estimates the possible spillover effects in terms of sea turtle bycatch resulting from market replacement when the Hawaii shallow-set longline swordfish fishery operates under various regulatory regimes, including past, current, and proposed regimes;

5) Estimates the spillover effects associated with projected production displacements in the North and central Pacific when the Hawaii shallow-set longline swordfish fishery operates under various regulatory regimes (including past, current, and proposed regimes); and

6) Presents summary discussion and conclusions.

BACKGROUND AND DATA

Global Production Trends

In 1991, global swordfish landings totaled 69,211 metric tons (mt). The Atlantic Ocean represented 54% of the world's landings, whereas the Pacific Ocean represented 39% and the Indian Ocean represented 7%. In 2009, total world landings increased by 52% compared to 1991, reaching 105,061 mt. However, over time, landings by ocean have changed dramatically.

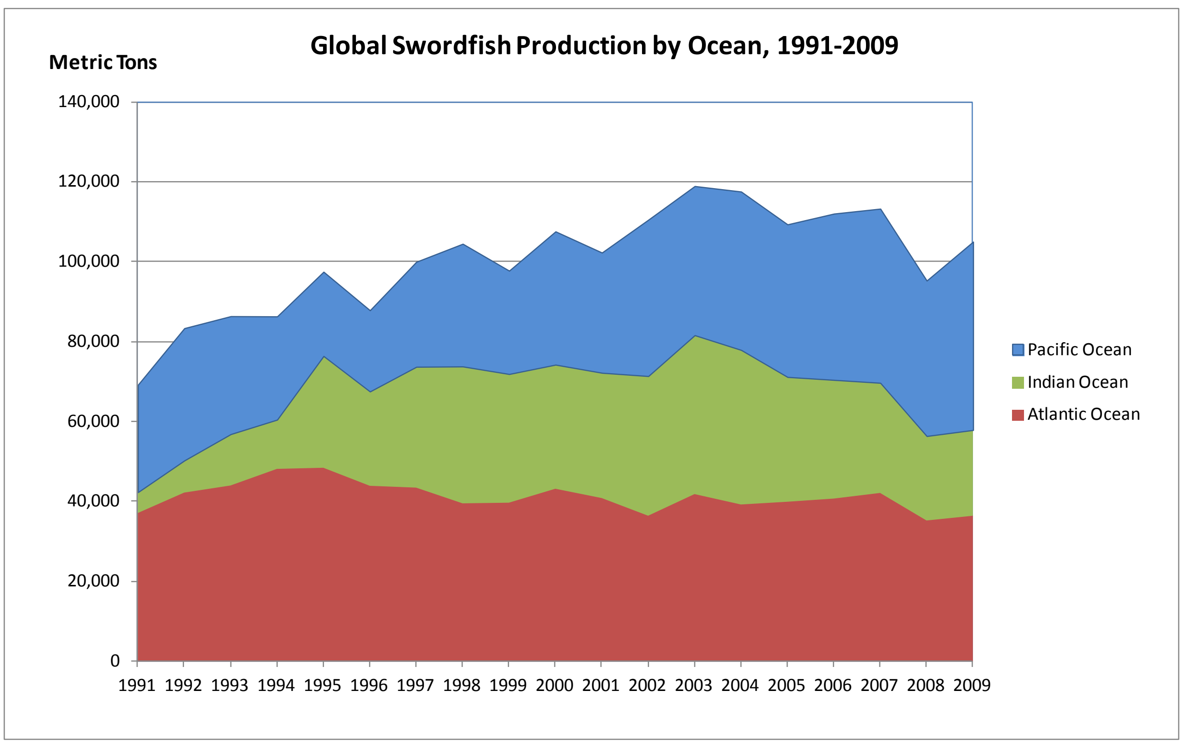

Figure 1.--Global Swordfish Production by Ocean, 1991-2009. Source: FAO Fisheries Global Information System.
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By 2004, landings by the three oceans were almost equally distributed, as swordfish landings from both Indian and Pacific Oceans had increased since 1991. Since 2004, the Indian Ocean's landings have been dropping significantly. According to the Indian Ocean Tuna Commission, overfishing of swordfish in the Indian Ocean is likely occurring in recent years as the catch level is above the estimated maximum sustainable yield and possibly not sustainable (Indian Ocean Tuna Commission, 2006). The Atlantic Ocean's landings are also showing a slightly decreasing trend in recent years whereas the Pacific Ocean's landings are trending upward. In 2009, landings from the Pacific, Atlantic, and Indian Oceans represented 45%, 35%, and 20% of global swordfish production, respectively. Figure 1 shows the swordfish production by the three oceans from 1991 to 2009.

U.S. and Hawaii Production Trends

In 1991, U.S. swordfish catch was 8148 mt, representing 12% of global swordfish landings; U.S. catches in the Atlantic Ocean (3551 mt) represented 10% of all Atlantic landings; and U.S. catches in the Pacific Ocean (4597 mt) represented 17% of all Pacific landings. U.S. production peaked at around 10,000 mt in 1993, representing 12% of global landings; with 70% of the domestic catch coming from the Pacific Ocean (6981 mt) and it represented 24% of all Pacific landings. In 2009, U.S. swordfish catch fell to 4021 mt, representing 4% of global landings and catches in the Atlantic (1856 mt) and Pacific (2165 mt) Oceans both represented 5% of its respective landings.

Hawaii represented the majority (74%) of all U.S. Pacific Ocean landings from 1991 to 2000. In April 2001, the Hawaii shallow-set longline fishery for swordfish was closed by the U.S. National Marine Fisheries Service as the result of a U.S. Federal court order to reduce incidental sea turtle bycatch[2]. During the closure period between 2001 and 2004, Hawaii's swordfish catch represented only 12% of all U.S. Pacific Ocean landings, the balance coming from various other U.S. fisheries, including the harpoon and longline fisheries off California, but there was no increase in the U.S. Pacific-wide catch. No increase in U.S. landings occurred in the Atlantic Ocean because of the U.S. swordfish fishing restrictions imposed by the International Commission for the Conservation of Atlantic Tuna (ICCAT) since 1991. Rather, to meet demand, higher production was observed in non-U.S. fleets in the Pacific Ocean as discussed later in this paper.

The Hawaii shallow-set longline swordfish fishery reopened after incorporating measures to reduce sea turtle bycatch, including (among others): 1) use of circle hooks to replace J hooks; 2) use of fish as bait instead of squid; 3) imposition of an annual sea turtle hard cap and annual fishing effort cap; and 4) 100% observer coverage. Sea turtle bycatch rates declined by 90% for loggerheads and 82.8% for leatherbacks (comparing the May 2004–March 2006 period with the March 1994–February 2002 period) (Gilman et al., 2007). Hawaii's total swordfish production increased 6 times more in 2005–2008 when compared with the closure period and represented 76% of total U.S. catch in the Pacific Ocean. Nonetheless, Hawaii's total swordfish production in the reopened period (2005-2008) remained 50% below the pre-closure period (1997-2000).

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[2] The Hawaii longline fishery operates in two modes: a shallow-set (< 100 m) longline fishery that targets swordfish and a deep-set (> 100 m) longline fishery that targets bigeye tuna. The shallow-set longline fishery has a much higher turtle interaction rate than the deep-set longline fishery because sea turtles, especially loggerheads, usually forage in shallower water (Polovina et al., 2004).

However, other U.S. production in the Pacific Ocean after the closure dropped significantly and production in the Atlantic Ocean also dropped directionally. Together, total U.S. production fell by 10% in the reopened period when compared with the closure period. Figure 2 shows the U.S. swordfish production in the Atlantic and Pacific Oceans between Hawaii and other U.S. areas.

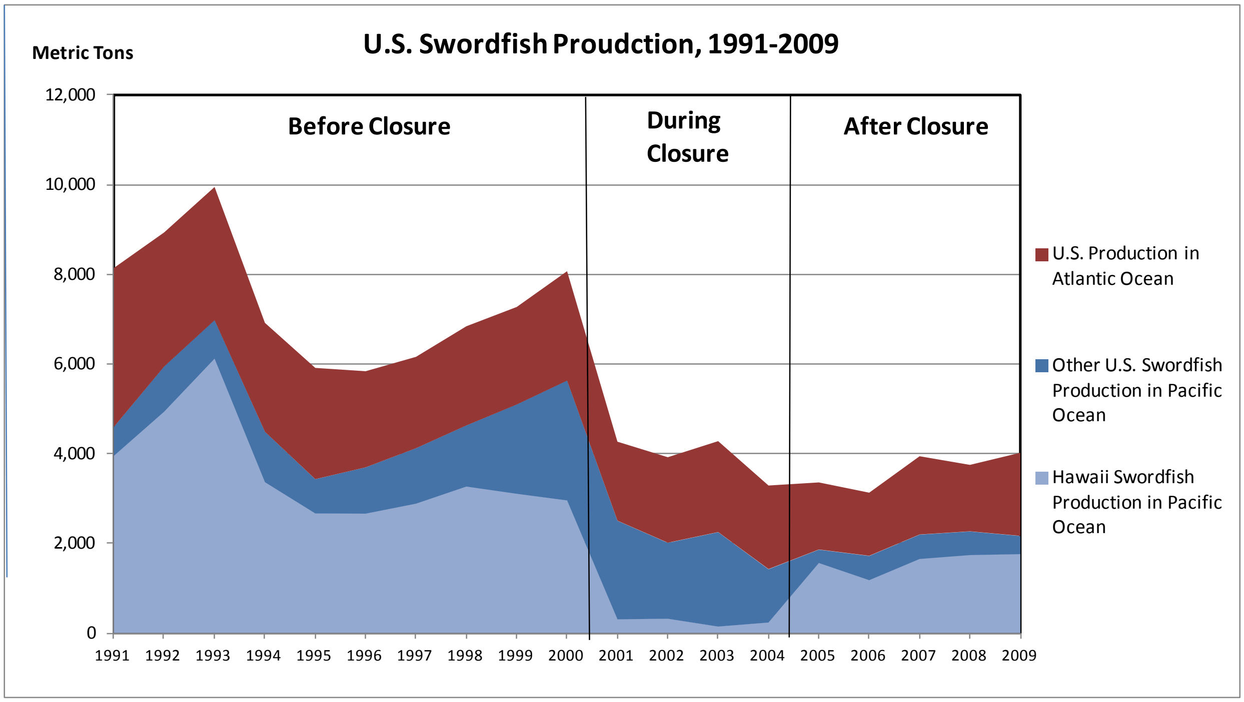

Figure 2.--U.S. Swordfish Production, 1991-2009. Sources: U.S. production in by ocean: FAO Fisheries Global Information System, and Hawaii production: NOAA Fisheries.
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http://www.st.nmfs.noaa.gov/st1/commercial/index.html

Based on the low demand for swordfish in Hawaii, most of the swordfish caught by the Hawaii-based shallow-set longline swordfish fishery is exported to the U.S. mainland (Ito et al., 1998). Prior to the closure, the Hawaii shallow-set longline swordfish fishery not only contributed a large fraction of U.S. swordfish production but also represented a significant component of the Hawaii commercial fisheries as a whole. In 2000, the Hawaii shallow-set longline swordfish fishery's ex-vessel revenue amounted to $12.7 million; however, it dropped to $1.2 million in 2001 (Western Pacific Regional Fishery Management Council (WPRFMC), 2003). After the reopening, the ex-vessel revenue increased but remained much lower than before the closure.

In contrast, swordfish production by foreign countries in the Pacific Ocean continued to increase. Foreign fishing nations were not restricted by the U.S. regulations and seized a market opportunity. This displacement of production can be defined as a "spillover effect": regional regulation to control access of fishery and externalities in one region leads fisheries in other unrestricted regions to increase production and may cause more environmental damage. On the other hand, Rausser et al. (2009) examined the "spillover effect" that stemmed from the market transfer effect associated with the closure of Hawaii shallow-set longline swordfish fishery during the 2001–2004 period and identified that more turtle interactions occurred in the central eastern Pacific Ocean during the closure period as a result of higher imports. Sarmiento (2006) also found similar results and concluded that the market transfer effect had occurred in Pacific

Rim countries including Ecuador and Panama during the Hawaii shallow-set longline swordfish fishery closure (see Section II for a detailed discussion of these analyses.) As shown in Figure 3, non-U.S. production in the Pacific Ocean increased by more than 41,000 mt during the closure period, while U.S. production fell by 11,000 mt.

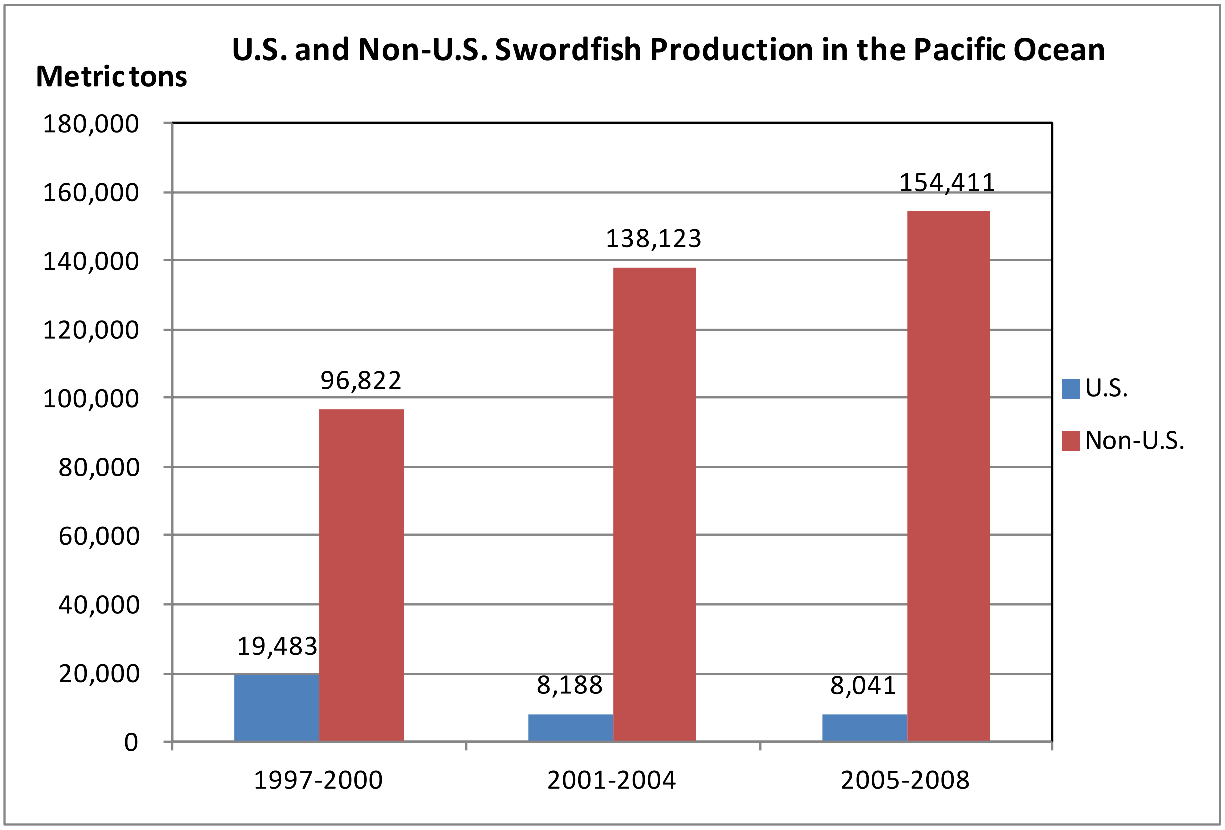

Figure 3.--U.S. and non-U.S. Swordfish Production in Pacific Ocean – Before, During and After Hawaii Closure. Source: U.S. and non-U.S. production by ocean: FAO Fisheries Global Information System.
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U.S. Consumption

The swordfish consumption pattern in the United States is similar to its production pattern. U.S. swordfish consumption is made up of domestic production plus imports (almost all U.S. production is consumed in the U.S.) Figure 4 shows U.S. fresh and frozen swordfish consumption from 1991 to 2009. Prior to 1997, imported cut swordfish products were not classified as swordfish but recorded as unclassified fish fillets by the U.S. Bureau of Customs and Border Protection. A change in coding in 1997 caused the apparent sudden jump in swordfish imports in 1997, but this simply reflects the coding change. The highest U.S. swordfish consumption was recorded in 1998 with more than 23,000 mt, of which 37% was fresh imports and 30% was fresh domestic product (the remaining 33% consumed was frozen swordfish). U.S. consumption trended downward beginning in 2000 and fell over 50% to 11,000 mt by 2009. Nonetheless, U.S. swordfish consumption has been about 2 to 3 times total U.S.

domestic landings. The difference has been supplied by imports; approximately two-thirds of imports were fresh and one-third was frozen.

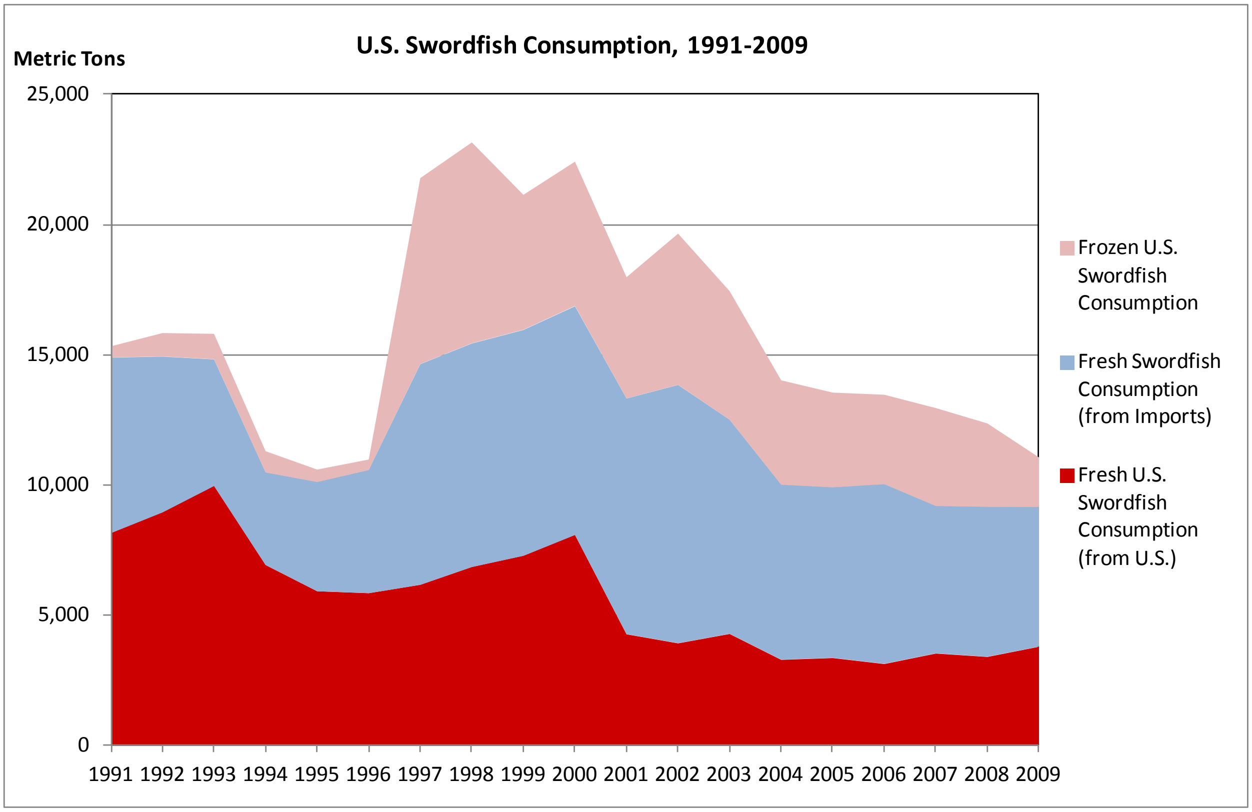

Figure 4.--U.S. Swordfish Consumption, 1991-2009.
Sources: Fresh U.S. consumption from imports and frozen consumption: NOAA Fisheries; fresh U.S. consumption (= U.S. production-exports): U.S. production from FAO Fisheries Global Information System and exports from NOAA Fisheries.
http://www.st.nmfs.noaa.gov/st1/commercial/index.html
http://www.fao.org/figis/servlet/TabLandArea?tb_ds=Capture&tb_mode=TABLE&tb_act=SELECT&tb_grp=COUNTRY
Note 1: U.S. swordfish production data are available from FAO and NOAA, but the estimates from these two sources are slightly different. Because the data for other countries and for production by ocean are from FAO, to be consistent, we use FAO data for both the United States and other countries.
Note 2: Import data are from NOAA foreign trade data, originating from the U.S. Census Bureau. A change occurred in the product definition in 1997. Prior to 1997, swordfish imports were recorded as either fresh or frozen swordfish products. Starting in 1997, three new swordfish categories were added: frozen fillets, fresh steaks and frozen steaks. Prior to the introduction of these codes, cut swordfish products had been recorded as ''unclassified fish fillets'' (pers. comm., Steve Koplin, NOAA Fisheries, Silver Spring, M.D.). The new codes led to a tripling in the amount of swordfish imports recorded by U.S. Customs from 5140 mt in 1996 to 15,598 mt in 1997, which in turn caused a doubling of U.S. consumption from 10,982 mt in 1996 to 21,761 mt in 1997.

One important question is whether the decline in U.S. swordfish consumption during the Hawaii closure period was based on lower domestic production or on other factors affecting consumption. Rausser et al. (2009) concluded that lower U.S. swordfish consumption during the closure period was a result of the U.S. Food and Drug Administration's advisory warning of high mercury levels in swordfish from both Atlantic and Pacific Oceans. With the continuing decline in consumption after the closure period, it is likely that the perceived safety issue remains the reason for lower consumption[3].

This attribution of consumption decline to the mercury advisory is further supported by the decline in both fresh and frozen U.S. consumption during and after the closure. Virtually all Hawaii swordfish were sold as fresh products (with a small amount of frozen meat exported in 2008). If the Hawaii closure had affected consumption, it would only affect fresh but not frozen consumption, especially because Hawaii produces high-quality fresh swordfish and most of the catch are sold to the U.S. mainland where U.S. customers prefer Hawaii swordfish over foreign imports[4]. Table 1 shows that both fresh and frozen swordfish consumption declined in similar proportions during and after the closure. This demonstrates that even though domestic fresh swordfish supplies fluctuated greatly across the pre-closure, closure, and reopened periods, these fluctuations were driven by demand changes rather than supply changes.

Table 1.— Fresh, frozen, and total U.S. consumption of swordfish and changes before, during, and after the closure of the Hawaii shallow-set longline swordfish fishery.

Total Consumption (mt)	Fresh U.S. Consumption	Frozen U.S. Consumption	Total U.S. Consumption
Pre-closure Period: 1997-2000	62,895	25,504	88,399
Closure Period: 2001-2004	49,687	19,357	69,044
Reopened Period: 2005-2008	38,324	14,000	52,324
Amount of Decrease in Consumption (mt)			
1997-2000 vs. 2001-2004	-13,208	-6147	-19,355
2001-2004 vs.2005-2008	-11,364	-5357	-16,721
Portion of Decrease from Total Decrease			
Between 1997-2000 and 2001-2004	68.2%	31.8%	100%
Between 2001-2004 and 2005-2008	68.0%	32.0%	100%

Sources: 1) Frozen U.S. consumption: NOAA Fisheries; 2) fresh U.S. consumption (fresh imports + U.S. production): fresh imports data was obtained from NOAA Fisheries, while U.S. production data was obtained from FAO Fisheries Global Information System.
http://www.st.nmfs.noaa.gov/st1/commercial/index.html
http://www.fao.org/figis/servlet/TabLandArea?tb_ds=Capture&tb_mode=TABLE&tb_act=SELECT&tb_grp=COUNTRY
Note: U.S. swordfish production data are available from FAO and NOAA, but the estimates from these two sources are slightly different. Because the data for other countries and for production by ocean are from FAO, to be consistent, we use FAO data for both the United States and other countries.

METHODS

Previous Studies Review

Spillover effects are commonly examined in environmental economics. Economic theory suggests that, in the case of the Hawaii shallow-set longline swordfish fishery, a reduction in domestic catch and effort would result in a negative spillover effect, which means that sea turtle

[3] This perception of compromised safety as a result of mercury levels is very likely the cause of the continuous decline even though NMFS disputes whether the mercury levels do in fact pose a safety hazard. Source: Morrissey, Michael T. (2006, August). *Mercury in Seafood: Facts and Discrepancies.* Food Technology, 60(8), 132. http://www.nmfs.noaa.gov/fishwatch/docs/mercury_in_seafood.pdf.
[4] http://www.hawaii-seafood.org/wild-hawaii-fish/billfish/broadbill-swordfish-mekajiki/

bycatch worldwide would increase. Specifically, fishing measures (fishing days, number of hooks set, etc.) would be effectively transferred from the United States to foreign fisheries, and from U.S. fishing vessels to foreign fishing vessels, which have higher sea turtle bycatch rates and thus, all else equal, have greater adverse effects on turtle populations. However, a positive spillover effect would occur if the Hawaii shallow-set longline swordfish fishery were allowed to increase its fishing effort at a lower bycatch rate and, therefore, would result in less sea turtle bycatch worldwide or ocean-wide. In the case of the Hawaii shallow-set longline swordfish fishery, four necessary conditions must exist for the negative spillover effect to occur:

1) Both turtles and swordfish are globalized resources in high seas: they are both pelagic species and swordfish are caught by many fisheries. In addition, turtles and shallow-set swordfish fisheries interact due to their co-occurrence in certain ocean environments such as specific water depths and sea surface temperatures (Howell et al., 2008).

2) Relatively free trade exists such that the United States can import swordfish from other countries.

3) U.S. swordfish imports increase as domestic production declines, and production in other countries increases to meet U.S. consumption demand.

4) Sea turtle bycatch rates are higher in the countries from which the U.S. imports swordfish.

Several studies have concluded that Hawaii shallow-set longline swordfish fishery regulations are likely to cause more turtle interactions globally because the turtle bycatch rate in the Hawaii longline fishery is one of the lowest in the world.

Sarmiento (2006) first examined whether spillover effects occurred after the Hawaii shallow-set longline swordfish fishery closure in 2000. He applied an econometric model that included variables such as U.S. fresh swordfish imports, its lag, and other variables that affected U.S. fresh imports. He found that the year after the closure, U.S. fresh swordfish imports from Ecuador and Panama had increased significantly. He therefore concluded that the Hawaii closure led to transferred fishing effort to some foreign countries and was unlikely to result in an overall reduction of sea turtle interactions. He referred to the spillover effect as “trade leakage”. However, Sarmiento’s study covered a limited period of data (1994-2003) and his paper did not specifically estimate the possible increase in the number of sea turtle interactions associated with the increased imports.

Bartram et al. (2010) calculated turtle bycatch-to-fish-catch ratios in different fisheries and showed that Hawaii longline tuna and swordfish fisheries (both deep-set and shallow-set) had the lowest bycatch-to-fish-catch ratios among other major Pacific longline fisheries, especially after the 2004 management measures took effect in the swordfish fishery. Specifically, Hawaii’s deep-set longline tuna fishery sets the benchmark of 1 sea turtle interaction per 190,000 kg of tuna caught. To catch the same amount of swordfish, the bycatch to fish catch ratios are 3.7 turtles for the Hawaii shallow-set longline swordfish fishery, 4.7 turtles for the Japan tuna fishery, 9.5 turtles for the Australia swordfish fishery, and 13.7 and 19 turtles for the Taiwan and China tuna fisheries, respectively[5].

Rausser et al. (2009) also examined the spillover effect, defined as a "market transfer effect" in this case, during the closure of the Hawaii shallow-set longline swordfish fishery from 2001 to 2004. They found that a market transfer effect occurred during the closure of the Hawaii shallow-set longline swordfish fishery by using a model that included fresh and frozen swordfish demand in the United States and import supply to the United States from different parts of the Pacific and Atlantic Oceans. One may assume that imports would increase as U.S. production declined but trade statistics showed that imports of fresh swordfish declined during the Hawaii closure period, as U.S. demand for swordfish declined. The downward trend in U.S. swordfish consumption made the analysis of the market transfer effect more complicated. To distinguish the impacts of the Hawaii production decline on imports, Rausser et al.'s (2009) model analyzed the pattern of U.S. consumption in relation to U.S. domestic production and imports. They projected that U.S. swordfish imports would decrease by 1602 mt if there were no closure of the Hawaii shallow-set longline swordfish fishery. They concluded that the market transfer effect occurred in the central eastern Pacific and that it transferred an additional 1602 mt of fresh swordfish imports annually during the closure period, resulting in an additional 2882 sea turtle interactions.

In summary, these studies concluded that Hawaii shallow-set longline swordfish fishery regulations are likely to cause more turtle interactions globally. However, the Sarmiento (2006) and Bartram et al. (2010) studies did not provide quantitative estimation of spillover effects in terms of the change in the total number of sea turtle interactions. Rausser et al. (2009) quantified the spillover effects, but they assumed the same bycatch rate for all the non-U.S. fisheries to calculate the sea turtle bycatch.

In contrast, this study seeks to quantify the spillover effects in terms of the change in number sea turtle interactions, and attempts to enhance the estimation in several ways. First, this study examines the spillover effects resulting from both market replacement and possible production displacement. Rausser et al. (2009) only examined the spillover effects resulting from the transferred swordfish imports, while spillover effects can be generated through either market flows (import and export) or production displacements. In the North and central Pacific Ocean where Hawaii shallow-set longline swordfish fleet fishes, other countries such as Japan, Taiwan, and the Philippines also target, or seasonally target, swordfish. Non-U.S. swordfish production in these areas increased while U.S. production declined (Fig. 8).

Second, this study tracks U.S. swordfish imports from the exported countries and associates the actual amount of swordfish exported from each country or fishery to the sea turtle bycatch rate reported for the specific fishery/country. This contrasts with the Rausser et al. (2009) methodology that uses a single bycatch rate generated from the average bycatch rates across 17 studies to calculate the net effect on sea turtle bycatch resulting from imports. Because the amount of swordfish exported to the United States and sea turtle bycatch rates in different countries vary substantially, we can estimate the number of sea turtle interactions more accurately by using country/fleet-specific bycatch rates rather than a multination average.

[5] For example, the bycatch-to-fish-catch ratio of 1 in the Hawaii tuna fishery versus 19 in the China tuna fishery means that Hawaii had 1 sea turtle interaction per 190,000 kg of tuna catch while China had 10 turtle interactions for the same amount of tuna catch.

Third, Rausser et al. (2009) used data obtained prior to and during the Hawaii closure period to identify and estimate the possible spillover/transfer effects as a result of the Hawaii closure by modeling U.S. fresh import changes with and without the closure. Rausser et al. (2009) needed to apply a model to first predict the market transfer effect in terms of an increase in swordfish imports, then to calculate the spillover effects in terms of the change that sea turtle interactions associated with that import increase. At the time we conducted this study, the Hawaii shallow-set longline swordfish fishery had been reopened (under a series of new restrictions) for 6 years, and we were able to use empirical data to examine the actual changes in U.S. imports (market transfers) during the three periods: pre-closure, closure, and reopened. The empirical data confirmed Rausser et al.'s (2009) prediction of the amount of increase in U.S. imports (referred to as "transferred catch" in their paper), based on the absence of the Hawaii shallow-set longline swordfish fishery. Rausser et al. predicted an annual average transferred catch of 1602 mt; the actual amount of annual average transferred catch – the increase in imports – was 2256 mt (see Table 2). So we do not need to repeat the modeling effort to first predict the market transfer effect in terms of swordfish imports; rather, we can use the actual import figures to calculate the transfer effect in terms of sea turtle interactions in different periods while the Hawaii shallow-set longline swordfish fishery operates under various regulatory regimes.

Table 2 shows U.S. swordfish production, trade, and consumption before, during, and after the Hawaii closure in 4-year increments. Nearly all U.S. swordfish landings were consumed domestically as fresh product with no foreign exports until 2007, when exported quantities were minimal. As shown in Table 1, fresh and frozen consumption represented the same percentage of the decline in total consumption across the three periods. Because fresh consumption is simply the sum of domestic production and fresh imports, domestic production and fresh imports must move in opposite directions, if consumption is static.

On average, total U.S. consumption fell by 22% (4839 mt) and total U.S. production fell doubly by 44% (3151 mt) during the closure period as a result of the dramatic decline in Pacific Ocean production (58%) and the moderate decline in the Atlantic Ocean production (15%). Fresh imports remained almost unchanged with a minor decline of 2%. After the closure period, total consumption fell by 24% (4180 mt) and total U.S. production fell only by 10% because of higher Pacific Ocean production (506%) and a moderate decline in Atlantic Ocean production (19%). Fresh imports fell dramatically by 27%. These opposite movements of domestic supply and fresh imports demonstrate that U.S. swordfish production and imports were highly influenced by the Hawaii shallow-set longline swordfish fishery restrictions, and that fresh imports served as a buffer to balance the gap between fresh demand and supply.

Table 2. —Annual average U.S. swordfish production, trade, and consumption before, during, and after the closure of the Hawaii shallow-set longline swordfish fishery.

			U.S. Production in Pacific Ocean			Total Imports		Total Exports		
Annual Average (mt)	**Total U.S. Production**	**U.S. Production in Pacific Ocean**	**Hawaii**	**Rest of Pacific**	**U.S. Production in Atlantic Ocean**	**Fresh Imports**	**Frozen Imports**	**Fresh Exports**	**Frozen Exports**	**Total U.S. Consumption**
Pre-closure Period: 1997-2000	7091	4871	3054	1817	2220	8633	6376	0	0	22,100
Closure Period: 2001-2004	3940	2047	253	1794	1893	8482	4839	0	0	17,261
Reopened Period: 2005-2008	3545	2010	1534	476	1535	6226	3500	80	111	13,081
Amount of Change Between Periods (mt)										
Pre-closure vs. Closure	-3151	-2824	-2801	-23	-327	-151	-1537	0	0	-4839
Closure vs. Reopened	-395	-37	1281	-1317	-358	-2256	-1339	80	111	-4180
Percent of Change Between Periods (%)										
Pre-closure vs. Closure	-44%	-58%	-92%	-1%	-15%	-2%	-24%	-	-	-22%
Closure vs. Reopened	-10%	-2%	506%	-73%	-19%	-27%	-28%	-	-	-24%

Sources: U.S. imports, exports, and Hawaii production: NOAA Fisheries; U.S. production by ocean: FAO Fisheries Global Information System.
http://www.st.nmfs.noaa.gov/st1/commercial/index.html
http://www.fao.org/figis/servlet/TabLandArea?tb_ds=Capture&tb_mode=TABLE&tb_act=SELECT&tb_grp=COUNTRY

The Estimation Approach

The detailed approach (steps) to estimate the spillover effects resulting from transferred swordfish imports (market replacement) is as follows:

1) Identify the amount of fresh swordfish imported from foreign countries into the U.S. under different regulation regimes, including: reopened with fishing effort limits; and reopened with no effort limits and assuming total annual fishing effort of 5500 sets (the fishery's historical peak);

2) Identify the sea turtle bycatch rates for each of the exporter countries in their respective fishing grounds (Pacific or Atlantic) as reported in current research;

3) Estimate the amount of sea turtle bycatch for each country according to the amount of swordfish exported to the U.S. and the exporter nation's bycatch rate[6];

4) Sum up the total sea turtle interactions from all the countries; and

5) Calculate the spillover effects (net effects) by comparing the amount of sea turtle bycatch if those imports were replaced by Hawaii shallow-set longline swordfish fishery production under different production levels.

[6] The estimation of sea turtle bycatch by fleet/country is sensitive to assumed bycatch rates. These rates may be specific to certain time periods or locations within a fishery, reflecting bycatch rates observed at that time and place, and they may not be strictly applicable to the entire spatial or temporal extent of the fishery. Also, the production reported by a country may be harvested by other countries so the bycatch rate applied to the reported country may not reflect the actual bycatch rate. For example, many foreign vessels, regardless of national origin, register in Panama to use Panama's quota. In this case, the bycatch rate for Panama could be misrepresented as it includes the bycatch rate of non-Panamanian vessels.

The detailed approaches (steps) of the estimation of the spillover effects resulting from the production displacement are as follows:

1) Examine the possible U.S. swordfish production displacement of non-U.S. swordfish production and estimate the displacement rate in the North and central Pacific Ocean, through a regression analysis;

2) Identify the sea turtle bycatch rates for each of the countries in the North and central Pacific Ocean;

3) Estimate the amount of sea turtle bycatch for each country according to the amount of swordfish production and the country's bycatch rate in the north and central Pacific Ocean;

4) Sum up the total sea turtle interactions from different countries; and

5) Calculate the spillover effect by comparing the amount of sea turtle bycatch under different production levels.

RESULT I - SPILLOVER EFFECTS FROM TRANSFERRED MARKET FLOW (IMPORTS)

This section estimates the spillover effect of the Hawaii shallow-set longline swordfish fishery closure (2001-2004) on sea turtle bycatch based on actual observation of import changes. In addition, this section predicts the spillover effect if Hawaii shallow-set longline swordfish fishery effort were to increase to 5500 sets as proposed in the regulatory action to remove the effort limit in Amendment 18 (WPRFMC, 2008)[7]. Because the Hawaii production of swordfish is primarily consumed by U.S. consumers, an increase in production of swordfish by the Hawaii-based shallow-set fishery would lead to decreased imports from countries with less turtle-friendly fishing practices and therefore lower the overall sea turtle bycatch associated with swordfish consumed in the United States. In this section, the sea turtle bycatch reduction is referring to the reduction in sea turtle bycatch associated with swordfish consumed in the United States.

[7] Amendment 18: http://www.federalregister.gov/articles/2009/12/10/E9-29444/international-fisheries-regulations-fisheries-in-the-western-pacific-pelagic-fisheries-hawaii-based#p-21.

Impacts to Sea Turtle Interactions Due to Reduction in U.S. Fresh Swordfish Imports (2005-2008)

Reduction in Turtle Interactions Worldwide, 2005-2008

Rausser et al. (2009) predicted that fresh swordfish imports would decline by 1602 mt if there were no Hawaii shallow-set longline swordfish fishery closure, which implies that the amount of annual average catch transferred to foreign fisheries would be 1602 mt. The actual trade data shows that when the Hawaii shallow-set longline swordfish fishery reopened, fresh imports declined by 2256 mt in annual average during the 2005-2008 reopened period (see Table 2). This shows that Rausser et al.'s (2009) prediction was correct: a transfer effect in terms of changes in swordfish imports would occur, but that their estimate was lower than the actual. Rausser et al. (2009) also estimated the change in sea turtle bycatch associated with the market transfer effect. However, their estimates used the average bycatch rate from 17 studies conducted in 4 countries (Peru, Ecuador, Panama, and Costa Rica) that constituted less than 40% of U.S. imports. Rausser et al. (2009) also did not distinguish among sea turtle species involved in bycatch. Since then, there have been more studies on sea turtle bycatch in various countries' fisheries. The specific bycatch rates for loggerhead and leatherback turtles are also available for some fisheries. Therefore, in this study, we are able to estimate the actual spillover effects by associating swordfish imports and turtle interactions to each of the foreign countries for 91% of total imports.

We estimate the annual average reduction in turtle interactions worldwide using the 10 major fresh swordfish exporting countries that represent 91% of U.S. fresh imports in 2005-2008, the fraction of U.S. imports that they contribute, their respective turtle bycatch rates (including leatherback, loggerhead, green, olive ridley, and unidentified), and swordfish catch-per-unit effort (CPUE). Table 3a shows that the estimated reduction in turtle interactions due to lower fresh swordfish imports during 2005-2008 was an annual average of 3242 turtles (including loggerhead, leatherback, green, and olive ridley). Detailed bycatch rates and CPUE by country and the sources are listed in Appendix A.

Reduction in Turtle Interactions by Ocean, 2005-2008

Among the 10 top countries from which the U.S. imported fresh swordfish, some countries fished in the Pacific Ocean and some fished in the Atlantic Ocean. Since the Hawaii shallow-set longline swordfish fishery only operates in the Pacific, one may want to only examine the market transfer effect occurring in the Pacific Ocean to focus on sea turtle populations that may be affected by the Hawaii swordfish fishery[8]. Table 3a also shows the estimated reduction in turtle interactions by ocean. Among the estimated reduction of 2950 turtle interactions from the 10 major fresh exporting countries, an annual average of 2053 turtles (70%) were in the Pacific Ocean and 897 turtles (30%) were in the Atlantic Ocean.

[8] Proposed regulations pursuant to the Endangered Species Act (2010) include the North Pacific loggerhead as one of nine distinct population segments of that species that qualify for listing as threatened: http://www.noaanews.noaa.gov/stories2010/20100310_loggerhead.html.

Reduction in Leatherback and Loggerhead Turtle Interactions Worldwide, 2005-2008

Section (a), above, estimates an annual average worldwide reduction of 3242 turtle interactions, including all turtle species. Since the Hawaii shallow-set longline swordfish fishery interacts mostly with loggerhead and leatherback turtles, we estimate the reduction in loggerhead and leatherback interactions, respectively. Table 3a shows the estimated change in leatherback and loggerhead interactions after the reopening of the Hawaii shallow-set longline swordfish fishery. Bycatch rates for leatherbacks and loggerheads are available for Canada, Chile, and Brazil, and also are available for Hawaii. These 4 areas represent about one-third of the total sea turtle bycatch; bycatch ratios for leatherbacks and loggerheads in these 4 areas are reliable. For Panama, Ecuador, Costa Rica where the ratios of leatherback and loggerhead bycatch to total bycatch are not available, we use the ratio of female leatherbacks and loggerheads to the total female turtle population (including leatherback, loggerhead, hawksbill, olive ridley, and green) reported by Sea Turtle Conservancy (2011). Australia's leatherback and loggerhead bycatch rates are estimated based on the ratio of the Hawaii shallow-set longline swordfish fishery's leatherback bycatch to total turtle bycatch and loggerhead bycatch to total turtle bycatch (in 1994-2002, before the fishing technology and other requirements changed) as they both target swordfish in the Pacific Ocean. Using the assumptions discussed above, the reduction in interactions based on lower imports is estimated to be an annual average of 202 leatherbacks, 892 loggerheads, and 2148 other sea turtles.

Reduction in Leatherback and Loggerhead Turtle Interactions by Ocean, 2005-2008

Table 3a shows that among the estimated annual average reduction of 184 leatherback interactions from the 10 major fresh swordfish exporting countries, approximately 84 (46%) were located in the Pacific Ocean and 100 (54%) were located in the Atlantic Ocean. For loggerhead interactions, among the estimated annual average reduction of 812 loggerhead interactions, 120 (15%) were located in the Pacific Ocean and 692 (85%) were in located in the Atlantic Ocean.

As demonstrated in the Hawaii shallow-set longline swordfish fishery, the use of circle hooks and fish bait has substantially reduced turtle interactions. The estimate above uses the bycatch rate associated with the use of J hooks or without any specification of the hook type (details are shown in Appendix A).

Table 3a.—Impacts to foreign sea turtle interactions based on lower U.S. imports during the reopened period for the Hawaii shallow-set longline swordfish fishery (2005-2008) – upper bound.

Countries that Export Fresh Swordfish to the United States	2005-2008 U.S. Fresh Imports Weight	Change in Total Fresh Imports: Closure vs. Reopened (mt)	Turtle Bycatch Rate (turtle interactions per 1000 hooks)			Swordfish CPUE (mt/1,000 hooks)	Annual Average Reduction in Turtle Interactions Based on Lower U.S. Imports		
			Overall	Leather-back	Logger-head		Overall	Leather-back	Logger-head
Panama	22%	496	1.80	0.07	0.08	0.08*	1110	40	50
Canada	17%	384	1.82	0.19	1.42	0.81	862	91	672
Mexico	9%	203	0.17**	0.03**	0.13**	1.04**	34	6	25
Chile	9%	203	0.034	0.027	0.006	1.04**	7	5	1
Brazil	8%	180	0.12	0.03	0.07	1.61	14	3	8
Ecuador	8%	180	2.35	0.08	0.11	0.08*	528	19	24
Costa Rica	6%	135	2.20	0.08	0.10	0.08*	370	13	17
South Africa	4%	90	0.12***	0.03***	0.07***	1.61***	7	2	4
Uruguay	4%	90	0.12***	0.03***	0.07***	0.80	14	3	8
Australia	4%	90	0.024	0.004	0.018	0.48	5	1	3
10 Major Countries	91%	2052					2950	184	812
Total	**100%**	**2256**					**3242**	**202**	**892**
By Ocean (according to country's fishing ground)									
Pacific							2053	84	120
Atlantic							897	100	692
10 Major Countries							**2950**	**184**	**812**
Misc.							292	18	80
Total							**3242**	**202**	**892**

Note 1: *Assume the same as Uruguay. **Assume the same as Hawaii: bycatch rate (1994-2002) and CPUE (1992-2002) in Hawaii before the new U.S. technology regulations were established in 2004, when the Hawaii fleet was still using J hooks and squid bait. *** Assume the same as Brazil. For countries without sea turtle bycatch rates and swordfish CPUEs, we assume the same as the countries with available sea turtle bycatch rates and CPUEs from credible sources that are fishing in the same fishing grounds. For example, Mexico's bycatch rates and CPUEs are assumed the same as Hawaii's bycatch rate (1994-2002) and CPUE (1992-2002) as they both targeted swordfish in the Pacific Ocean. This is before the new U.S. technology regulations were established in 2004, when the Hawaii fleet was still using J hooks and squid bait. Currently, the United States is the only country that requires C hooks and fish bait. For Chile, whose CPUEs are not available, we assume the same as Hawaii's swordfish CPUE from 1992 to 2002. For South Africa, bycatch rate and CPUE are not available and for Uruguay bycatch rate is not available; we assume the same as Brazil as they all targeted swordfish in the Atlantic Ocean. For Panama, Ecuador, and Costa Rica, we assume Uruguay bycatch rate.
Note 2: Countries that operate in the Pacific include: Panama, Mexico, Chile, Ecuador, Costa Rica, and Australia; countries that operate in Atlantic include: Canada, Brazil, South Africa, and Uruguay.
Note 3: Leatherback and loggerhead bycatch rate for Canada, Chile and Brazil are obtained from creditable sources (see Appendix A for the references) and they comprise approximately one-third of the estimate.
Note 4: Swordfish CPUE may reflect targeting of a mix of species, not just swordfish; e.g., Australia's CPUE reflects mixed targeting of swordfish/tuna/s. marlin (see Appendix A for details).

However, circle hooks were widely introduced to longline fisheries worldwide as an effective tool to reduce bycatch mortality. In some cases, alternative bycatch rates are available for some fisheries that were transitioning to or experimenting with circle hooks. Those rates typically are lower. Table 3b presents an alternative bycatch estimate that uses revised rates for countries that experimented with circle hooks, including Panama, Ecuador, and Costa Rica. On average, the turtle interaction rates in these 3 countries show a reduction of 53% when using circle hooks compared to using J hooks (Inter-American Tropical Tuna Commission (IATTC), 2006). The total turtle interactions reduction due to lower fresh swordfish imports during 2005-2008 is estimated at an annual average of 1509 turtles, 53% lower than the upper bound estimate of 3242 turtles.

Table 3b. —Impacts to foreign sea turtle interactions based on lower U.S. imports during the reopened period for the Hawaii shallow-set longline swordfish fishery (2005-2008) – lower bound.

Countries that Export Fresh Swordfish to the United States	2005-2008 U.S. Fresh Imports Weight	Change in Total Fresh Imports: Closure vs. Reopened (mt)	Turtle Bycatch Rate (turtle interactions per 1000 hooks)			Swordfish CPUE (mt/1000 hooks)	Annual Average Reduction in Turtle Interactions Based on Lower U.S. Imports		
			Overall	Leather-back	Logger-head		Overall	Leather-back	Logger-head
Panama	22%	496	0.70	0.03	0.03	0.80*	432	16	19
Canada	17%	384	0.96	0.10	0.75	0.81	455	48	355
Mexico	9%	203	0.08	0.01	0.06	1.04**	16	3	12
Chile	9%	203	0.016	0.013	0.003	1.04**	3	2	1
Brazil	8%	180	0.06	0.01	0.03	1.61	6	2	4
Ecuador	8%	180	1.10	0.04	0.05	0.80*	247	9	11
Costa Rica	6%	135	1.20	0.04	0.05	0.80*	202	7	9
South Africa	4%	90	0.06	0.01	0.03	1.61***	3	1	2
Uruguay	4%	90	0.06	0.01	0.03	0.80	6	2	4
Australia	4%	90	0.011	0.002	0.008	0.48	2	0	2
10 Major Countries	91%	2052					1373	89	418
Total	**100%**	**2256**					**1509**	**98**	**459**
By Ocean (according to country's fishing ground)									
Pacific							902	37	54
Atlantic							471	52	364
10 Major Countries							**1373**	**89**	**418**
Misc.							136	9	41
Total							**1509**	**98**	**459**

Note 1: *Assume the same as Uruguay. **Assume the same as Hawaii: bycatch rate (1994-2002) and CPUE (1992-2002) in Hawaii before the new U.S. technology regulations were established in 2004, when the Hawaii fleet was still using J hooks and squid bait. *** Assume the same as Brazil.

Note 2: Countries that fish in Pacific include: Panama, Mexico, Chile, Ecuador, Costa Rica, and Australia; countries that fish in Atlantic include: Canada, Brazil, South Africa, and Uruguay.

For the remainder of this section, "upper bound" estimates refer to those generated using J-hook or unspecified-hook bycatch rates for countries that use J and C hooks; "lower-bound" estimates are those that incorporate C-hook bycatch rates for those countries.

Net Spillover Effect of the Increase in Hawaii Swordfish Production (2005-2008)

It is important to note that the decrease in fresh imports after the closure period was the result of a combination of higher Hawaii production and lower U.S. consumption. That is, the estimated annual average reduction of 2747 turtle interactions resulted from two events: 1) lower fresh swordfish imports as a result of the reopening of the Hawaii shallow-set longline swordfish fishery; and 2) the reduction in U.S. consumption of swordfish. At the time the Hawaii shallow-set longline swordfish fishery reopened (under effort and sea turtle caps), annual average swordfish production increased by 1281 mt (from Table 2). To quantify the impact on turtle interactions associated with lower imports based on higher Hawaii production, fresh imports are assumed to be lower by 1281 mt. Table 4a shows the results. The annual average reduction in turtle interactions under this scenario was 1841 turtles. In other words, of the annual average of 3242 fewer turtle interactions, the increase in Hawaii swordfish production contributed 1841 fewer turtle reductions and the reduction in swordfish consumption contributed 1401 (3242 turtles – 1841 turtles) fewer turtle interactions.

Next, we consider the *net* reduction in interactions. The Hawaii shallow-set longline swordfish fishery still interacted with sea turtles when it reopened, but the interaction rate was much lower after switching to circle hooks and fish bait (Gilman et al., 2007). Based on the data recorded with 100% observing coverage, actual turtle interactions in the Hawaii shallow-set longline swordfish fishery in 2005-2008 totaled an annual average of 15 turtles. Thus, the net benefit of reopening the Hawaii shallow-set longline swordfish fishery was 1826 fewer turtle interactions (1841 turtles – 15 turtles).

Since the Hawaii shallow-set longline swordfish fishery only operates in the Pacific, one may want to only examine the impact in the Pacific Ocean. Table 4a also shows the estimated reduction in turtle interactions by ocean.

Table 4a.— Impacts to sea turtle interactions attributed to higher Hawaii production during the reopened period for the Hawaii shallow-set longline swordfish fishery (2005-2008) – upper bound.

Countries Export Fresh Swordfish to the United States	2005-2008 U.S. Fresh Imports Weight	Change in Total Fresh Imports: Closure vs. Post-Closure (mt)	Turtle Bycatch Rate (turtle interactions per 1000 hooks)			Swordfish CPUE (mt/1000 hooks)	Annual Average Reduction in Turtle Interactions Based on Lower U.S. Imports		
			Overall	Leather-back	Logger-head		Overall	Leather-back	Logger-head
Panama	22%	282	1.80	0.07	0.08	0.08*	630	23	28
Canada	17%	218	1.82	0.19	1.42	0.81	490	52	382
Mexico	9%	115	0.17**	0.03**	0.13**	1.04**	19	3	14
Chile	9%	115	0.034	0.027	0.006	1.04**	4	3	1
Brazil	8%	102	0.12	0.03	0.07	1.61	8	2	4
Ecuador	8%	102	2.35	0.08	0.11	0.08*	300	11	13
Costa Rica	6%	77	2.20	0.08	0.10	0.08*	210	8	9
South Africa	4%	51	0.12***	0.03***	0.07***	1.61***	4	1	2
Uruguay	4%	51	0.12***	0.03***	0.07***	0.80	8	2	4
Australia	4%	51	0.024	0.004	0.018	0.48	3	0	2
10 Major Countries	91%	1165					1675	104	461
Total	**100%**	**1281**					**1841**	**115**	**507**
By Ocean (according to country's fishing ground)									
Pacific							1166	48	68
Atlantic							509	56	393
10 Major Countries							**1675**	**104**	**461**
Misc.							166	11	46
Total							**1841**	**115**	**507**
Fishery		**Hawaii Fresh Production: Closure vs. Reopened (mt)**	**Turtle Bycatch Rate (turtle interactions per 1,000 hooks)**			**Swordfish CPUE (mt/1,000 hooks)**	**Annual Average Increase in Turtle Interactions Due to Higher Hawaii Production**		
			Overall	**Leather-back**	**Logger-head**		**Overall**	**Leather-back**	**Logger-head**
Hawaii		**1281**	0.013	0.003	0.009	1.13	**15**	**4**	**10**
Net Reduction (Annual Average) in Sea Turtle Interactions During the Reopened of Hawaii Swordfish Fishery							**1826**	111	497

Note 1: *Assume the same as Uruguay. **Assume the same as the Hawaii shallow-set longline swordfish fishery: bycatch rate (1994-2002) and CPUE (1992-2002) in Hawaii before the new U.S. technology regulations were promulgated in 2004, when the Hawaii fleet was still using J hooks and squid bait. *** Assume the same as Brazil.
Sources for current Hawaii shallow-set longline swordfish fishery bycatch and CPUE: Projected sea turtle captures and mortalities estimated in the shallow-set fishery, NMFS PRD July 2011 and swordfish 2005-2008 catch data, NMFS.
Note 2: Countries that fish in the Pacific include: Panama, Mexico, Chile, Ecuador, Costa Rica, and Australia; countries that fish in the Atlantic include: Canada, Brazil, South Africa, and Uruguay.

Table 4b shows the lower bound estimate of the reduction in turtle interactions attributed to higher Hawaii shallow-set longline swordfish fishery production during the reopened period was 857 turtles. The net benefit of reopening the Hawaii shallow-set longline swordfish fishery was

842 fewer turtle interactions (857 turtles – 15 turtles). This is 54% lower than the upper bound estimate (842 vs. 1826 turtles).

Net Spillover Effect if Hawaii Shallow-Set Longline Swordfish Fishery Effort Increased to 5500 Sets

We are asked to consider the spillover effects if the Hawaii shallow-set longline swordfish fishery were to conduct 5500 sets annually (WPRFMC, 2011). If Hawaii shallow-set longline swordfish fishery effort increases to 5500 sets, what would be the impacts on fresh swordfish

Table 4b.— Impacts to sea turtle interactions attributed to higher Hawaii production during the reopened period for the Hawaii shallow-set longline swordfish fishery (2005-2008) – lower bound.

Countries that Export Fresh Swordfish to the United States	2005-2008 U.S. Fresh Imports Weight	Change in Total Fresh Imports: Closure vs. Reopened (mt)	Turtle Bycatch Rate (turtle interactions per 1000 hooks)			Swordfish CPUE (mt/1000 hooks)	Annual Average Reduction in Turtle Interactions Based on Lower U.S. Imports		
			Overall	Leather-back	Logger-head		Overall	Leather-back	Logger-head
Panama	22%	282	0.70	0.03	0.03	0.80*	245	9	11
Canada	17%	218	0.96	0.10	0.75	0.81	259	27	202
Mexico	9%	115	0.08	0.01	0.06	1.04**	9	1	7
Chile	9%	115	0.016	0.013	0.003	1.04**	2	1	0
Brazil	8%	102	0.06	0.01	0.03	1.61	4	1	2
Ecuador	8%	102	1.10	0.04	0.05	0.80*	140	5	6
Costa Rica	6%	77	1.20	0.04	0.05	0.80*	115	4	5
South Africa	4%	51	0.06	0.01	0.03	1.61***	2	0	1
Uruguay	4%	51	0.06	0.01	0.03	0.80	4	1	2
Australia	4%	51	0.011	0.002	0.008	0.48	1	0	1
10 Major Countries	91%	1165					780	51	237
Total	**100%**	**1281**					**857**	**56**	**261**
By Ocean (according to country's fishing ground)									
Pacific							512	21	30
Atlantic							268	30	207
10 Major Countries							**780**	**51**	**237**
Misc.							77	5	24
Total							**857**	**56**	**261**
Fishery		**Hawaii Fresh Production: Closure vs. Reopened (mt)**	**Turtle Bycatch Rate (turtle interactions per 1000 hooks)**			**Swordfish CPUE (mt/1000 hooks)**	**Annual Average Increase in Turtle Interactions Based on Higher Hawaii Production**		
			Overall	**Leather-back**	**Logger-head**		**Overall**	**Leather-back**	**Logger-head**
Hawaii		**1281**	0.013	0.003	0.009	1.13	**15**	**4**	**10**
Net Reduction (Annual Average) in Sea Turtle Interactions During the Reopened of Hawaii Swordfish Fishery							**842**	52	251

Note 1: *Assume the same as Uruguay. **Assume the same as Hawaii shallow-set longline swordfish fishery: bycatch rate (1994-2002) and CPUE (1992-2002) in Hawaii before the new U.S. technology regulations were established in 2004, when the Hawaii fleet was still using J hooks and squid bait. *** Assume the same as Brazil.

Sources for current Hawaii shallow-set longline swordfish fishery bycatch and CPUE: Projected sea turtle captures and mortalities estimated in the shallow-set fishery, NMFS PRD July 2011 and swordfish 2005-2008 catch data, NMFS.

Note 2: Countries that fish in Pacific include: Panama, Mexico, Chile, Ecuador, Costa Rica, and Australia; countries that fish in the Atlantic include: Canada, Brazil, South Africa, and Uruguay.

imports and turtle interactions? Using the same methodology as in the previous section and based on assumptions presented below for the swordfish market, we estimate the market transfer effect in terms of the number of turtle interactions associated with the production level of 5500 sets.

It is important to note that, however, the magnitude of spillover effect would depend on how Hawaii shallow-set longline swordfish production is linked to the production of the rest of the world. If higher Hawaii shallow-set longline swordfish production is capable of completely displacing other nations' production by the same amount, the maximum reduction in turtle interactions would occur. Therefore, the scenario presented in this analysis can be considered the maximum reduction in turtle interactions worldwide if the Hawaii shallow-set longline swordfish fishery were able to fish 5500 sets annually. See Section V for a detailed analysis of the potential effort changes in foreign fleets operating in the North and central Pacific (where the Hawaii shallow-set longline swordfish fishery operates) as a result of U.S. effort increases in this fishery.

The assumptions are as follows:

1) U.S. swordfish consumption would be stable at the average of 2005-2008 levels, i.e., approximate average of 13,000 mt per year or continue to decline but with a minimum of 7,472 mt. As a result, increased swordfish production of 3927 mt in the Hawaii shallow-set longline swordfish fishery (associated with the 5500-set effort level) plus the current U.S. swordfish production (3545 mt) can be 100% absorbed by the domestic demand and displacing some imports.

2) Hawaii fresh swordfish production would replace U.S. fresh swordfish imports one-for-one. This assumption is supported by:

    a) U.S. customers prefer U.S.-produced swordfish because of various quality attributes (e.g., freshness, patriotism, etc.). When Hawaii swordfish production was at its historical high, the entire amount produced was consumed in the U.S. domestic market.

    b) U.S. product displaced foreign product one-for-one during and after the Hawaii shallow-set longline swordfish fishery closure (as shown in Table 2).

    c) The U.S. still needs to import a substantial amount of fresh swordfish for domestic consumption. If the Hawaii shallow-set longline swordfish fishery were able to fish 5500 sets in 2009, that would only represent 58% of U.S. fresh consumption and the U.S. would still import almost 4000 mt of fresh swordfish.

    d) Demand for swordfish is price inelastic. Changes in price have a relatively small effect on the quantity demanded, i.e., consumers are relatively insensitive to price changes. As mentioned in Rausser et al. (2009), the extent to which the Hawaii closure would cause higher U.S. imports may be influenced by the own-price elasticity of demand for swordfish. If the demand is price inelastic, this increases the likelihood of a market transfer effect. They estimated the own-price elasticity for fresh swordfish demand in the United States to be price-inelastic (-0.40 in 1990-2005 and -0.38 in 2001-2004). Several studies of demand for seafood and tuna also support this assumption. Cheng and Capps (1988) found that U.S. demand for finfish is price-inelastic (-0.67). Eales, Durhan, and Wessells (1997) also found the demand for high-value fresh fish in Japan is price-inelastic (-0.46 to -0.99). In addition, Wessells and Wilen (1994) and Johnson, Durham, and Wessells (1998) studied the demand for tuna in Japan and both found the demand to be price- inelastic (own-price elasticity is -0.93 and -0.85, respectively).

3) Hawaii swordfish production would not change the world price appreciably because Hawaii is a world price taker for swordfish instead of price setter. Hawaii production only constitutes a small percentage of world production. If Hawaii production were to increase, additional production would be absorbed by the U.S. mainland or foreign markets and the world price would not change significantly. As shown in 1993 when Hawaii swordfish production was at its historical high of 6117 mt, it only represented 7% of total world production. If the Hawaii shallow-set longline swordfish fishery were able to fish 5500 sets in 2009, this would represent only 5% of world production in 2009.

Based on the above assumptions and facts, higher Hawaii swordfish production would be completely offset by lower fresh imports.

a. Turtle Interactions

Based on Hawaii shallow-set longline swordfish fishery logbook statistics, the average number of hooks per set for U.S. longline vessels landing in Hawaii and targeting swordfish was 876 hooks between 2005 and 2008. For 5500 sets, this yields an estimate of 4,818,000 hooks. In addition, actual Hawaii shallow-set longline swordfish fishery capture data from NMFS and 100% observer coverage in that fishery indicates that the 2005 to 2008 average swordfish CPUE was 1.133 and the turtle bycatch rate was 0.013[9]. This would produce an annual average 5461 mt of swordfish and an annual average 63 turtle interactions (Table 5a).

Table 5a shows the reduction in turtle interactions based on a reduction of 5461 mt in fresh swordfish imports. The total reduction in turtle interactions is estimated to be 7848 turtles. Therefore, the net annual average reduction in turtle interactions associated with 5500 sets of swordfish production in the Hawaii shallow-set longline swordfish fishery would be 7785 turtles (7848 turtles – 63 turtles).

[9] Sources for Hawaii shallow-set longline swordfish fishery bycatch and CPUE: Projected sea turtle captures and mortalities estimated in the shallow-set fishery, NMFS PRD July 2011 and swordfish 2005-2008 catch data, NMFS.

b. Turtle Interactions by Ocean

Table 5a shows the estimated reduction in turtle interactions by ocean. Among the estimated annual average of 7140 fewer turtle interactions from the 10 nations that make up 91% of U.S. fresh imports, 4970 interactions (70%) would be saved in the Pacific Ocean and 2170 interactions (30%) would be saved in the Atlantic Ocean.

c. Leatherback and Loggerhead Turtle Interactions

Table 5a also shows the estimated leatherback and loggerhead interactions if the Hawaii shallow-set longline swordfish fishery fishes 5500 sets of swordfish. The reductions in interactions due to lower imports are estimated to be an annual average of 489 leatherbacks and 2160 loggerheads. The increased interactions as a result of higher production in this fishery are estimated to be an annual average of 17 leatherbacks and 43 loggerheads.

d. Leatherback and Loggerhead Turtle Interactions by Ocean

Among the estimated annual average of 445 leatherback interactions from the 10 nations that make up 91% of U.S. fresh imports, approximately 204 (46%) would be in the Pacific Ocean and 241 (54%) would be in the Atlantic Ocean. For loggerhead interactions, among the estimated annual average of 1965 loggerhead interactions, 291 (15%) would be in the Pacific Ocean and 1674 (85%) would be in the Atlantic Ocean.

Table 5a.— Impacts to sea turtle interactions associated with 5500 sets annually in Hawaii shallow-set longline swordfish fishery – upper bound.

Countries that Export Fresh Swordfish to the United States	2005-2008 U.S. Fresh Imports Weight	Change in Total Fresh Imports (mt)	Turtle Bycatch Rate (turtle interactions per 1000 hooks)			Swordfish CPUE (mt/1000 hooks)	Annual Average Reduction in Turtle Interactions Based on Lower U.S. Imports		
			Overall	Leather-back	Logger-head		Overall	Leather-back	Logger-head
Panama	22%	1200	1.80	0.07	0.08	0.08*	2687	97	121
Canada	17%	928	1.82	0.19	1.42	0.81	2087	220	1627
Mexico	9%	491	0.17**	0.03**	0.13**	1.04**	82	14	62
Chile	9%	491	0.034	0.027	0.006	1.04**	16	13	3
Brazil	8%	437	0.12	0.03	0.07	1.61	33	8	19
Ecuador	8%	437	2.35	0.08	0.11	0.08*	1277	46	57
Costa Rica	6%	328	2.20	0.08	0.10	0.08*	897	32	40
South Africa	4%	218	0.12***	0.03***	0.07***	1.61***	17	4	9
Uruguay	4%	218	0.12***	0.03***	0.07***	0.80	33	8	19
Australia	4%	218	0.024	0.004	0.018	0.48	11	2	8
10 Major Countrie	91%	4968					7140	445	1965
Total	**100%**	**5461**					**7848**	**489**	**2160**
By Ocean									
Pacific							4970	204	291
Atlantic							2170	241	1674
10 Major Countries							**7140**	**445**	**1965**
Misc							708	44	195
Total							**7848**	**489**	**2160**
Fishery		**Change in Hawaii Fresh Production (mt)**	**Turtle Bycatch Rate (turtle interactions per 1,000 hooks)**			**Swordfish CPUE (mt/1,000 hooks)**	**Annual Average Increase in Turtle Interactions Based on Higher Hawaii Production**		
			Overall	**Leather-back**	**Logger-head**		**Overall**	**Leather-back**	**Logger-head**
Hawaii		**5461**	0.013	0.003	0.009	1.13	**63**	**17**	**43**
Net Reduction (Annual Average) in Sea Turtle Interactions Associated with 5500 Sets of Swordfish in Hawaii							**7785**	472	2117

Note 1: *Assume the same as Uruguay. **Assume the same as the Hawaii shallow-set longline swordfish fishery: bycatch rate (1994-2002) and CPUE (1992-2002) in Hawaii before the new U.S. technology regulations were established in 2004, when the Hawaii fleet was still using J hooks and squid bait. *** Assume the same as Brazil.
Sources for current Hawaii shallow-set longline swordfish fishery bycatch and CPUE: Projected sea turtle captures and mortalities estimated in the shallow-set fishery, NMFS PRD July 2011 and swordfish 2005-2008 catch data, NMFS.
Note 2: Countries that fish in Pacific include: Panama, Mexico, Chile, Ecuador, Costa Rica, and Australia; countries that fish in the Atlantic include: Canada, Brazil, South Africa, and Uruguay.

Table 5b shows that the lower bound estimate of the reduction in turtle interactions associated with 5500 Hawaii shallow-set longline swordfish sets is 3654 turtles. After taking into account the 63 turtle interactions in that fishery, the net annual average reduction in turtle interactions would be 3591 turtles (3654 turtles – 63 turtles). This is 54% lower than the upper bound estimate (3591 turtles vs. 7785 turtles).

Table 5b.— Impacts to sea turtle interactions associated with 5500 sets annually in Hawaii shallow-set longline swordfish fishery – lower bound.

Countries that Export Fresh Swordfish to the United States	2005-2008 U.S. Fresh Imports Weight	Change in Total Fresh Imports (mt)	Turtle Bycatch Rate (turtle interactions per 1000 hooks)			Swordfish CPUE (mt/1000 hooks)	Annual Average Reduction in Turtle Interactions Based on Lower U.S. Imports		
			Overall	Leather-back	Logger-head		Overall	Leather-back	Logger-head
Panama	22%	1200	0.70	0.03	0.03	0.80*	1045	38	47
Canada	17%	928	0.96	0.10	0.75	0.81	1102	116	859
Mexico	9%	491	0.08	0.01	0.06	1.04**	39	6	29
Chile	9%	491	0.016	0.013	0.003	1.04**	8	6	1
Brazil	8%	437	0.06	0.01	0.03	1.61	16	4	9
Ecuador	8%	437	1.10	0.04	0.05	0.80*	598	22	27
Costa Rica	6%	328	1.20	0.04	0.05	0.80*	489	18	22
South Africa	4%	218	0.06	0.01	0.03	1.61***	8	2	4
Uruguay	4%	218	0.06	0.01	0.03	0.80	16	4	9
Australia	4%	218	0.011	0.002	0.008	0.48	5	1	4
10 Major Countries	91%	4968					3324	216	1011
Total	**100%**	**5461**					**3654**	**238**	**1111**
By Ocean									
Pacific							2183	90	130
Atlantic							1141	126	881
10 Major Countries							**3324**	**216**	**1011**
Misc							330	22	100
Total							**3654**	**238**	**1111**
Fishery		**Change in Hawaii Fresh Production (mt)**	**Turtle Bycatch Rate (turtle interactions per 1,000 hooks)**			**Swordfish CPUE (mt/1,000 hooks)**	**Annual Average Increase in Turtle Interactions Due to Higher Hawaii Production**		
			Overall	**Leather-back**	**Logger-head**		**Overall**	**Leather-back**	**Logger-head**
Hawaii		**5461**	0.013	0.003	0.009	1.13	**63**	**17**	**43**
Net Reduction (Annual Average) in Sea Turtle Interactions Associated with 5500 Sets of Swordfish in Hawaii							3591	221	1068

Note 1: *Assume the same as Uruguay. **Assume the same as the Hawaii shallow-set longline swordfish fishery: bycatch rate (1994-2002) and CPUE (1992-2002) in Hawaii before the new U.S. technology regulations were established in 2004, when the Hawaii fleet was still using J hooks and squid bait. *** Assume the same as Brazil.
Sources for current Hawaii shallow-set longline swordfish fishery bycatch and CPUE: Projected sea turtle captures and mortalities estimated in the shallow-set fishery, NMFS PRD July 2011 and swordfish 2005-2008 catch data, NMFS.
Note 2: Countries that fish in the Pacific include: Panama, Mexico, Chile, Ecuador, Costa Rica, and Australia; countries that fish in the Atlantic include: Canada, Brazil, South Africa, and Uruguay.

RESULT II - SPILLOVER EFFECTS FROM PRODUCTION DISPLACEMENT

Production Trends in the North and Central Pacific Oceans

This section examines swordfish production and sea turtle bycatch in the north and central Pacific Ocean to identify impacts of market transfer/spillover effects within the area where the Hawaii swordfish fleet fishes.

The majority of U.S. swordfish production occurs in the eastern central Pacific, with minor production in the northeast Pacific using fishing areas classified by the U.N. Food and

Agriculture Organization (FAO). Appendix B shows these areas in a map[10]. Figure 5 divides the total swordfish production in the Pacific Ocean into three areas: 1) the area where U.S. primarily targets swordfish, i.e., the eastern central and northeast Pacific, 2) the western central and northwest Pacific, and 3) southwest and southeast Pacific. Figure 5 shows that production in the eastern central and northeast Pacific (where the Hawaii shallow-set longline swordfish fishery is located) has remained relatively stable or has slightly declined since 1996, whereas the western central and northwest Pacific is showing a strong increasing trend since 1996. In 2009, the total swordfish production from North and central Pacific (i.e., combining 1 and 2 above) reached 28,757 mt, almost double that of the early and mid-1990s.

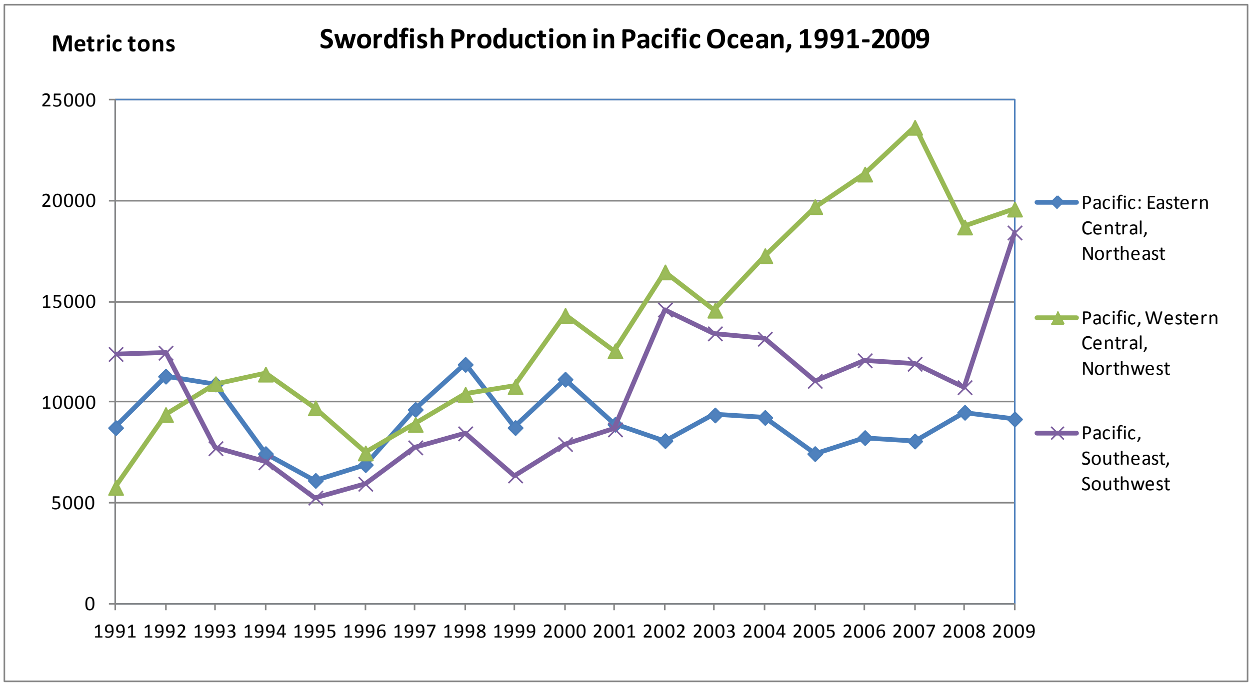

Figure 5.— Global swordfish production in Pacific Ocean by area, 1991-2009. Source: FAO Fisheries Global Information System.
http://www.fao.org/figis/servlet/TabLandArea?tb_ds=Capture&tb_mode=TABLE&tb_act=SELECT&tb_grp=COUNTRY

Many studies have determined that a single stock of leatherbacks and a single stock of loggerheads migrate across the North Pacific Ocean between west and east (Benson et al., 2007, Polovina et al., 2004, and Kobayashi et al., 2008). Figures 6 and 7 show the loggerhead and leatherback migration route in the North Pacific. Therefore, even if the Hawaii shallow-set longline swordfish fishery were completely closed, swordfish production in the North Pacific by other countries would still continue (shown in Figs. 5 and 8) and impact the same stock of turtles to some extent. Thus, the amount of sea turtle bycatch in these areas is expected to increase as the production increases in the western central and northwest Pacific.

[10] We define fishing areas using the FAO zoning scheme because the production data are obtained from an FAO database. The FAO East and West Pacific zones are defined differently than those of the Inter-American Tropical Tuna Commission and the Western and Central Pacific Fisheries Commission. In the geographic designations defined by the latter organizations, most Hawaii swordfish production occurs in the western Pacific Ocean.

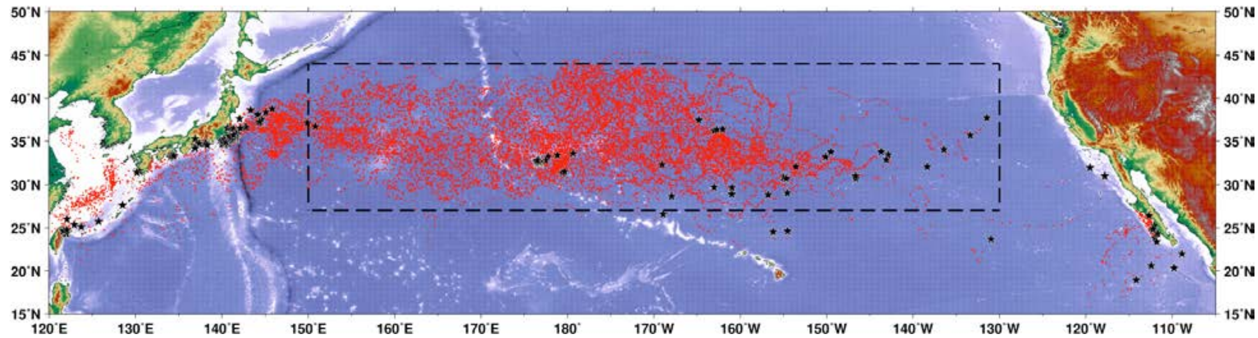

Figure 6.— Map of North Pacific Ocean and 186 satellite-tagged loggerhead sea turtle locations (red) covering the time span January 26, 1997 – July 1, 2006.
Dashed line delineates grid used for pelagic habitat study, 150°E– 130°W longitude, 27°N–44°N latitude. Stars indicate release points for individual tracks. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.) Kobayashi et al. (2008).

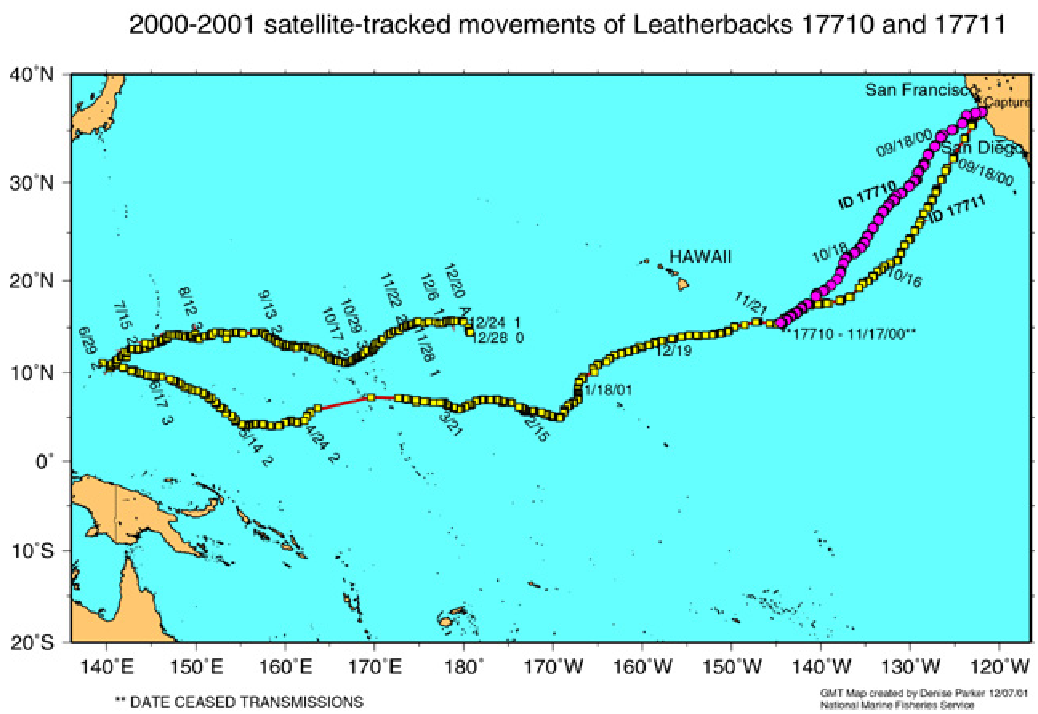

Figure 7.--2000-2001 Satellite-Tracked Movements of Leatherbacks.
Source: New International Leatherback Turtle Research Initiative in Papua New Guinea, Southwest Fisheries Science Center, NOAA. http://swfsc.noaa.gov/textblock.aspx?Division=PRD&ParentMenuId=212&id=3994

Production Displacement Analysis

The previous section demonstrates that the increase in Hawaii fresh swordfish production associated with an effort increase to 5500 sets in the Hawaii shallow-set longline swordfish fishery can displace foreign fresh swordfish one-for-one in the U.S. fresh swordfish market. This will create positive spillover effects on sea turtles assuming no change in U.S. swordfish consumption. However, U.S. swordfish imports were harvested in different oceans by different countries, and the estimate of spillover effects above is in a global scale (including various oceans). If one wants only to examine the spillover effects on sea turtle stocks in the fishing grounds where the Hawaii shallow-set longline swordfish fleet fishes, we need to investigate the fishing activities of all the fleets that operate in those areas and the sea turtle bycatch in these fleets. If the decline in Hawaii swordfish production results in a production increase in foreign fleets and if the sea turtle bycatch rates of those foreign fleets are higher, spillover effects can occur. Therefore, in this section, our analysis focuses on the swordfish production and sea turtle interactions in the Pacific Ocean areas where the Hawaii shallow-set longline swordfish fleet and its competitor foreign fleets fish. Because multiple fleets fish for the same stock, they may conduct any number of actions in response to the changes in the market and in U.S. production (Hawaii represented the majority (74%) of all U.S. Pacific Ocean landings prior to the fishery closure). Therefore, it is important to determine the extent to which foreign fleets would react to production changes in the U.S. fleets so that we can estimate the spillover effects under different production levels in the Hawaii shallow-set longline swordfish fleet, such as an increase in effort to 5500 sets.

This section focuses on the likely response of foreign fleets in the North and central Pacific, since this area is where most of the Hawaii shallow-set longline swordfish fleet fishes.

To determine the likely change in foreign fleet behavior, we perform a statistical analysis of historical production trends in the North and central Pacific (details of the statistical results are shown in Appendix D).[11] All the data used in the statistical analysis is obtained from the FAO Fisheries Global Information System. Figure 8 shows U.S. and non-U.S. swordfish production in the North and central Pacific from 1991 to 2009[12]. The time series suggests a negative correlation between U.S. and non-U.S. production during that time period. That is, an increase in U.S. production is associated with a decrease in foreign fleet production.

To test whether U.S. and non-U.S. production are correlated statistically, we look at the Pearson Correlation between non-U.S. and U.S. production from 1991 to 2009:

$$r_{XjYj}$$

Y_j is non-U.S. production in period j, and Xj is U.S. production in period j, where j = 1991 to 2009 (N = 19). The correlation $r_{XjYj} = -0.711$ is significant at the 99% level, indicating that the production of the non-U.S. fleets in the North and central Pacific is negatively and highly correlated with U.S. production.

[11] All the data used in the statistical analysis are obtained from the FAO Fisheries Global Information System.

[12] We use data from 1991 in the graph and for the statistical analysis below because 1991 was the first year of the federal logbook program in the Hawaiii longline fishery. It is believed that the reported Hawaii (U.S. Pacific) catch data are more reliable since then.

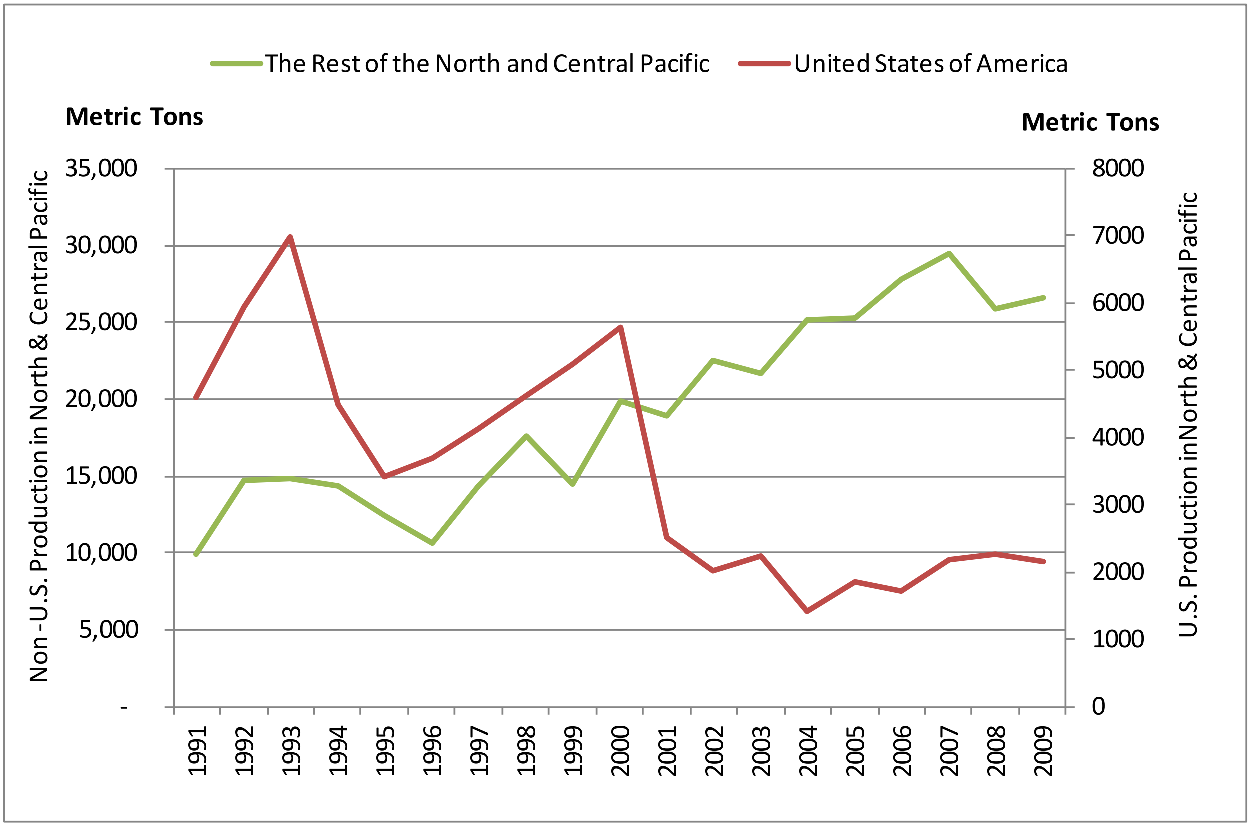

Figure 8. —U.S. swordfish production vs. other countries' production in the North and central Pacific Ocean (1991-2009) Source: FAO Fisheries Global Information System.
http://www.fao.org/figis/servlet/TabLandArea?tb_ds=Capture&tb_mode=TABLE&tb_act=SELECT&tb_grp=COUNTRY

The next step in the analysis is to establish causality: did non-U.S. swordfish production indeed respond to the changes of U.S. production? If it did, to what degree? An increasing trend in non-U.S. production may have existed regardless of the changes in U.S. production. However, if the de-trended changes in non-U.S. production are still associated with U.S. production, it may suggest that non-U.S. production was indeed linked to U.S. production. Therefore, we conduct a statistical analysis to test the hypothesis that the change in U.S. production results in displacement of non-U.S. production. First, we estimate the trend in non-U.S. production independent of U.S. regulation. Second, we test whether the de-trended changes in non-U.S. production are significantly related to U.S. production.

Using the period before the Hawaii shallow-set longline fishery closure (1991 to 2000), we estimate the non-U.S. production time trend. This trend represents non-U.S. production without any regulatory impact. The equation is specified as follows:

$$Y_j = a + bT$$

Y_j is non-U.S. production in period j, where j = 1991 to 2000 (N = 10), and T stands for year. The regression result from the equation shows that the coefficient b = 603, significant at the 90% level, indicates the positive trend in production over time. The detailed result is presented in Model 1 in Appendix D.

The residuals of this equation represent the difference between actual non-U.S. production and the prediction from the time trend estimated in the above equation (Y_j-$\hat{Y}j$). Figure 9 shows the residuals from the estimated time period (1991 to 2000) and also the period during and after the Hawaii shallow-set longline fishery closure (2001 to 2009).

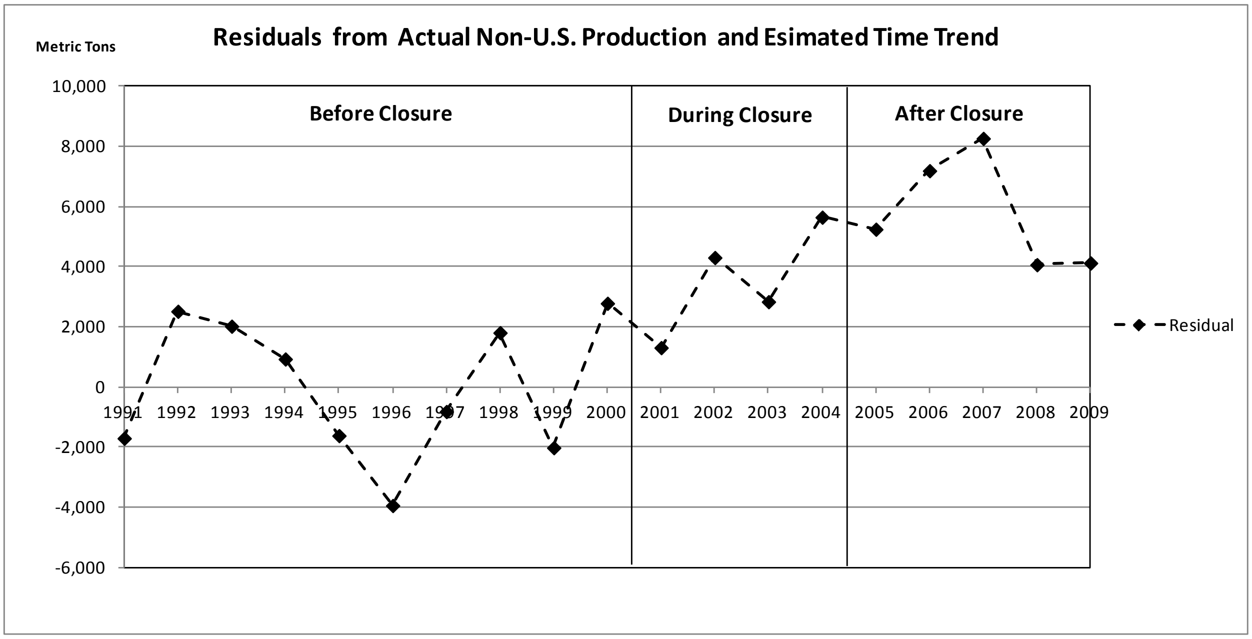

Figure 9.—Residuals from actual non-U.S. production and estimated time trend (1991-2009).

We then test whether the non-U.S. production residuals are related to U.S. production. A significant coefficient resulting from this regression would imply that U.S. production affects non-U.S. production in the North and central Pacific. The equation is specified as follows:

$$Y_j - \hat{Y}_j = \boldsymbol{c} + d\,X_j$$

X_j stands for U.S. production in period *j*, where *j* = 1991 to 2009 (*N* = 19). The coefficient *d* = -1.04 is significant at the 95% level. The detailed result is presented in Model 2 in Appendix D. This result indicates that U.S. production displaces non-U.S. production in the North and central Pacific nearly one-for-one (coefficient = -1.04). The coefficient of the equation implies that, on the margin, a decrease of one unit of U.S. production causes an increase of 1.04 units of non-U.S. production, and vice versa. The regression results suggest that the displacement between U.S. swordfish production and non-U.S. swordfish production in the North and central Pacific exists.

Based on the results from above regression analysis, we can assume that an increase in one unit of Hawaii shallow-set longline swordfish fleet production will prompt a one-unit decrease in foreign fleet production (i.e., one-for-one displacement) in the North and central Pacific.

Net Spillover Effect under Different Production Levels

Using this result (i.e., one-to-one displacement), we estimate the spillover effects associated with the Hawaii shallow-set swordfish fishery under different production levels. To estimate the spillover effect associated with an increase in Hawaii shallow-set longline swordfish fishery production to 5500 sets from the current level (1761 mt caught in 2009), we perform the following analysis:

1) Estimate the number of sea turtle interactions for all the fleets/countries that fish in the North and central Pacific based on the current (2009) production level and bycatch ratio of each individual country;
2) Estimate Hawaii shallow-set longline swordfish fishery production at the effort level of 5500 sets; that is, 5461 mt;
3) Assume one-to-one displacement for the increased Hawaii swordfish production (3700 mt = 5461 mt – 1761 mt) which is proportionally deducted from each country;
4) Estimate the number of sea turtle interactions for all the fleets/countries based on their production levels when the Hawaii shallow-set longline swordfish fishery is at the 5500 set effort level; and
5) Estimate the net change by comparing sea turtle bycatch in these two scenarios.

First, we estimate the number of sea turtle interactions for each country that fishes in the North and central Pacific based on 2009 production levels. Table 6 shows estimated turtle interactions in the North and central Pacific in 2009, using data on 2009 swordfish production in the north and central Pacific by the major producing countries (U.S., Japan, Taiwan, China, Korea, Mexico, Philippines, Indonesia, Australia, representing 95% of production in the region) and their corresponding bycatch rates. For 95% of production, we estimate about 1781 sea turtle interactions annually. We apply a weighted average bycatch rate to the remaining 5% of production. The analysis estimates 1,866 turtle interactions resulting from swordfish production in the north and central Pacific in 2009.

Table 6.— Estimated north and central Pacific turtle interactions in 2009 associated with swordfish production.

Top Countries that Produce Swordfish in North & Central Pacific	2009 Production Weight in North & Central Pacific	Production (mt)	Turtle Bycatch Rate (turtle interactions per 1000 hooks)	Swordfish CPUE (mt/1000 hooks)	Annual Turtle Interactions
Top Swordfish Production Countries in Eastern Central and Northeast Pacific					
Hawaii	6%	1761	0.013	1.13	20
The rest of United States	1%	404	0.013	1.13	5
Japan	7%	2072	0.009	0.36	52
Taiwan	6%	1675	0.024	0.33	122
China	4%	1137	0.024	0.24	114
Korea	3%	758	0.024**	0.24**	76
Mexico	3%	738	0.174*	1.04*	124
Top Swordfish Production Countries in Western Central and Northwest Pacific					
Japan	22%	6313	0.009	0.36	158
Philippines	19%	5530	0.024**	0.24**	553
Taiwan	12%	3334	0.024	0.33	242
Indonesia	4%	1220	0.024**	0.24**	122
Australia	4%	1133	0.024	0.48	57
China	3%	882	0.024	0.24	88
Korea	2%	489	0.024**	0.24**	49
Major Production Countries	95%	27,446			1781
Total	**100%**	**28,757**			**1866**

Notes: *Assume the same as the Hawaii shallow-set longline swordfish fishery: bycatch rate (1994-2002) and CPUE (1992-2002) in Hawaii before the new U.S. technology regulations were established in 2004, when the Hawaii fleet was still using J hooks and squid bait as Mexico is near the United States. ** Assume China's bycatch rate and swordfish CPUE**.** Most of the countries (except Hawaii and Mexico) that harvested swordfish in the central and north Pacific Ocean did not have reported upper and lower bycatch rates available. Therefore, there were no upper- and lower bound estimations of turtle interactions associated with swordfish production. Mexico's bycatch rates were assumed to be the same as those of Hawaii and the estimated turtle interactions were based on the interaction rate with J hooks.

Table 7 shows the results if the Hawaii shallow-set longline swordfish fishery production increases to 5500 sets (produces 5461 mt swordfish). This is an increase of 3700 mt from the 2009 production level (5461 mt – 1761 mt). Production by foreign fleets in the North and Central Pacific is assumed to decline by the same amount (with the amount of decrease distributed across fleets in the same pattern (percentage) as 2009) so that the total production in the north and central Pacific remains the same as 2009 (28,757 mt). If the Hawaii shallow-set longline swordfish fishery produces 5461 mt swordfish, and the rest of the north and central Pacific reduces its production by that same amount distributed across fleets in the same proportion as in 2009, then the Hawaii shallow-set longline swordfish fishery would contribute 19% of the total production in the north and central Pacific. This figure actually reflects the same ratio of Hawaii shallow-set longline swordfish fishery production to total production in the north and central Pacific as during the 1991–2000 period. Under this scenario, turtle interactions would total 1645 incidents. This implies 12% fewer turtle interactions (or 221 fewer interactions, Table 9) when compared with the number of interactions estimated from actual 2009 effort data (i.e., 1866 turtles in Table 6).

Table 7. —North and central Pacific turtle interactions assuming the Hawaii shallow-set longline swordfish fishery conducts 5500 sets and one-for-one replacement of non-U.S. production.

Top Countries that Produce Swordfish in North & Central Pacific	Production Weight (Adjusted Based on 2009 Weight in North & Central Pacific)	Production (mt)	Turtle Bycatch Rate (turtle interactions per 1000 hooks)	Swordfish CPUE (mt/1000 hooks)	Annual Turtle Interactions
Top Swordfish Production Countries in Eastern Central and Northeast Pacific					
Hawaii	19%	5461	0.013	1.13	63
The rest of United States	1%	346	0.013	1.13	4
Japan	6%	1774	0.009	0.36	44
Taiwan	5%	1434	0.024	0.33	104
China	3%	973	0.024	0.24	97
Korea	2%	649	0.024**	0.24**	65
Mexico	2%	632	0.174*	1.04*	106
Top Swordfish Production Countries in Western Central and Northwest Pacific					
Japan	19%	5404	0.009	0.36	135
Philippines	16%	4733	0.024**	0.24**	473
Taiwan	10%	2854	0.024	0.33	208
Indonesia	4%	1044	0.024**	0.24**	104
Australia	3%	970	0.024	0.48	48
China	3%	755	0.024	0.24	75
Korea	1%	419	0.024**	0.24**	42
Major Production Countries	95%	27,446			1570
Total	**100%**	**28,757**			**1645**

Note: Assume the same as Hawaii shallow-set longline swordfish fishery: bycatch rate (1994-2002) and CPUE (1992-2002) in Hawaii before the new U.S. technology regulations were established in 2004, when the Hawaii fleet was still using J hooks and squid bait as Mexico is near the United States. ** Assume China's bycatch rate and swordfish CPUE.

Currently, the Hawaii shallow-set longline swordfish fishery has the most restrictive regulations to minimize sea turtle bycatch of any fleet fishing in the North and central Pacific, including 100% observer coverage. As a result, the turtle interaction estimates for the Hawaii shallow-set longline swordfish fishery are very reliable. In addition, there are annual hard caps for the number of sea turtle interactions, and the fishery closes as soon as the turtle interaction cap is reached. In contrast, foreign fisheries have lower or no observer coverage, resulting in underestimation of turtle interactions in those fisheries.[13] The annual average sea turtle bycatch in the Hawaii shallow-set longline swordfish fishery is 25 turtles, about 1.5% of the total sea turtle bycatch in the North and central Pacific. Table 8 shows the results if all fisheries in the North and central Pacific had the same bycatch rate as the Hawaii fleet. Turtle interactions under this scenario would decline to 333. This scenario shows 82% lower turtle interactions (or 1533 fewer turtles, Table 9) when compared with the current level of 1866 turtles (from Table 6).

[13] Canada's swordfish and other tunas longline at-sea observer program's target coverage was 10% in 2010, http://www.dfo-mpo.gc.ca/csas-sccs/Publications/SAR-AS/2011/2011_057-eng.pdf.

Table 8. —Estimated turtle interactions if all longline fisheries in North and central Pacific had the same bycatch rate as the Hawaii shallow-set longline swordfish fishery.

Fishery	Production (mt)	Turtle Bycatch Rate (turtle interactions per 1000 hooks)	Swordfish CPUE (mt/1000 hooks)	Annual Turtle Interactions
North and Central Pacific Had Same Bycatch Rate as Hawaii Shallow-Set Longline Swordfish Fishery	**28,757**	0.013	1.13	**333**

Table 9.— Summary of sensitivity analysis.

	Annual Hawaii Swordfish Production (mt)	Annual Swordfish Production in North and Central Pacific (All Countries Combined) (mt)	Annual Turtle Interactions in North and Central Pacific (All Countries Combined)	Annual Reduction in Turtle Interactions (Number of Decrease from 2009)	Annual Reduction in Turtle Interactions (Percent of Decrease from 2009)
Current (2009) landings and sea turtle interactions (Table 6)	1761	28,757	1866	-	-
Scenario 1: Hawaii shallow-set longline swordfish fishery production increases to 5500 sets with one-for-one replacement of foreign production (Table 7)	5461	28,757	1645	221	12%
Scenario 2: Production by all countries if all had the same bycatch rate as the Hawaii shallow-set longline swordfish fishery (Table 8)	-	28,757	333	1533	82%

Comparison in Global Scale

To understand sea turtle bycatch in the North and central Pacific in a global context, we consider the total amount of sea turtle bycatch associated with swordfish production worldwide. Using the method and parameters as above (swordfish landings, swordfish CPUE, and sea turtle bycatch rate of individual countries), we estimate the total amount of sea turtle bycatch of the world swordfish production. First, we estimate the amount of sea turtle bycatch in the world's top 10 swordfish producing countries. On average, these top 10 countries represent 73% of worldwide production in 2005-2008; fleet-specific, sea turtle bycatch rates are available for most of these countries. For the remaining portion (27%) of worldwide production that does not have fleet-specific bycatch rates, we assume a bycatch rate equal to the weighted average sea turtle bycatch rate of the 73% that do. We estimate that worldwide turtle interactions associated with swordfish production worldwide total approximately 89,000[14] (Appendix C). Thus, sea turtle interactions associated with swordfish production in the North and central Pacific comprise about 2.1% of the worldwide total.

CONCLUSION AND DISCUSSION

The study examined, in 2 analyses the possible spillover effects associated with effort changes in the Hawaii shallow-set longline swordfish fishery: 1) an assessment of the market flow for U.S. domestic swordfish consumption during 3 time periods (before, during, and after the closure of the Hawaii shallow-set longline swordfish fishery), including associating the fresh swordfish supply from different sources (countries) to the amount of sea turtle bycatch in those fisheries in the 3 periods; 2) an investigation of the correlations between Hawaii swordfish production and production in the rest of the fisheries that share swordfish and sea turtles as common property in the North and central Pacific, including associating their swordfish production with sea turtle bycatch in different time periods.

The first part of this study indicates that higher Hawaii swordfish production results in lower demand for imported swordfish, which in turn reduces sea turtle bycatch worldwide because the sea turtle bycatch rates in the exporting countries' fleets are higher than that in the Hawaii shallow-set longline swordfish fishery. During the period when the Hawaii shallow-set longline swordfish fishery reopened (2005-2008, under fishing effort and sea turtle caps), annual average swordfish production increased by 1281 mt. This is estimated to have contributed to 1841 fewer turtle interactions worldwide by displacing foreign imports whose fisheries had higher sea turtle bycatch rates. Of this reduction of 1841 interactions, 1166 are estimated to occur in the Pacific Ocean and 509 occur in the Atlantic Ocean. In other words, higher Hawaii swordfish production reduced sea turtle bycatch. If the Hawaii shallow-set longline swordfish fishery effort were to increase to 5500 sets (the effort at the historical high level), it is expected that this output would replace imports from foreign countries worldwide. We estimate the net annual average reduction in turtle interactions associated with 5500 sets to be 7848 worldwide. Since the use of circle hooks and fish bait substantially reduces the turtle interactions, this study also provides the lower bound estimate of the change in sea turtle interactions if circle hooks and fish bait were commonly adopted by all the fisheries. This is about 54% lower than the upper bound estimate.

The second portion of this study suggests that non-U.S. fresh swordfish production in the North and central Pacific moves in the opposite direction of U.S. (mostly Hawaii) fresh swordfish production. This implies that reducing Hawaii shallow-set longline swordfish production through regulatory changes (closures and gear changes) did not cause an overall lower level of sea turtle bycatch in the North and central Pacific. This is because the Hawaii shallow-set longline swordfish fishery has one of the lowest sea turtle bycatch rates among the fleets fishing in the North and central Pacific. When the U.S. fleet reduced production, foreign fleets

[14] Our estimate of global turtle interactions is relatively low compared to other estimates. According to Lewison et al. (2004), it is estimated that at least 50,000 leatherbacks and 200,000 loggerheads worldwide were caught by pelagic longline gear in 2000. Although swordfish fleets are only one of many types of fleets that use longline gear, swordfish fisheries usually have higher sea turtle interaction rates because they operate at shallower depths.

increased production to maintain overall production levels. Conversely, an increase in effort in the Hawaii shallow-set longline swordfish fishery is expected to displace production by non-U.S. fisheries in the North and central Pacific. Econometric modeling indicates that Hawaii production would displace foreign fleet production in the North and central Pacific one-for-one. As such, the analysis indicates that 12% fewer turtle interactions (or 221 fewer interactions) would occur when compared with the current level of 1866 interactions.

The sea turtle bycatch rates for different fisheries are one of the critical elements for determining the magnitude and direction of the spillover effects. The bycatch rates used in this study are based on a limited number of studies conducted in certain time periods or locations that may not be strictly applicable to the entire fishery(ies). Some fisheries did not have any data on sea turtle bycatch; in these cases, we identify similar fisheries and assume the catch rates from those fisheries. In addition, production data may not be consistent with the export data for some fleets that use other countries' flags (fishing quota or rights) and the fish caught may be sold or reported as the production of the 'flag' countries. In this case, the sea turtle bycatch rate could be mis-represented as being associated with a different country than that in which it was actually produced. Nonetheless, the data that are available and the analysis herein suggest strong spillover (market transfer effects) from regulation of the Hawaii shallow-set longline fishery for swordfish.

ACKNOWLEDGMENTS

The authors would like to thank Samuel Pooley, Sarah Malloy, Alan Haynie, Kathryn Bisack, and Keith Bigelow for their review comments and expert assistance.

REFERENCES

Bartram, P. K., J. J. Kaneko, and K. Kucey-Nakamura.
2010. Sea turtle bycatch to fish catch ratios for differentiating Hawaii longline-caught seafood products. Marine Policy 34:145-149.

Benson, S. R., P. H. Dutton, C. Hitipeuw, B. Samber, J. Bakarbessy, and D. Parker.
2007. Post-nesting migrations of leatherback turtles (*Dermochelys coriacea*) from Jamursba-Medi, Bird's Head Peninsula, Indonesia. Chelonian Conserv. Biol. 6(1):150-154.

Brazner, J. C., and J. McMillan.
2008. Loggerhead turtle (*Caretta caretta*) bycatch in Canadian pelagic longline fisheries: relative importance in the western North Atlantic and opportunities for mitigation. Fish. Res. 91:310-324.

Cheng, H.-T., and O. Capps, Jr.
1988. Demand analysis of fresh and frozen finfish and shellfish in the United States. Agricultural & Applied Economics. American Journal of Agricultural Economics 70(3):533-542.

Eales, J. E., C. A. Durham, and C. R. Wessells.
1997. Generalized models of Japanese demand for fish. American Journal of Agricultural Economics 79(4):1153-1163.

Gilman, E., D. Kobayashi, T. Swenarton, N. Brothers, P. Dalzell, and I. Kinan-Kelly.
2007. Reducing sea turtle interactions in the Hawaii-based longline swordfish fishery. Biol. Conserv. 139:19-29.

Howell, E. A., D. R. Kobayashi, D. M. Parker, G. H. Balazs, and J. J. Polovina.
2008. Turtle Watch: a tool to aid in the bycatch reduction of loggerhead turtles *Caretta caretta* in the Hawaii-based pelagic longline fishery. Endangered Specific Research 5:267-278.

Indian Ocean Tuna Commission.
2006. Report of the Fifth Session of the IOTC Working Party on Billfish. Indian Ocean Tuna Commission. http://www.iotc.org/files/proceedings/2006/wpb/IOTC-2006-WPB-R%5BEN%5D.pdf.

Inter-American Tropical Tuna Commission (IATTC).
2006. The sea turtle bycatch mitigation program for the coastal longline fleets and preliminary results of circle hook experiments. Working Group on Bycatch, 5th Meeting. Busan, Korea.

Ito, R. Y., R. A. Dollar, and K. E. Kawamoto.
1998. The Hawaii-based longline fishery for swordfish, *Xiphias gladius*. NOAA Technical Report NMFS 142.

Johnson, A. J., C. A. Durham, and C. R. Wessells.
1998. Seasonality in Japanese household meat and seafood. Agribusiness: An International Journal 14(4):337-351.

Kobayashi, D. R., J. J. Polovina, D. M. Parker, N. Kamezaki, I.-J. Cheng, I. Uchida, P. H. Dutton, and G. H. Balazs.
2008. Pelagic habitat characterization of loggerhead sea turtles, *Caretta caretta,* in the North Pacific Ocean (1997–2006): insights from satellite tag tracking and remotely sensed data. J. Exp. Mar. Biol. Ecol. 356:96-114.

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

Morrissey, M. T.
2006. Mercury in seafood: facts and discrepancies. Food Technol. 60(8), 132.

Polovina, J. J., G. H. Balazs, E. A. Howell, D. M. Parker, M. P. Seki, and P. H. Dutton.
2004. Forage and migration habitat of loggerhead *(Caretta caretta)* and olive ridley *(Lepidochelys olivacea)* sea turtles in the central North Pacific Ocean. Fish. Oceanogr. 13(1):36-51.

Rausser, G. C., S. F. Hamilton, M. Kovach, and R. Stifter.
2009. Unintended consequences: the spillover effects of common property regulations. Marine Policy 33:24-39.

Sarmiento, C.
2006. Transfer function estimation of trade leakages generated by court rulings in the Hawaii longline fishery. Applied Economics 38:183-190.

Sea Turtle Conservancy.
2011. Information about sea turtles, their habitats and threats to their survival. http://www.conserveturtles.org/seaturtleinformation.php?page=loggerhead (accessed in November 15, 2011).

Wessells, C. R., and J..E. Wilen.
1994. Seasonal patterns and regional preferences in Japanese household demand for seafood. Canadian Journal of Agricultural Economics 42(1):87-103.

Western Pacific Regional Fishery Management Council.
2003. Pelagic Fisheries of the Western Pacific Region 2001 Annual Report.

Western Pacific Regional Fishery Management Council.
2008. Amendment 18 to the Fishery Management Plan for Pelagic Fisheries of the Western Pacific Region, Including a Draft Supplemental Environmental Impact Statement, Regulatory Impact Review, and Initial Regulatory Flexibility Act Analysis.

Western Pacific Regional Fishery Management Council.
2011. Pelagic Fisheries of the Western Pacific Region 2009 Annual Report.

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APPENDICES

Appendix A. Turtle Bycatch Rates and Swordfish CPUEs by Country and Sources

Fishery	Target Species	Depth of Set	Sea Turtle Impacted	Year	Type of Hook	Bycatch Rate (turle interact-ions per 1000 hooks)	CPUE (mt /1000 hooks)	Fishing Area	Gear
Hawaii	Swordfish	Shallow	Loggerhead, leatherback, olive ridley, green, unidentified	1994-2002	J	0.17[a]	1.04[a]	ECP	Longline
	Swordfish	Shallow	Leatherback	1994-2002	J	0.03[a]	1.04[a]		
	Swordfish	Shallow	Loggerhead	1994-2002	J	0.13[a]	1.04[a]		
Panama	Tuna/Billfish/Shark	Shallow	Eastern Pacific turtle	2005	J	1.80[b]	0.80*	ECP	Longline
	Tuna/Billfish/Shark	Shallow	Eastern Pacific turtle	2005	C	0.70[b]	0.80*		
Canada	Swordfish	Shallow	Loggerhead, leatherback, green, kemp's ridley, unidentifie	2005-2009	Mostly C	1.82[d]		NWA	Longline
	Swordfish	Shallow	Leatherback	2005-2009	Mostly C	0.19[d]			
	Swordfish	Shallow	Loggerhead	2005-2007	Mostly C	1.42[c]			
	Swordfish	Shallow	Loggerhead, leatherback, green, kemp's ridley, unidentifie	1999-2004	Mostly C	0.96[d]			
	Swordfish	Shallow	Leatherback	1999-2005	Mostly C	0.10[d]			
	Swordfish	Shallow	Loggerhead	1999-2006	Mostly C	0.75[e]			
	Swordfish			2004-2008	?		0.81[f]		
Mexico	Swordfish	Shallow	Loggerhead, leatherback, olive ridley, green, unidentified	1994-2002	J	0.17**	1.04**	ECP	Longline
	Swordfish	Shallow	Leatherback	1994-2002	J	0.03**	1.04**		
	Swordfish	Shallow	Loggerhead	1994-2002	J	0.13**	1.04**		
Chile	Swordfish	Shallow	Leatherback, loggerhead, green, and unidentified	2001-2005	J	0.03[g]	1.04**	SEP	Longline
	Swordfish	Shallow	Leatherback	2001-2005	J	0.03[g]	1.04**		
	Swordfish	Shallow	Loggerhead	2001-2005	J	0.01[g]	1.04**		
Brazil	Swordfish/Tuna		Leatherback, loggerhead, green, olive ridley and unidentif	2001-2005	?	0.12[h]		SWA	Longline
	Swordfish/Tuna		Leatherback	2001-2005	?	0.03[h]			
	Swordfish/Tuna		Loggerhead	2001-2005	?	0.07[h]			
	Swordfish			2004-2008	?		1.61[i]		
Ecuador	Tuna/Billfish/Shark	Shallow	Eastern Pacific turtle	2004-2005	J	2.35[b]	0.80*	SEP	Longline
	Tuna/Billfish/Shark	Shallow	Eastern Pacific turtle	2004-2005	C	1.10[b]	0.80*		
Costa Rica	Tuna/Billfish/Shark	Shallow	Eastern Pacific turtle	2004-2005	J	2.20[b]	0.80*	ECP	Longline
	Tuna/Billfish/Shark	Shallow	Eastern Pacific turtle	2004-2005	C	1.20[b]	0.80*		
South Afric	Swordfish/Tuna		Leatherback, loggerhead, green, olive ridley and unidentif	2001-2005	?	0.12***		SEA	Longline
	Swordfish/Tuna		Leatherback	2001-2005	?	0.03***			
	Swordfish/Tuna		Loggerhead	2001-2005	?	0.07***			
	Swordfish			2004-2008	?		1.61***		
Uruguay	Swordfish/Tuna		Leatherback, loggerhead, green, olive ridley and unidentif	2001-2005	?	0.12***		SWA	Longline
	Swordfish/Tuna		Leatherback	2001-2005	?	0.03***			
	Swordfish/Tuna		Loggerhead	2001-2005	?	0.07***			
	Swordfish			2004-2008	?		0.80[j]		
Australia	Swordfish/Tuna/S.Marlin	35-50m	Southwest Pacific loggerheads and greens	1997-2001	mixed	0.024[k]	0.48[l]	WCP	Longline
Spain	Swordfish	Shallow	Loggerhead	1999-2004	?	0.79[m]	0.40[f]	Various Atlantic	Longline
Italy	Swordfish	Shallow	Loggerhead	2004-2008	?	0.79****	0.40****	Mediterranean	Longline
Portugal	Swordfish	Shallow	Loggerhead	2004-2008	?	0.79****	0.36[f]	Various Atlantic	Longline
*Assume the same as Uruguay. **Assume the same as Hawaii. ***Assume the same as Brazil. ****Assume the same as Spain.									

Top Swordfish Production Countries in North and Central Pacific

Japan	Bigeye/Yellowfin Tuna	45-400m	Western Pacific green, olive ridley	2001-2004	?	0.009[n]	0.36[o]	Mostly NWP,ECP	Longline
Taiwan	Bigeye/Yellowfin Tuna/Billfish	35-250m	Western Pacific green, olive ridley	2001-2004	?	0.024[n]	0.33[p]	Mostly NWP,ECP	Longline
China	Bigeye/Yellowfin Tuna/Billfish	35-120m	Western Pacific green, olive ridley	2001-2004	?	0.024[n]	0.24[q]	Mostly ECP,WCP	Longline
Mexico	Swordfish	Shallow	Loggerhead, leatherback, olive ridley, green, unidentified	1994-2002	J	0.17**	1.04**	ECP	Longline
Korea	Bigeye/Yellowfin Tuna/Billfish	35-120m	Western Pacific green, olive ridley	2001-2004	?	0.024*****	0.24*****	ECP,WCP,SWP	Longline
Philippines	Bigeye/Yellowfin Tuna/Billfish	35-120m	Western Pacific green, olive ridley	2001-2004	?	0.024*****	0.24*****	WCP	Longline
Indonesia	Bigeye/Yellowfin Tuna/Billfish	35-120m	Western Pacific green, olive ridley	2001-2004	?	0.024*****	0.24*****	WCP	Longline
Australia	Swordfish/Tuna/S.Marlin	35-50m	Southwest Pacific loggerhead and green	1997-2001	mixed	0.024[k]	0.48[l]	WCP	Longline

Fishing Area: ECP-Eastern Central Pacific, WCP-Western Central Pacific, SEP-Southeast Pacific, NWP-Northwest Pacific, SWP-Southwest Pacific, NWA-Northwest Atlantic, SWA-Southwest Atlantic, SEA-Southeast Atlantic

[a] For Hawaii shallow-set longline swordfish fishery turtle bycatch 1994-2002 (J hook and squid bait) and CPUE = 13.29 fish/1000 hooks: Gilman E., D. Kobayashi, T. Swenarton, P. Dalzell, I. Kinan, and N. Brother. 2006. Efficacy and Commercial Viability of Regulations Designed to Reduce Sea Turtle Interactions in the Hawaii-based Longline Swordfish Fishery. 9 August 2006. Honolulu, Hawaii: Western Pacific Regional Fishery Management Council. For Hawaii average weight of swordfish 1992-2000 = 0.078mt/fish: Western Pacific Regional Fishery Management Council. 2005. Pelagic Fisheries of the Western Pacific Region: 2004 Annual Report. Prepared by the Pelagics Plan Team and Council staff. June 30. Honolulu, Hawaii: Western Pacific Regional Fishery Management Council.

[b] For Panama, Ecuador and Costa Rica bycatch: Inter-American Tropical Tuna Commission(IATTC). 2006. The sea turtle bycatch mitigation program for the coastal longline fleets and preliminary results of circle hook experiments. Working Group on Bycatch, 5th Meeting. Busan,

[c] For Canada loggerhead bycatch (upper bound): Paul, S.D., A. Hanke, S.C. Smith, and J.D. Nelison, 2010. An Examination of Loggerhead Sea Turtle (Caretta caretta) Encounters in the Canadian Swordfish and Tuna Longline Fishery, 2002-2008. Canadian Science Advisory Secretariat; Research Document 2010/88.

[d] For Canada overall and leatherback bycatch: Derived from observer data provided by Department of Fisheries and Oceans in Canada, 2005-2009. Use the ratio of total sea turtle interactions (leatherback, loggerhead, green, kemp's ridley and unidentified) from observer data to loggerhead from Paul et al. (2010) and ratio of leatherback from observer data to Paul et al. (2010).

[e] For Canada loggerhead bycath (lower bound): Brazner, John C., and James McMillan. 2008. Loggerhead Turtle (Caretta caretta) Bycatch in Canadian Pelagic Longline Fisheries: Relative Importance in the Western North Atlantic and Opportunities for Mitigation. Fisheries Research; 91: 310-324.

[f] For Canada CPUE: Ortiz M., M. Jamie, S. Paul, K. Yokawa, M. Neves, and M. Idrissi, 2010. An Updated Biomass Index of Abundance for North Atlantic Swordfish (Xiphias Gladius), For the Period 1963-2008. International Commission for the Conservation of Atlantic Tunas (ICCAT) Collective Volume of Scientific Papers, 65(1): 171-184.

[g] For Chile bycatch: Donoso, M. and P.H. Dutton, 2010. Sea Turtle Bycatch in the Chilean Pelagic Longline Fishery in the Southeastern Pacific: Opportunities for Conservation. Biological Conservation. 143: 2672-2684.

[h] For Brazil bycatch: Sales, G.; B.B. Giffoni, P.C.R. Barata. 2008. Incidental catch of sea turtles by the Brazilian pelagic longline fishery. Journal of the Marine Biological Association of the United Kingdom; 88(4): 853-864.

[i] For Brazil CPUE (2004-2008): Report of the 2009 Atlantic Swordfish Stock Assessment Session (Madrid, September 7 to 11, 2009). International Commission for the Conservation of Atlantic Tunas, Report of the Standing Committee on Research and Statistics (SCRS)/2009/016.

[j] For Uruguay CPUE (2004-2008): Report of the 2009 Atlantic Swordfish Stock Assessment Session (Madrid, September 7 to 11, 2009). International Commission for the Conservation of Atlantic Tunas, Report of the Standing Committee on Research and Statistics (SCRS)/2009/016.

[k] For Australia bycatch: Robins, C.M., S.J. Bache, and S.R. Kalish. 2002. Bycatch of Sea Turtles in Pelagic Longline Fisheries – Australia. Bureau of Rural Sciences Final report to the Fisheries Resources Research Fund, Agriculture, Fisheries, and Forestry. Canberra, Australia.

[l] For Australia CPUE: Calculated from D. Bromhead, and J. Findlay. 2003. National Tuna Fishery Report. Tuna and billfish fisheries of the eastern Australian fishing zone and adjacent high seas. SCTB16 Working Paper NFR-2. 16th Meeting of the Standing Committee on Tuna and Billfish. Mooloolaba, Queensland, Australia. (Table1, average of 1999–2002) by adjusting processed weight to whole weight (PW/0.89 ¼ WW).

[m] For Spain bycatch: Camiñas, Juan A., José C. Báez, Xulio Valeiras, and Raimundo Real. 2006. Differential Loggerhead By-catch and Direct Mortality due to Surface Longlines According to Boat Strata and Gear Type. Scientia Marina; 70(4): 661-665.

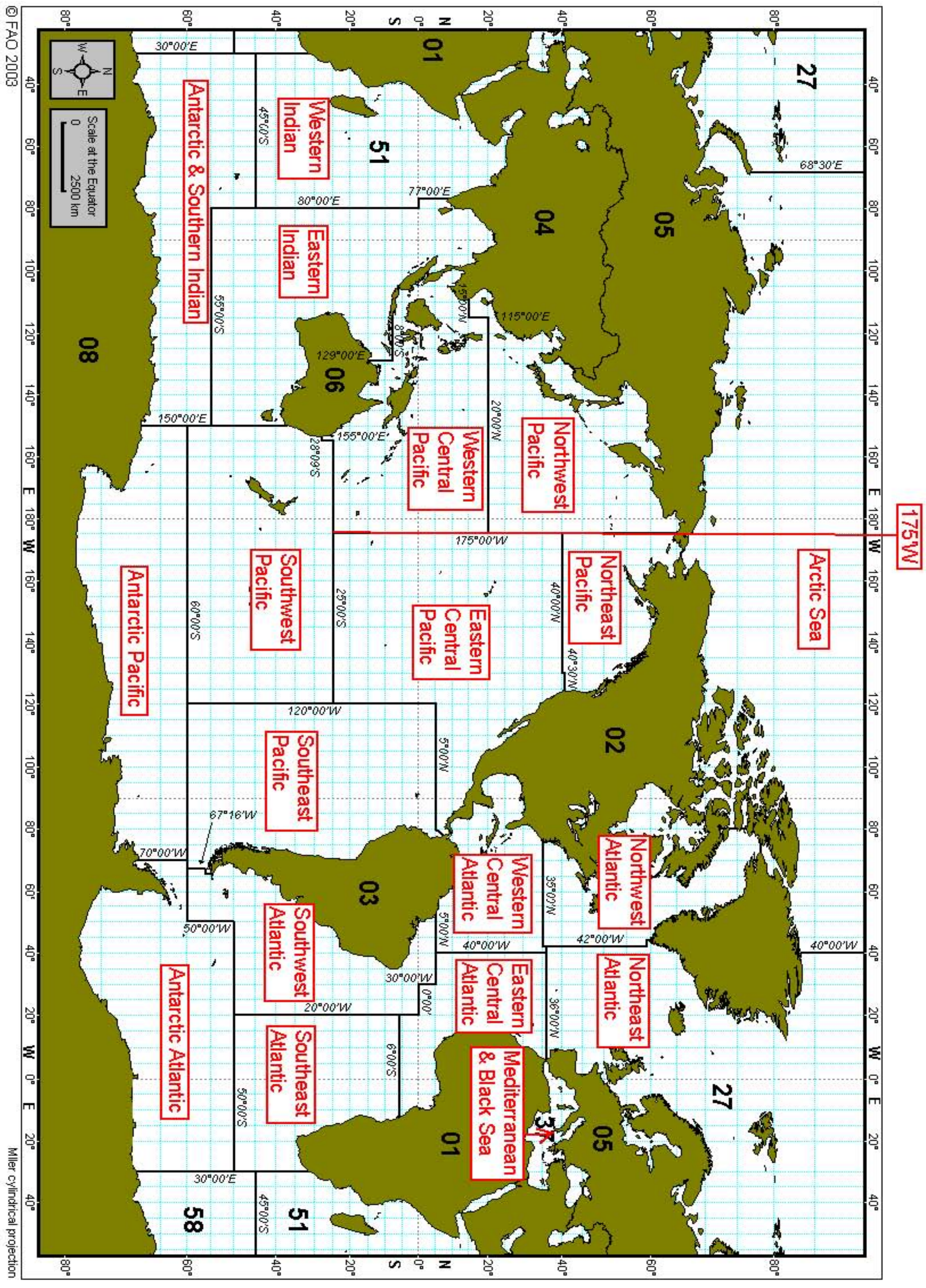
[n] For Japan, Taiwan, China bycatch (2001-2004): Secretariat of the Pacific Community observer data base. B. Molony, 2005.

[o] For Japan CPUE: Calculated from Table 2, 2001–2005 annual data longline vessels > 20 GT), H. Matsunaga, H. Okamoto, K. Uosaki, K. Sato, Y. Semba and N. Miyabe. WCPFC-SC2-2006, National Tuna Fishery Report, Japan. Scientific Committee Second Regular Session, Western and Central Pacific Fisheries Commission, 7–18 August, 2006. Manila, Philippines.

[p] For Taiwan CPUE: Calculated from 1993 to 2004 catch/effort statistics of Taiwan offshore longline fleet, Table 19, T. Lawson(Ed.), 2006. Draft Western and Central Pacific Fisheries Commission Tuna Fishery Yearbook 2005. Oceanic Fisheries Programme, Secretariat of the Pacific Community.

[q] For China CPUE: Calculated from X. Liuxiong, 2002. National Report of China. SCTB15 Working Paper NFR-14. 15th Meeting of the Standing Committee on Tuna and Billfish, 22–27 July 2002. Honolulu, HI (Table 1,3, average of 2000–2001).

Appendix B. FAO Fishing Areas.



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Appendix C. Worldwide Turtle Interaction Estimate

Top 10 Countries that Produce Swordfish in the World	2005-2008 Average World Production Weight	Production (mt)	Turtle Bycatch Rate (turtle interactions per 1000 hooks)	Swordfish CPUE (mt/1,000 hooks)	Annual Average Turtle Interactions
Spain	20%	21,677	0.788[a]	0.40[b]	42,554
Taiwan	14%	14,933	0.024	0.33	1086
Japan	12%	13,204	0.009	0.36	330
Italy	6%	6645	0.788*	0.40*	13,045
Philippines	5%	4875	0.024**	0.24**	487
Brazil	4%	3966	0.122	1.61	301
United States	3%	3545	0.013	1.13	41
Chile	3%	3415	0.034	1.04***	113
China	3%	.,927	0.024	0.24	293
Portugal	3%	2797	0.788*	0.36[b]	6099
Major Production Countries	73%	77,983			64,350
Total	**100%**	**107,523**			**88,726**

* Assume the same as Spain. **Assume the same as China. *** Assume the same as the Hawaii shallow-set longline swordfish fishery: bycatch rate (1994-2002) and CPUE (1992-2002) in Hawaii before the new U.S. technology regulations were established in 2004, when the Hawaii fleet was still using J hooks and squid bait as Mexico is near the United States.

[a] For Spain bycatch (1999-2004): Camiñas, Juan A., José C. Báez, Xulio Valeiras, and Raimundo Real. 2006. Differential Loggerhead By-catch and Direct Mortality due to Surface Longlines According to Boat Strata and Gear Type. Scientia Marina; 70(4): 661-665.

[b] For Spain and Portugal CPUE (2004-2008): Ortiz M., M. Jamie, S. Paul, K. Yokawa, M. Neves, and M. Idrissi, 2010. An Updated Biomass Index of Abundance for North Atlantic Swordfish (Xiphias Gladius), For the Period 1963-2008. International Commission for the Conservation of Atlantic Tunas (ICCAT) Collective Volume of Scientific Papers, 65(1): 171-184.

The remaining bycatch rates and CPUEs are listed in Appendix A.

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Appendix D. Statistical Results for Hawaii and North and Central Pacific Production

Data used in the statistical analysis include swordfish production in U.S. and non-U.S countries in the North and central Pacific Ocean before and after the Hawaii closure. Table D1 shows the time series data from 1991 to 2009.

Table D1. U.S. and Non-U.S. Swordfish Production in North and Central Pacific Ocean, 1991-2009.

Year	U.S. Swordfish Production in North and Central Pacific (mt)	Non-U.S. Swordfish Production in North and Central Pacific (mt)
1991	4597	9914
1992	5948	14,736
1993	6981	14,843
1994	4490	14,356
1995	3431	12,413
1996	3695	10,693
1997	4122	14,419
1998	4631	17,643
1999	5098	14,424
2000	5632	19,825
2001	2504	18,955
2002	2012	22,552
2003	2249	21,688
2004	1423	25,099
2005	1860	25,302
2006	1720	27,850
2007	2195	29,526
2008	2266	25,932
2009	2165	26,592

Source: FAO Fisheries Global Information System
http://www.fao.org/figis/servlet/TabLandArea?tb_ds=Capture&tb_mode=TABLE&tb_act=SELECT&tb_grp=COUNTRY

Pearson Correlation Summary

Pearson correlation between U.S. and non-U.S production, using data from 1991 to 2009, is specified as follows:

$$r_{XjYj}$$

where Y_j is non-U.S. production in period j, and Xj is U.S. production in period j, j = 1991 to 2009 (N = 19).

The correlation r_{XjYj} = -0.711 is significant at the 99% level. Table D2 summarizes the statistical result.

Table D2. Pearson Correlation for U.S. Production and Non-U.S. Production: 1991-2009.

		U.S. Production (X_j)	Non-U.S. Production (Y_j)
U.S. Production (X_j)	Pearson Correlation (r)	1	-0.711**
	Sig. (2-tailed)	-	0.001
	N	19	19
Non-U.S. Production (Y_j)	Pearson Correlation (r)	-0.711**	1
	Sig. (2-tailed)	0.001	-
	N	19	19

**Correlation is significant at the 99% level (2-tailed).

Model 1: Estimation of Time Trend for Non-U.S. Production, 1991-2000 (prior to the Hawaii Shallow-Set Longline Swordfish Fishery Closure)

Using the period prior to the Hawaii shallow-set longline swordfish fishery closure (1991 to 2000), a time trend model was estimated by regressing non-U.S. production against year to isolate the residuals associated with the non-U.S. production trend. This trend represents the non-U.S. production without any regulatory impact. The equation is specified as follows:

$$Y_j = a + bT$$

where Y_j is Non-U.S. production in period *j*, where *j* = 1991 to 2000 (*N* = 10), and T stands for year. The detailed result is presented in Table D3.

Table D3. Regression Result for Time Trend for Non-U.S. Production.

***R* Square**
0.384

Variable	Unstandardized Coefficients		Standardized Coefficients	*t*	Sig.
	B	**Std. Error**	**Beta**		
a	1188826.867	538308.983		-2.208	0.058
b	602.933	269.761	0.620	2.235	0.056

Dependent Variable: Y_j, Independent Variable: *T*.

The non-U.S. production ($\hat{Y}$) is estimated as follows:

$$\hat{Y}j = 1188826.867 + 602.933\ T$$

The coefficient *b* = 603, significant at the 90% level, indicates the positive trend in production over time. The difference between actual non-U.S. production and the prediction from the time trend (Y_j - $\hat{Y}_j$) is the residuals. Table D4 shows the residuals from the estimated time period (1991 to 2000) and also the period during and after the Hawaii shallow-set longline swordfish fishery closure (2001 to 2009).

Table D4. Residuals from Non-U.S. Production and Predication from Time Trend (Y_j-$\hat{Y}j$), 1991-2009.

Year	Non-U.S. Swordfish Production in North and Central Pacific (Y_j)	Predicted Value for Non-U.S. Swordfish Production Using Time Trend ($\hat{Y}j$)	Residual from Actual and Predicted Value for Non-U.S. Production (Y_j-$\hat{Y}j$)
1991	9,914	11,613	-1699
1992	14,736	12,216	2520
1993	14,843	12,819	2024
1994	14,356	13,422	934
1995	12,413	14,025	-1612
1996	10,693	14,628	-3935
1997	14,419	15,231	-812
1998	17,643	15,834	1809
1999	14,424	16,437	-2013
2000	19,825	17,040	2785
2001	18,955	17,643	1312
2002	22,552	18,246	4306
2003	21,688	18,849	2839
2004	25,099	19,452	5647
2005	25,302	20,054	5248
2006	27,850	20,657	7193
2007	29,526	21,260	8266
2008	25,932	21,863	4069
2009	26,592	22,466	4126

Model 2: Estimate of U.S. Production Affecting Non-U.S. Production, 1991-2009

To test whether U.S. production causes changes in the amount of non-U.S. production, we regress non-U.S. production residuals from the time trend against U.S. production. A significant coefficient resulting from this regression would imply that U.S. production affects non-U.S. production in the North and central Pacific. The equation is specified as follows:

$$Y_j - \hat{Y}_j = c + d\,X_j$$

where (Y_j - $\hat{Y}_j$) is the non-U.S. production residuals from time trend in period j and X_j stands for U.S. production in period j, j = 1991 to 2009 (N = 19). The detailed result is presented in Table D5.

Table D5. Regression Result for U.S. Production Affecting Non-U.S. Production

R Square
0.276

Variable	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
c	5933.055	1582.698		3.749	0.002
d	-1.040	0.408	-0.526	-2.548	0.021

Dependent Variable: $Y_j - \hat{Y}_j$, Independent Variable: X_j.

The non-U.S. production residuals from time trend ($Y_j - \hat{Y}_j$) are estimated as follows:

$$Y_j - \hat{Y}_j = 5933.055 - 1.04\, X_j$$

The coefficient $d = -1.04$ is significant at the 95% level. This result indicates that U.S. production displaces non-U.S. production in the North and central Pacific almost one-for-one (negative coefficient). The coefficient of the equation (-1.04) implies that, on the margin, an increase of one unit of U.S. production causes a reduction of 1.04 units of non-U.S. production.

Availability of NOAA Technical Memorandum NMFS

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