I. Introduction

The broadbill swordfish (*Xiphias gladius*) complements seafood palates throughout the developed world especially in the United States, Europe, and Japan, where it is considered luxury cuisine (Govender et al., 2003). Fisheries in the Pacific, Indian, and Atlantic Oceans including the Mediterranean Sea supply the demand. Swordfish are highly migratory and cosmopolitan in distribution ranging between the 50°N and 50°S latitudes (Ward, Porter and Elscot, 2000; Hinton, 2003).

As is true for nearly all fisheries, the harvest of swordfish can incur unintended impacts to the ecosystem such as the capture and discard of non-targeted mega fauna (e.g., sharks, marine mammals, seabirds, and sea turtles). These associated ecological costs, known as “bycatch,” come as an incidental part of most any food production system such as commercial fishing (Bartram and Kaneko, 2004).

Probably more attention and effort has been directed towards sea turtle interactions than any other fauna as fisheries bycatch is recognized to be a major threat to all seven sea turtle species (Wallace et al., 2010). In the North Pacific Ocean (NPO), international efforts to recover sea turtle populations, all of which are threatened or endangered under the Endangered Species Act (ESA), have suggested a holistic suite of broad-based terrestrial and marine actions. The use of sustainable fishery practices designed to reduce sea turtle interactions and mortalities in at-sea and coastal fisheries is considered the primary ocean-based strategy to restore sea turtles (Bellagio Steering Committee, 2004; FAO, 2004; Kaplan, 2005; Seminoff et al., 2007; Dutton and Squires, 2008).

In federal NPO swordfish fisheries, NOAA’s National Marine Fisheries Service’s (NMFS) fishery managers have used different strategies to minimize sea turtle interactions for addressing ecosystem sustainability. Conservation measures have included hard cap limits on sea turtle interactions, use of specific hook and bait modifications, time/area closures, and even disapproving particular fishery plans due to inadequate conservation measures. Such strategies are ideally designed to achieve desired conservation objectives while attempting not to seriously compromise economic aspects of the fishery. However, fisheries management schemes are adaptive, meaning that management actions may be adjusted if the impacts of fishing operations change. For example, NMFS opined in a 2000 ESA Section 7 consultation that the U. S. West Coast California/Oregon drift gillnet (DGN) fishery would likely jeopardize the existence of sea turtles (NMFS, 2000). Consequently, NMFS implemented time/area closures to protect
these stocks, an appropriate avoidance strategy for mitigating the effects of entanglement
gear (Valdermarsen and Suuronen, 2003). One of these closures, designed to protect
leatherback sea turtles, annually closes off over 213,000 sq. miles of prime swordfish
fishing grounds during a 3-month period.

In another effort to protect leatherback and loggerhead sea turtles, NMFS disapproved the
high seas longline swordfish fishery component of the Fishery Management Plan (FMP)
for U.S. West Coast Fisheries for Highly Migratory Species (HMS FMP) because the
plan did not limit fishing effort on the seaward side of the U. S. Exclusive Economic
Zone (EEZ). The agency then proceeded to implement regulations prohibiting swordfish
longline sets on the high seas in the Pacific Ocean east of 150°W, longitude by vessels
managed under the HMS FMP.2

These examples of ecosystem-based fishery management substantially curtailed one
swordfish fishery and closed another because sufficient safeguards were not in place. The
net result is that while there is better protection for sea turtles, the U.S. West Coast
now plays an even smaller role in providing a source of sustainable swordfish to meet
strong U.S. consumer demand. With less locally caught product available, it is expected
that U.S. consumers will rely more on foreign sources of swordfish. In 2009, the United
States imported 77 percent of the 18,000 metric tons of swordfish it consumed.
Ironically, these foreign sources of swordfish are believed to elicit greater ecosystem
impacts especially to sea turtles because of less stringent and enforceable fishing
restrictions compared to heavily regulated U.S. fisheries (Santora, 2003; Bartram and
Kaneko, 2004; Gilman et al. 2006; Sarimento, 2006; Rausser et al. 2009; Bartram et al.,
2010).

In a 2008 workshop convened by NMFS to explore ways of coupling adaptive but well-
regulated fisheries management, the need for an active U.S. West Coast swordfish fishery
was recognized, not only for generating economic benefits to local fishing communities,
but also to provide societal benefits by giving U.S. consumers a reliable and local source
of sustainably caught swordfish (NMFS 2009). However, U.S. fisheries such as the
California DGN fishery are often overlooked in environmental efforts designed to shape
public opinion and change consumer behavior (e.g., boycotts, seafood guides,
ecolabelling, and retailer pressure) for seafood harvested from sustainable stocks and by
harvesting methods based on the best available science. Oftentimes, the substantive
regulations placed on U. S. fishing operations compared to foreign counterparts due to
the intertwined conservation mandates of the Magnuson Steven Act, the Marine Mammal
Protection Act, and the ESA go unnoticed by the public.

The potential consequence of diminishing U.S. fisheries such as the California DGN
swordfish fishery is that U.S. consumers will continue to enjoy the benefits of imported
fish products that may come at the cost of imparting greater harm to ecosystems beyond
U.S. jurisdiction. Consumers continue to enjoy swordfish through foreign fishermen

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2 Because these regulations only apply to U.S. fishermen, they have no impact on the approximately 11
foreign fleets known to fish this same area (Hinton et al., 2005).
harvesting their seafood without having to incur any of the concomitant environmental costs in their own waters. The question then becomes how well consumers understand the importance of knowing where their seafood came from and how it was harvested?

This workshop will probe that question by working towards a common understanding among the invited participants on current issues facing and the potential future of the U.S. west coast swordfish fisheries. In order to achieve this objective, the workshop is structured so that participants will leave with a shared understanding of the current state of knowledge on the biological, ecological, and socio-economic factors affecting these fisheries. The reminder of this paper provides a general glimpse of the current situation.

II. Swordfish Supply and Demand

Global Scale: The global catch of swordfish has progressively increased since the United Nation’s Food and Agricultural Organization (FAO) began maintaining records in 1950 (Figure 1). Beginning in the early 1980s, catches started to increase dramatically, corresponding to the expansion of the swordfish market (Miyake et al., 2004). By 2003, landings peaked at 119,000 mt with almost similar landings taken from the Indian, Atlantic and Pacific Oceans. Since then, total landings have exhibited a downward trend to about 95,000 mt in 2008. Sixty-six countries are known to fish commercially for swordfish (Govender et al., 2003). In terms of landed weight, Japan, Spain, Chinese Taipei, Italy, the United States, and Chile are considered the top six countries fishing (Govender et al., 2003).

![Fig. 1 Swordfish Landings by Major Fishing Area (1950-2008)](source: FAO Fisheries Department. 2010. Fishery Information, Data and Statistics Unit. FishSTAT Plus: Universal software for fishery statistical time series. Version 2.3.2000)

On an individual country basis, the United States is the largest swordfish-consuming country in the world (Figure 2). However, when considering the European Union (EU)
as a single economic entity, the EU far exceeds U.S. consumption or all other countries combined. The EU consumed more than 60% of the global swordfish landings in 2007, reaching a record high of 107,000 mt in 2007, an increasing trend that began in 2000. Conversely, U.S. consumption has exhibited a downward trend since 2000.

U.S. Scale: Sources of swordfish products to meet U.S. demand come both from U.S. fishermen landings and foreign imports (Figure 3). Based on statistics from NOAA Fisheries, U.S. demand for swordfish products hovered around 23,000 mt for several years until 2007 and since then, demand has declined with demand close to 18,000 mt in 2009. Several reasons may explain the decrease including the global economic recession and competition from less expensive seafood products, especially with the continuing increase in aquaculture products.

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3 When taking trade flow and the conversion factors defined by NMFS for swordfish, global swordfish consumption in round weight is estimated higher than total landings before 2007. Based on reported FAO commodity trade statistics, U.S. swordfish consumption is actually lower than those reported by NMFS, so U.S. swordfish consumption reported by NMFS is used in Figure 2. It is suggested that underreporting in landings and trade elsewhere in the world before 2007 may account for the discrepancy.

4 U.S. swordfish imports before 1997 were not assigned a specific Harmonized System Code precluding the ability to identify the imports of swordfish fillets and meats. Consequently, total U.S. swordfish imports prior to 1997 were under-reported.

Landings by U.S. fishermen in the Atlantic and Pacific swordfish fisheries have remained fairly stable since 2001 with landings ranging between 2,700 – 4,200 mt. However, annual U.S. landing provide less than 25 percent of the swordfish consumed in the United States. Consequently, the reliance on foreign imports remains at more than three times that supplied by U.S. fishermen.

III. Status of Swordfish

The most recent stock assessment conducted by the International Scientific Committee (ISC) for NPO swordfish was completed in 2009 (ISC, 2010). Two hypotheses regarding the stock structure were reviewed. Available evidence from genetic analysis supports a two-stock hypothesis with the two stocks located within an area bounded in the south originating at $20^\circ$ S latitude from Chile to the $150^\circ$ W meridian that then jumps up to the equator before extending west. The two stocks are separated by an irregular boundary extending to the southwest from Mexico that includes section of the eastern South Pacific extending to $20^\circ$ S latitude. The western part of the area is defined as the Western-Central Pacific Ocean (WCPO) stock and the eastern area is defined as the Eastern Pacific Ocean (EPO) stock.
Results from the stock assessment indicate that the exploitable biomass of both stocks is above biomass levels necessary to achieve maximum sustainable yield (i.e., $B_{MSY}$) and that both stocks are in good condition. As a result of this latest stock status, it was concluded that the WCPO and EPO stocks of swordfish are healthy and above the level required to sustain recent catches (ISC, 2010).

IV. Status of Pacific Sea Turtles (adapted from NMFS, 2009)

The waters off the U.S. West Coast are considered a productive area for North Pacific swordfish, but they are also considered an important foraging area for ESA-listed leatherback and loggerhead sea turtles. Analyses of genetic data and satellite tracking of leatherbacks by the SWFSC indicate that these animals originate from nesting beaches in the western Pacific (e.g., Indonesia and Solomon Islands) (Benson et al. 2007). These turtles are genetically distinct from turtles nesting in the eastern Pacific that forage in the southeastern Pacific (Dutton et al. 2007) and are threatened by swordfish fisheries operating out of Central and South America.

All swordfish fleets operating in the North Pacific have the potential to directly interact with the western leatherback sea turtle stock (Benson, et al. 2007). In the western Pacific, there are an estimated 1,100 to 1,800 females nesting each year at 28 nesting sites, and leatherbacks typically nest every other year. The overall estimate of nesting females in this area is approximately 2,700 to 4,500 individuals, although these are considered rough estimates, since they are derived from nest counts (Dutton et al. 2007). While this subpopulation is not experiencing the dramatic declines that are evident in the eastern Pacific subpopulation, there have been significant declines at long-term monitored beaches since the 1980s (Hitipeuw et al. 2007).

V. History and Current Status of U. S. West Coast Swordfish Fisheries

Off the U. S. West Coast, the swordfish fishery predates European settlement. From at least the 1st century AD, the Chumash tribe in California’s Santa Barbara region caught swordfish with harpoons thrown from plank canoes (Davenport et al. 1993). This method depended on a behavioral trait of swordfish called “finning” where they periodically surface. The harpoon fishery was revived in the early 1900’s by southern California fishermen (Coan et al., 1998) and grew in response to consumer demand for swordfish (Sakagawa, 1989).

Harpone fishing remained the only legal means of harvesting swordfish until the late 1970s when a few vessels began targeting common thresher sharks (Alopias vulpinus) using gillnets. Almost immediately, swordfish and shortfin mako (Isurus oxyrinchus) became important components of the catch (Hanan and Coan, 1993). It was soon discovered that for targeting swordfish, the nets were more cost effective in terms of fuel economy and yielded greater catches than harpoons. Swordfish was also worth nearly four times the dockside value of sharks (Bedford 1987; Holts 1988), and by the early 1980s, swordfish became the primary target species for the DGN fleet.
Due to the harpoon fishery’s dependency on calm seas (Sakagawa, 1989; Coan et al., 1998), and the greater efficiency of entanglement, the DGN fishery evolved as the primary means of harvesting swordfish off the U. S. West Coast until around 1991. During the 1991-1992 fishing season, three high seas\(^5\) longline vessels relocated to California, fishing seaward of the 200 mile EEZ of the West Coast. By 1994, the number of vessels grew to 31 (Vojkovich and Barsky, 1998). Beginning in 1995, the majority of these vessels departed for Hawaii and began following swordfish movements by operating out of Hawaii in the spring and summer and California in the fall and winter (PFMC, 2003). The west coast fishery continued until 2004 when the Pacific Council’s HMS FMP was implemented, effectively prohibiting shallow set longlines between the mainland and the 150\(^0\) W. longitude due to inadequate sea turtle protections.\(^6\) Since then, the DGN fishery returned as the predominate method used to harvest swordfish off the U. S. West Coast with the current fleet operating out of California.

Up until 1990, the U.S. west coast DGN fishery accounted for the majority of U. S. swordfish fishing in the NPO (Figure 4). Beginning in 1990, the Hawaii longline swordfish fishery entered the Pacific U. S. fishery, and except for the years 2001-2004 when the fishery was closed under court order, the Hawaii fishery has been the dominant source of U. S. Pacific-caught swordfish.

![Swordfish Landings in California and Hawaii](image)

**Figure 4. Swordfish landing in the Hawaii and U.S. West Coast fisheries since 1981**

\(^5\) Beyond the U. S. 200 nautical mile Exclusive Economic Zone.

\(^6\) An ESA Section 7 consultation was conducted by NMFS on the SSLL fishery operating out of California as part of the HMS FMP, and a jeopardy conclusion was reached for loggerhead sea turtles. Regulations written through the ESA essentially prohibited this component of the fishery to protect loggerhead sea turtles.
Since 1990, when NMFS approved observers were first placed on DGN vessels, the number of active vessels participating in the DGN fishery has ranged from a high of 129 vessels in 1990 and 1994 to a low of 32 in 2009. Industry representatives attribute the decline in vessel participation and annual effort to regulations implemented to protect threatened and endangered marine mammals, sea turtles, and seabirds (PFMC, 2009). It is believed that the closure especially affected vessels home ported north of Pt. Conception, and especially smaller vessels that have a harder time getting around the frequent rough waters near Pt. Conception.

The DGN fleet effort in annual total vessel days has consistently declined from the all time high of about 5,400 vessel days per year in sea in 1993 to about 1,100 days in 2008 (Figure 5). The fleet effort further fell to 760 days in 2009 and 492 days in 2010. The fleet effort had stayed about 3000 days per year till 1998, but the decline in fleet effort accelerated after 1998. Although the fleet effort has declined significantly during the past two decades, however, participating vessels’ effort in terms of the number of days at sea per year in the DGN fishery has remained fairly constant to about 34 days in sea per year per vessel.

![Fleet Effort & Vessel Effort for the Drift Gillnet Fishery](image)

**Figure 5.** Fleet effort and individual vessel effort for the DGN fishery.

Fleet effort for the DGN fishery was forecasted out to year 2020 based on three time series models using the annual fishing days by all DGN vessels from 1990 to 2010 (Figure 6). An exponential growth model using least squares regression indicates that the DGN fleet effort decayed at an annual rate of 9.57 percent over the past two decades and based on this trajectory, it is forecasted that DGN fleet effort in 2015 and 2020 will be about 500 and 300 fishing days, respectively. Two other time series forecast modeling
techniques (Auto Regressive (AR) and Auto Regressive Moving Average(ARMA)) produced nearly similar forecasted values at around 500 fishing days during 2011-2015, and around 450 fishing days during 2016-2020.

Figure 6. Forecasted swordfish fishing effort in the DGN fishery for 2011 to 2020 based on three modeling techniques: exponential growth (logarithmic linear trend model), auto regressive (AR), and auto regressive moving average (ARMA).

The number of vessels and landed catch in the west coast harpoon fishery has shown similar downward trends as the DGN fishery beginning in the early 1990s (Figure 7). As mentioned, harpoon caught swordfish command a higher price but possibly offsetting the higher prices is the increased cost due to higher fuel prices and competition with less expensive imports. The fishery supports a very small niche source of swordfish that provides an alternative source.
The age of DGN fishermen may also factor into the future of this fishery. The average age of drift gillnet permit holders ranged from 41 year in 1994 to 59 years in 2009. A significant increase in the mean age of the permit holders over the last 15 years might be due to entry barriers to the less experienced young fishers to be in the drift gillnet fishery or a very slow replacement of the retiring permits. In 2010, the average age of participants in the DGN fishery is approximately 60 years and since 2001, the average number of new entrants transferring into the fishery is approximately 1.1 per year at an average age of 44. Depending on a number of factors that may affect attrition in the fleet such as death and a change in employment, and an assumed retirement age at 65 with a steady 1.1 annual recruitment into the fishery, the number of vessels participating in the fishery is expected to continue to erode.

A duration analysis over the last 15 years shows that the number of fishermen fishing in the DGN fishery has mostly been short lived, i.e., about 35 percent, 8 percent, and 12 percent of the vessels remained in the DGN fishery only for one, two, and three years, respectively (Figure 8). The number of fishermen fishing for longer years in the DGN fishery was few. Only nine percent of the fishermen remained in the fishery for about 15 years (during 1994-2009).
An entry-exit analysis of the DGN fishers during 1994-2009 in the US West Coast indicates that the number of vessels exiting from the fishery has mostly been higher than they entered to the fishery (Figure 9). The net change in the DGN fleet has mostly been negative for most of the years. For example, 16 vessels entered to the DGN fishery in 1995, but 24 exited in the same year with a net change of negative eight vessels for that year. A large number of the vessels that left from the DGN fishery were during 1995-2002 and the trend has remained mostly unabated till in the recent years.

Figure 8. Number of years in the DGN fishery.
VI. References


**FAO. 2009. Species Identification and Data Programme: fact sheet, Xiphias gladius**


