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TURTLE BYCATCH MITIGATION IN THE HAWAII LONGLINE FISHERY

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Analyses of Observer Program Data for the Hawaii-Based Longline Swordfish Fishery for:

- Effects of sea turtle regulations on sea turtle interactions, catch rates of retained marketable species and catch rate of sharks;
- Economic viability and potential for temporal or spatial closures to reduce turtle capture rates;
- Comparison between 2005 and 2006 turtle catch rates and temporal distribution of effort to explain cause of loggerhead cap being reached in 2006 but not in 2005; and
- Hook position in a basket of caught turtles and retained fish.

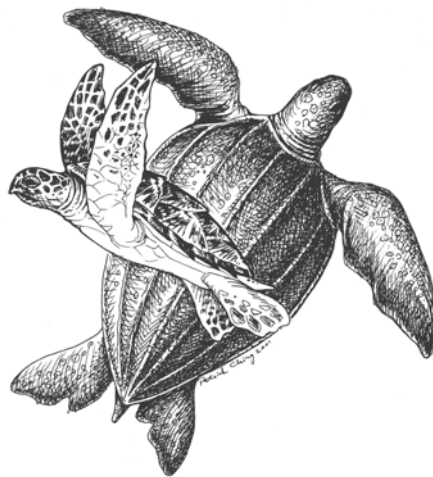
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SUMMARY

Reducing sea turtle bycatch in pelagic longline fisheries may contribute to the recovery of sea turtle populations. The effectiveness and commercial viability of a turtle avoidance strategy, such as replacing J-shaped hooks with wider circle-shaped hooks, may be fishery-specific, depending on the size and species of turtles and target fish and other differences between fleets. Assessing the effects of turtle avoidance methods in individual fleets is therefore necessary. Regulations based on research conducted in the U.S. North Atlantic longline swordfish fishery came into effect for the Hawaii-based pelagic longline swordfish fishery in May 2004. We conduct the first analysis of the U.S. National Marine Fisheries Service observer program database for the Hawaii-based pelagic longline swordfish fishery, in part, to infer possible effects of regulations on turtle interactions, catch rates of retained marketable species and shark capture. There were significant reductions in sea turtle and shark capture rates and reduced proportion of deeply hooked turtles, indicating increased post release survival prospects, without comprising target species catches. Results identify effective and commercially viable turtle avoidance methods that may be suitable for use in other longline fisheries worldwide, potentially resulting in substantial reductions in turtle bycatch in global pelagic longline fisheries.

The existence of confounding factors prevents definitive conclusions regarding single factor effects on turtle and fish interactions. Regulations designed to reduce turtle capture rates and proportion of deep-hookings, which came into effect in May 2004, changed the type and size of fishing hook and bait used by the Hawaii-based longline swordfish fleet (from using a 9/0 J hook with squid bait to a 10 degree offset 18/0 circle hook with fish bait). Regulations designed to reduce seabird interactions, which came into effect for the Hawaii-based longline swordfish fishery in June 2001, include requirements for swordfish-targeting vessels to night set and dye bait blue, two changes that may affect sea turtle and fish capture rates. Prior to this rule coming into effect, swordfish vessels did not dye bait blue and initiated gear setting an average of 76 minutes earlier than after the requirement for night setting was instituted. Hawaii-based swordfish vessels were subject to the night setting and blue bait requirements for the entire period after the sea turtle regulations came into effect and for the last eight months of the period before the sea turtle regulations came into effect. Another confounding factor is variability in turtle abundance at fishing grounds. Analysis of the location of Hawaii-based longline swordfish effort by quarter for the periods before vs. after the sea turtle regulations came into effect indicate that there was generally no substantial differences in the temporal distribution of effort for these two periods.

Turtle Capture Rates

The loggerhead, leatherback and combined turtle species capture rates significantly declined by 90.0%, 82.8% and 89.1%, respectively, from the period before the turtle regulations came into effect to the period after the regulations came into effect. There were also significantly lower turtle catch rates for combined turtle species and individual species for each quarter of each year in the period after the sea turtle regulations came into effect compared to the same quarter of each year before the regulations came into effect, except for leatherback turtle catch rates during the 1st quarter for which the difference was not significant. Thus, differences in temporal distribution of fishing effort between the two periods is not likely a large factor in explaining the differences in turtle CPUE between the two time periods. While it is not possible to determine single factor effects on observed changes in turtle catch rates, these observed reductions in turtle catch rates are consistent with results from controlled experiments on the effects of switching from a J or Japan hook to a wider circle hook and switching from using squid to fish for bait. Changes in the timing of setting and gear retrieval between the two time periods may be another cause of the observed changes in turtle catch rates.

Proportion of Caught Turtles Lightly Hooked vs. Deeply Hooked vs. Entangled

A larger proportion of turtles were lightly hooked (hooked in the mouth or body) or entangled after the sea turtle regulations came into effect vs. for the period before the sea turtle regulations came into effect, which may increase post-release survival prospects. For the period before sea turtle regulations came into effect, 60% of caught hardshelled turtles were deeply hooked (the turtles ingested the hook), 38% were lightly hooked, and 2% were entangled (N = 180, 163 loggerhead turtles). After the regulations came into effect, 63% of caught hardshelled turtles were lightly hooked, 22% ingested the hook, and 15% were entangled (N = 27, all loggerheads). Before the turtle regulations came into effect, 84% of leatherbacks were light hooked, 10% ingested the hook, and 6% were entangled (N = 31). After the turtle regulations came into effect, 100% were light hooked (N = 10). There was no significant difference in the proportion of lightly hooked, deeply hooked, and entangled turtles for the four individual species observed captured between the two time periods before and after the sea turtle regulations came into effect. While it is not possible to determine single factor effects on observed changes in turtle interactions, this observed reduction in proportion of turtle deep hooking is consistent with results from controlled experiments on the effects of switching from a J or Japan tuna hook to a circle hook.

Proportion of Hooked Turtles with vs. without Terminal Tackle Attached Upon Release

For the period before the sea turtle regulations came into effect 40% of hooked turtles (combined species) were released after removing all terminal tackle (hook, line, and in rare cases where it is used, wire trace) (N = 178). After the sea turtle regulations came into effect 67% of hooked turtles were released after removing all terminal tackle (N = 33), which was significantly more than the period before the regulations came into effect. This observed difference between the two time periods is likely a result of a smaller proportion of hooked turtles being deeply hooked in the second period, likely a result of switching from a J to circle hook, which makes it easier to remove hooks than when turtles are deeply hooked.

2005 vs. 2006 Turtle Capture Rates and Annual Turtle Interaction Caps

The Hawaii-based longline swordfish fishery reached a cap of 17 loggerhead captures in March 2006 but did not reach this cap for the entire year in 2005. (A total of 12 loggerhead turtles were observed caught in 2005, 9 in the first quarter). There was no significant difference in loggerhead CPUE between the first quarters of 2005 and 2006. Effort in the first quarter of 2006 was 48% higher than in 2005. The higher number of loggerhead captures during the first quarter of 2006 relative to 2005 is a result of the higher fishing effort in 2006, and not the result of a significant difference in loggerhead capture rates.

Proportion of Caught Turtles Alive vs. Dead

For the entire period that the Hawaii longline swordfish fishery has been observed, less than 1% of caught turtles were dead when hauled to the vessel (2 of 255 caught turtles, both from the period before the turtle regulations came into effect), and there was no significant difference in the proportion of alive vs. dead turtles for the four species observed captured between the time periods before and after the sea turtle regulations came into effect. This observed low rate of caught turtles being drowned when hauled to the vessel during gear retrieval is expected for shallow-set longline fisheries with relatively light gear vs. deeper setting longline tuna fisheries with heavier weighted gear.

Rarity of Turtle Captures

Turtle captures are relatively rare events: No turtles were caught in 95% of the observed 4,261 sets made by Hawaii-based longline swordfish vessels. Of the 264 turtles caught during the

observed period, 77% (202) were caught alone (one turtle caught in a single set) with the remaining 23% (62) being caught in clusters (two or more caught in a single set). Because 23% of turtles observed caught were caught in clusters, this indicates that methods to avoid real time turtle bycatch hotspots, such as fleet communication programs, could contribute to reducing turtle catch rates in the Hawaii-based longline swordfish fishery.

Vessels with High vs. Low Turtle Catch Rates

Since observer coverage of the Hawaii-based swordfish fishery began, there were a total of 68 Hawaii-based longline vessels that made swordfish sets, of which 53 caught one or more turtles. Fifteen (22%) of the vessels did not catch any turtles, while half of the fleet (34 vessels) caught < 3 turtles. The maximum number of turtles caught by a single vessel was 23, the second highest was 22. The vessel that caught 23 turtles had a sea turtle capture rate of 0.3595 turtle captures per 1000 hooks, which is 4.7 times the average turtle CPUE of swordfish-targeting vessels. The vessel that caught 22 turtles had a sea turtle capture rate of 0.1420 turtle captures per 1000 hooks, 1.9 times the average turtle CPUE. These two vessels, representing 3% of the number of vessels participating in the fishery, caught 17% of the total turtles caught by the fleet. It is a research priority to investigate differences between vessels with high vs. low turtle CPUE to possibly identify new strategies to reduce turtle catch rates. Additional research can be conducted to determine if the vessels with the relatively high turtle catch rates might be a result of their having higher fishing effort during periods when turtle catch rates are highest, or if they employ different fishing methods and gear compared to vessels with relatively low turtle catch rates.

Length of Caught Turtles

Average length of caught loggerhead turtles was greater during the period after the sea turtle regulations came into effect than during the period before the regulations when comparing the straight carapace and curved carapace lengths of loggerheads that were (i) mouth hooked and ingested hooks, (ii) foul-hooked in the body or entangled, or (iii) all caught loggerheads. However, differences in length were not significant. For the period prior to the sea turtle regulations coming into effect, straight carapace length of loggerheads was a mean of 56.4 cm (+/- 0.8 cm standard deviation of the mean, N = 155) and mean curved carapace length was 61.3 cm (+/- 0.8 cm standard deviation of the mean, N = 154). For the period after sea turtle regulations came into effect, mean loggerhead straight carapace length was 60.9 cm (+/- 1.9 cm standard deviation of the mean, N = 26) and mean curved carapace length was 66.1 cm (+/- 1.9 cm standard deviation of the mean, N = 26).

When comparing the length of caught loggerhead turtles for just the first quarters of the periods before vs. after the turtle regulations came into effect, again the average length of caught loggerheads for the same three categories was greater during the period after the regulations came into effect, but the differences were not significant. In the period before the turtle regulations, 58% of loggerhead turtles were caught in the first quarter, while 86% were caught in the first quarter during the period after the regulations came into effect. If there are significantly larger or smaller loggerhead turtles at the Hawaii longline swordfish fishing grounds during January-March relative to other seasons, because a higher proportion of loggerheads were caught in the first quarter during the period after the turtle regulations came into effect, this could result in a significantly different mean length of turtles during the two periods. Results eliminate any possible seasonal effect that might have occurred during this first quarter. Too few loggerheads were caught in the other quarters during the period after regulations came into effect to conduct an accurate comparison of loggerhead lengths.

For loggerheads that were hooked in the mouth or ingested the hook, the larger size of turtles caught after the turtle regulations came into effect is likely a result of only larger turtles being capable of fitting the wider 18/0 circle hook in their mouths relative to the narrower 9/0

hooks used before the regulations came into effect. However, it is unclear why larger turtles were caught by entanglement or foul-hooked in the body for the period after the regulations came into effect.

Retained Fish Capture Rates

In the period after sea turtle regulations came into effect, swordfish CPUE was significantly higher by 16.0% while combined tuna species and combined mahimahi, opah, and wahoo CPUE was significantly lower by 50.0% and 34.1%, respectively. The CPUE of combined retained fish for the two periods was not significantly different, and was 2.6% lower in the second period. When analyzed by quarter, differences in CPUE of retained fish were generally consistent with results for the full period, except for swordfish. Results on changes in retained fish CPUE need to be considered with caution because the fishing effort was distributed very differently by quarter for the two periods before and after the turtle regulations came into effect. For example, if there had been more fishing effort during the fourth quarter and less during the first quarter for the period after the regulations came into effect, because swordfish CPUE was significantly higher by 23% during the first quarter but significantly lower by 27% during the fourth quarter, the change in swordfish CPUE for the full period could have resulted in an overall reduction after the regulations came into effect. Observed differences in swordfish and tuna catch rates for the periods when a 9/0 J hook with squid bait was in use vs. the period when a 10 degree offset 18/0 circle hook with fish bait was in use are consistent with results from a controlled experiment in the U.S. North Atlantic longline swordfish fishery.

Shark Capture Rate

Shark combined species CPUE was significantly lower in the period after the regulations came into effect vs. for the period before the turtle regulations came into effect for the full periods and by quarter. This is likely due to the change from squid to mackerel for bait, based on a review of results from studies in the U.S. North Atlantic and Azores pelagic longline fisheries. However, the decrease in shark CPUE could be a result of the change to using blue dyed bait, change in timing of setting and hauling as a result of the requirement for night setting, or other differences between the two time periods before vs. after the sea turtle regulations came into effect.

Spatial and Temporal Closures

We compare the CPUE of swordfish and sea turtles by quarter (January - March, April - June, etc.) for the full study period to determine if seasonal fishery restrictions are feasible to reduce turtle captures. Turtle CPUE was significantly lower in the second quarter than the other three quarters. There was no significant difference in turtle CPUE for the first, third, and fourth quarters, with the highest turtle CPUE point estimate occurring in the third quarter, and second highest in the fourth quarter. Swordfish CPUE was significantly different for each quarter. Swordfish CPUE was significantly lower than all other quarters in the third quarter. The first and fourth quarters had significantly highest and second highest swordfish CPUE, respectively. Based on this, the voluntary historical practice of concentrating 34% of swordfish fishing effort in the second quarter of the year when sea turtle CPUE is lowest has resulted in lower turtle captures than if effort were distributed more evenly by quarter. There is no obvious economically viable change to temporal distribution of effort to reduce turtle catch rates: if the fishery were required to reduce effort in the first quarter, which could result in increased effort in the second quarter (when the turtle catch rate is significantly lowest), such as by starting the season later in the year than the current opening on 1 January, this would result in a significant reduction in the swordfish catch rate. Before instituting a seasonal or spatial closure designed to reduce turtle interactions, analysis of the potential effects on bycatch rates of other sensitive species groups, such as seabirds, sharks, and cetaceans, should be conducted.

We also compare the (i) distribution of swordfish effort and observed turtle captures and (ii) spatial distribution of turtle CPUE to determine if area closures hold promise to reduce turtle capture rates. There were two areas with relatively high turtle capture rates that had a relatively small proportion of the fleets' fishing effort, indicating that closing areas at a 5 degree cell-scale incorporating these areas would have reduced turtle capture rates without eliminating main fishing areas. The turtle catch rates of these areas are higher than any of the observed turtle catch rates by quarter, and are an order of magnitude higher than the observed turtle capture rate for the full period. The turtle captures in these two areas represent 8.7 % of the total observed 264 caught turtles and 1.4% of the total observed effort made by the Hawaii-based longline swordfish fishery. Closing these observed turtle bycatch hotspots to Hawaii-based longline swordfish vessels at a scale of 5 degree cells might result in displacing effort to other areas where the turtle capture rate might not be significantly different, thus not reducing total turtle captures. There is low certainty that the observed areas of relatively high turtle CPUE will continue to be turtle bycatch hotspots in the future. The locations of high densities of foraging sea turtles will be highly variable, as turtle abundance is correlated with temporally and spatially variable large-scale oceanographic features and short-lived hydrographic features such as eddies and fronts.

Hook Position of Caught Turtles and Retained Fish

We assess the hook position of caught turtles and retained fish to determine if there are significant differences in catch rates on hooks closest to float lines vs. hooks not located immediately next to floats. It is hypothesized that hooks located adjacent to float lines are at shallower depths than the hooks not located immediately adjacent to float lines. Sea turtles spend a majority of their time at depths < 40 m, indicating that setting longline gear deeper than 40 m will reduce turtle captures. Vessels primarily set 4 hooks per basket (between floats): 75% of hooks set to target swordfish by the Hawaii-based longline fleet were in baskets containing 4 hooks. Twenty one percent of hooks set by Hawaii longline vessels to target swordfish were in baskets containing 5 hooks.

There was no significant difference between catch rates of sea turtles combined species, loggerheads, leatherbacks, and hardshelled turtle combined species on hooks in a basket that are not located next to floats vs. hooks located immediately next to floats, and there were nominal differences between sea turtle CPUE point estimates for the two different categories of hooks. This indicates that the depth of baited hooks in these two groups are likely not substantially different, and that all of the hooks are above depths where sea turtles are abundant. Baited hooks may need to be set at depths deeper than the current deepest hook in a basket to result in substantial benefits towards reducing turtle catch rates.

The catch rate of retained fish combined species, retained swordfish and retained tunas are slightly higher on hooks in a basket that are not located next to floats vs. hooks located immediately next to floats. The catch rate of combined retained mahimahi, opah, and wahoo is higher on hooks located closest to floats vs. hooks not located immediately adjacent to floats. Differences in CPUE for swordfish and combined mahimahi, opah, and wahoo were significantly different. Differences in CPUE for all retained fish and combined tuna species were not significantly different. These observations indicate that setting baited hooks deeper may enable the fleet to increase swordfish CPUE potentially without substantially compromising tuna species CPUE.

Priority Research Needs

It is a research priority to assess the differences between Hawaii-based longline swordfish vessels with high vs. low turtle capture rates, including various design and operational differences and differences in temporal and spatial distribution of effort. It is also a priority to assess the efficacy at reducing turtle catch rates and commercial viability of deeper setting of

Hawaii-based longline swordfish gear. These studies could result in the identification of new solutions to turtle bycatch in pelagic longline fisheries.