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# Sea Turtle Interactions in the Hawaii-Based Longline Swordfish Fishery

## First Quarter 2007 and Comparison to Previous Periods

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Results presented here are subject to change. At the time of conducting the query of the U.S. National Marine Fisheries Service observer program database on 7 May 2007, the U.S. National Marine Fisheries Service Pacific Islands Regional Office had yet to complete checking and validating some of the observer data from longline swordfish trips included in this analysis.

### Summary

To reduce turtle interactions, regulations for the Hawaii-based longline swordfish fishery, which came into effect in May 2004, required vessels to switch from using a J-shaped hook with squid bait to a wider circle-shaped hook with fish bait. We analyzed observer data to understand the changes in sea turtle interactions since the introduction of the regulations through the end of the first quarter of 2007. Following the introduction of the regulations, significant and large reductions in sea turtle capture rates occurred. Capture rates of combined turtle species, leatherback and loggerhead turtles significantly declined by 89%, 85% and 90%, respectively. Sea turtle catch rates during the first quarter of 2007 were similar and not significantly different from turtle catch rates during the other periods since the turtle regulations came into effect. Since the introduction of the regulations, there has been a highly significant reduction in the proportion of turtles that swallowed hooks into the esophagus or deeper (deeply hooked, versus being hooked in the mouth or body or entangled) and a highly significant increase in the proportion of caught turtles that were released after removal of all terminal tackle, which may increase the likelihood of turtles surviving the interaction. During the pre-regulations period, 53% (111 of 211) of caught sea turtles were deeply hooked, while 12% (6 of 51) were deeply hooked in the post-regulations period. During the first quarter of 2007, all 14 caught sea turtles (12 loggerheads, two leatherbacks) were lightly hooked. During the pre-regulations period, 60% (106 of 178) of hooked turtles were released with terminal tackle attached, while 26% (12 of 47) were released with terminal tackle attached in the post-regulations period. During the first quarter of 2007, one of the 14 (7%) caught sea turtles was released with terminal tackle attached.

## 1. Introduction

Reducing sea turtle bycatch in fisheries contributes to recovering populations. Due to concerns over turtle interactions, the Hawaii-based longline swordfish (*Xiphias gladius*) fishery was closed for over two years and is now subject to strict management measures. These measures include prescribed use of 10° offset 18/0 circle hooks and fish bait (vessels had previously used narrower 9/0 J hooks with squid bait), restricted annual effort, annual limits on loggerhead and leatherback turtle captures and 100% onboard observer coverage. The required use of wider circle hooks and fish bait are intended to reduce turtle capture rates and proportion of turtles that swallow hooks into the esophagus or deeper (“deep” hooking), versus being hooked in the mouth or body or entangled. There is a growing body of literature demonstrating the efficacy of using wider circle hooks and fish bait in place of narrower J or Japan tuna hooks and squid bait at reducing turtle catch rates and the proportion of caught turtles that are deeply hooked (Bolten and Bjorndal, 2005; Largacha et al., 2005; Watson et al., 2005; Read, 2007; Gilman et al., 2006, In Press). Here we update analyses conducted by Gilman et al. (In Press) by analyzing observer data to determine the sea turtle catch rates, manner of capture and disposition (alive vs. dead when the turtle is hauled to the vessel) for the first quarter of 2007, and compare these observations to previous periods. Results contribute to inferring the effects of the prescribed change in hook and bait on turtle interactions.

## 2. Methods

We analyzed data from the Hawaii longline observer program for Hawaii-based longline swordfish-targeting shallow sets for the first quarter of 2007, including sets that began between midnight on 31 December 2006 through midnight on 31 March 2007. Observer data for this period were analyzed for the following three study components:

- (i) Sea turtle catch rates;
- (ii) Manner of capture. The proportion of caught turtles that were lightly hooked (hooked in the mouth or body), deeply hooked (hooks are swallowed into the esophagus or deeper) and entangled is determined. If a turtle was observed to be both hooked and entangled, we counted it as being hooked only;
- (iii) Proportion of caught turtles that were alive vs. dead; and
- (iv) Proportion of caught turtles that were released after removal of all terminal tackle.

We compared the turtle catch rates observed during the first quarter of 2007 to the first quarters of 2005 and 2006, when the sea turtle regulations were also in effect, and to the first quarter of combined years for the pre-sea turtle regulations period. We also compared turtle catch rates of the full periods (all quarters) pre vs. post turtle regulations. For the latter three study components, we compare results for the full periods pre vs. post regulations. The pre-sea turtle regulations period is from 2 March 1994 – 20 February 2002. The post regulations period is from 3 May 2004 – 31 March 2007. The inclusion of a set into a specified period is based on the recorded date and time of the beginning of the haul.

All study components analyzed data from swordfish-targeting sets only. Prior to the promulgation of regulations to reduce turtle interactions Hawaii longline vessels would conduct mixed trips where they targeted swordfish in some sets and yellowfin and bigeye tuna in other sets of a single trip. The sets where the vessel targeted tuna were not included in this analysis (where gear is usually set deeper than when targeting swordfish). For the pre-regulations period, sets where swordfish was the target species identified by the captain and with  $\leq 15$  hooks per basket were included in the analyses. For the post-regulations period, all declared shallow swordfish-targeting sets were included.

Probable error of point estimates for sea turtle catch rates are reported as nonparametric 95% confidence intervals derived from percentile method bootstrapping at  $N = 1000$ . The chi-square test, Fisher’s exact test and odds ratio test were used to determine any significant

difference between pre and post regulation periods for the proportion of caught turtles that were deeply hooked, proportion of caught turtles that were alive vs. dead, and proportion of caught turtles that were released with terminal tackle attached.

### **3. Results and Discussion**

Before the regulations, there were 120 observed Hawaii-based pelagic longline swordfish trips during which 1,631 sets of 1,282,748 hooks were made. After the regulations came into effect, there were 222 observed trips during which 3,632 sets of 2,977,632 hooks were made. During the first quarter of 2007 there were 58 trips during which 963 sets of 837,768 hooks were made.

Table 1 and Figs. 1-2 present sea turtle capture rates pre and post regulations.

Following the introduction of the regulations, significant and large reductions in sea turtle capture rates occurred. Capture rates of combined species, leatherback and loggerhead turtles significantly declined by 89%, 85% and 90%, respectively. Sea turtle catch rates during the first quarter of 2007 were similar and not significantly different from turtle catch rates during the other periods since the turtle regulations came into effect.

Table 1. Sea turtle capture rates by the Hawaii longline swordfish fishery before and after regulations designed to reduce sea turtle interactions came into effect.

Observed turtle captures, effort, and CPUE	Period, Pre- Regulations		Period, Post-Regulations				
	2 March 1994 – 20 Feb 2002		3 May 2004 – 31 March 2007		2005	2006	2007
	1 <sup>st</sup> quarter	Full period	1 <sup>st</sup> quarter	Full period	1 <sup>st</sup> quarter	1 <sup>st</sup> quarter	1 <sup>st</sup> quarter
<b>Observed Turtle Captures</b>							
Combined species	105	223	44	55	11	19	14
Loggerhead	97	167	36	40	9	15	12
Leatherback	2	37	6	13	2	2	2
Olive ridley	3	10	0	0	0	0	0
Green	2	5	0	0	0	0	0
Unknown	1	4	2	2	0	2 <sup>2</sup>	0
<b>Effort</b>							
Number hooks observed	471,212	1,282,748	1,965,071	2,977,632	450,667	676,636	837,768
<b>Turtle CPUE</b> <sub>1</sub>							
Combined species CPUE (number captured per 1000 hooks)	0.223	0.174	0.0224	0.0185	0.0241	0.0281	0.0167
Combined species CPUE 95% CI	0.179 – 0.272	0.150 – 0.199	0.0163 – 0.0288	0.0138 – 0.0234	0.0109 – 0.0397	0.0162 – 0.0410	0.0094 – 0.0262
Loggerhead CPUE (number captured per 1000 hooks)	0.206	0.130	0.0183	0.0134	0.0197	0.0222	0.0143
Loggerhead CPUE 95% CI	0.161 – 0.249	0.109 – 0.152	0.0127 – 0.0244	0.0094 – 0.0178	0.0087 – 0.0328	0.0117 – 0.0354	0.0071 – 0.0223
Leatherback CPUE (number captured per 1000 hooks)	0.004	0.029	0.0031	0.0044	0.0044	0.0030	0.0024
Leatherback CPUE 95% CI	0.000 – 0.011	0.020 – 0.038	0.0010 – 0.0056	0.0023 – 0.0068	0.0000 – 0.0111	0.0000 – 0.0075	0.0000 – 0.0060

<sup>1</sup> CPUE point estimates and error intervals determined from percentile method bootstrapping at N = 1000.

<sup>2</sup> Conservatively assumed to be loggerhead turtles.

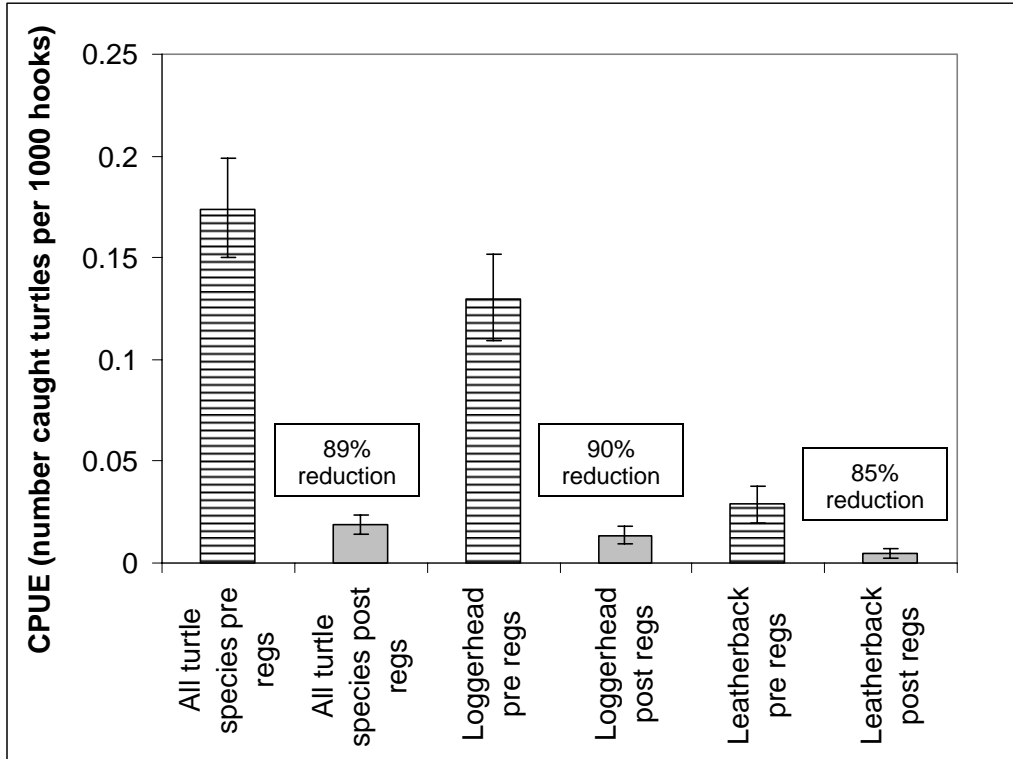


Fig. 1. Sea turtle capture rates in the Hawaii-based longline swordfish fishery pre and post sea turtle regulations.

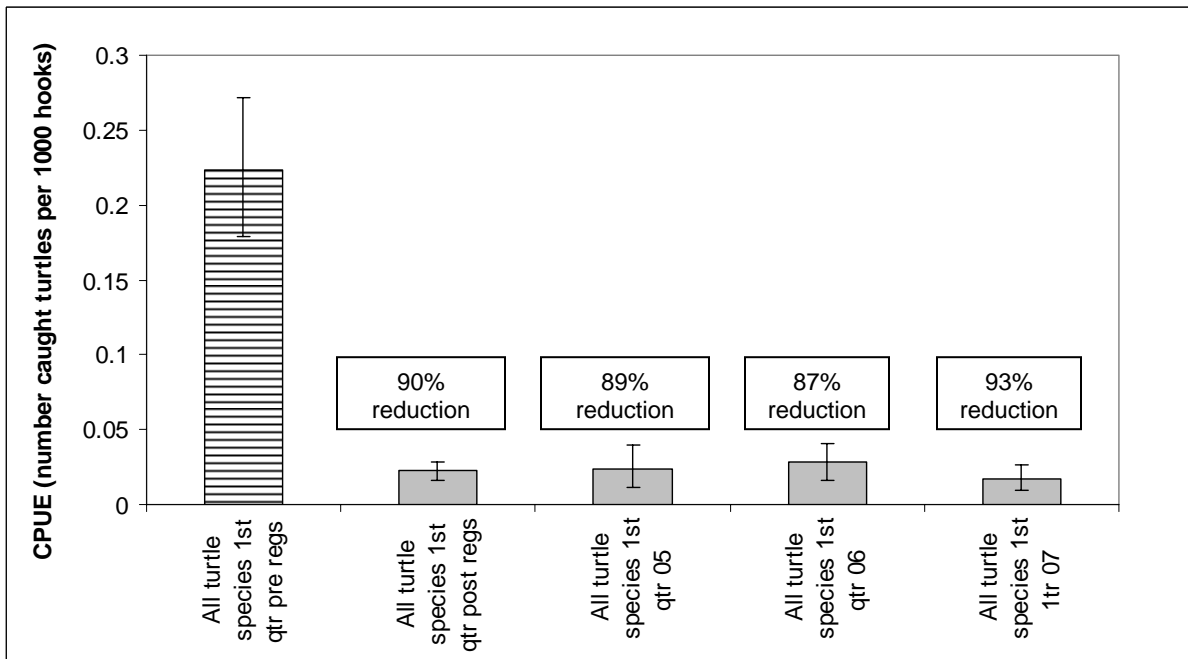


Fig. 2. Sea turtle capture rates in the Hawaii-based longline swordfish fishery, first quarter of combined years pre-regulation vs. first quarter of combined years post-regulations vs. first quarters of 2005, 2006 and 2007.

Table 2 and Figs. 3-4 summarize the manner in which turtles were caught. Before the sea turtle regulations came into effect, for turtles where the manner of capture was known, 60% of caught hardshelled turtles ingested the hook (N = 180, 163 loggerheads). After the regulations came into effect, for turtles where the manner of capture was known, 74% of caught hardshelled turtles were lightly hooked (N = 39, all loggerheads) (Table 2, Fig. 16). Before the turtle regulations came into effect, for turtles where the manner of capture was known, 84% of leatherbacks were light hooked (N = 31), while after the turtle regulations came into effect, 100% were light hooked (N = 12). There was a highly significant difference in the proportion of deeply hooked turtles for combined species observed captured of known condition between the two time periods pre and post regulations (Chi-square test,  $X^2 = 27.72$ ,  $DF = 1$ ,  $P < 0.01$ ; Fisher's exact test  $P < 0.01$ ; odds ratio test odds ratio = 8.33 [ $> 8$  - fold significantly greater odds of being deeply hooked in the pre-turtle regulations period vs. the post regulations period], 2.57 – 26.93 99% CI,  $P < 0.01$ ). During the first quarter of 2007, all 14 caught sea turtles (12 loggerheads, 2 leatherbacks) were lightly hooked.

Table 2. Number of turtles entangled, lightly-hooked, vs. deeply-hooked in the Hawaii-based pelagic longline swordfish fishery before and after regulations designed to reduce sea turtle interactions came into effect, 1994-2007.

	Manner of Sea Turtle Capture			
	Lightly Hooked	Deeply Hooked	Entangled <sup>1</sup>	Unknown <sup>2</sup>
<b>2 March 1994 – 20 Feb 2002</b>				
Combined species	95	111	5	12
Loggerhead	61	99 <sup>3</sup>	3	4
Leatherback	26	3	2	6
Olive ridley	3	7	0	0
Green	5	0	0	0
Unknown hardshell	0	2	0	2
<b>3 May 2004 – 31 March 2007</b>				
Combined species	41	6	4	4
Loggerhead	29	6	4	1
Leatherback	12	0	0	1
Olive ridley	0	0	0	0
Green	0	0	0	0
Unknown hardshell	0	0	0	2

<sup>1</sup> Turtles that were entangled but not hooked are recorded in this column. Turtles that were hooked and also entangled are recorded in the lightly or deeply hooked column.

<sup>2</sup> Turtle came free of the gear before getting close enough to the vessel for the observer to determine the turtle's condition or otherwise there was no record of the manner of the sea turtle capture.

<sup>3</sup> Two of these deeply hooked loggerheads were dead when hauled to the vessel.

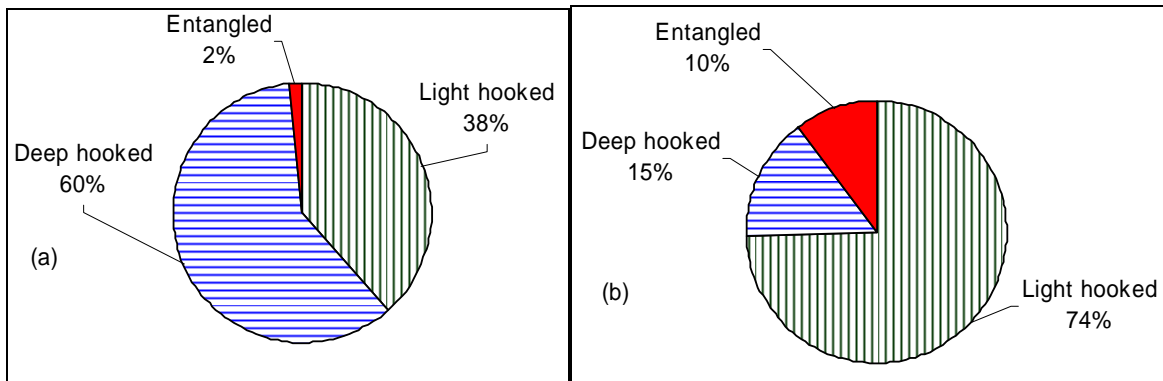


Fig. 3. Proportion of hardshelled sea turtles caught in the Hawaii longline swordfish fishery that were lightly hooked vs. deeply hooked vs. entangled (a) before and (b) after sea turtle regulations came into effect.

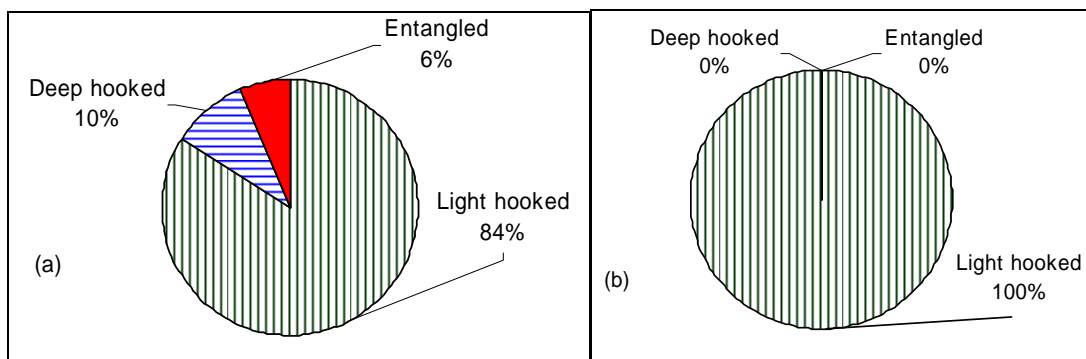


Fig. 4. Proportion of leatherback sea turtles caught in the Hawaii longline swordfish fishery that were lightly hooked vs. deeply hooked vs. entangled (a) before and (b) after sea turtle regulations came into effect.

Table 3 summarizes the condition of turtles caught in the Hawaii longline swordfish fishery. For the period before the sea turtle regulations came into effect, of the 182 caught hardshelled turtles of known condition (known to be alive or dead), 99% (180) were alive, while 100% of the 35 caught leatherbacks of known condition were alive. One hundred percent of the 39 hardshelled turtles and 13 leatherbacks of known condition that were caught after the turtle regulations came into effect were alive. There was no significant difference in the proportion of alive vs. dead turtles for combined species observed captured between the two time periods pre and post regulations (Chi-square test,  $X^2 = 0.4829$ ,  $DF = 1$ ,  $P > 0.05$ ; Fisher's exact test  $P > 0.05$ ).

Table 3. Condition of sea turtles caught in the Hawaii-based pelagic longline swordfish fishery for periods before and after regulations designed to reduce sea turtle interactions came into effect, 1994-2007.

	Condition of Caught Turtles				
	Alive		Dead		Unknown <sup>1</sup>
	No.	% of total known condition	No.	% of total known condition	No.
<b>Pre-regulations 2 March 1994 – 20 Feb 2002</b>					
Combined species	215	99	2	1	6
Loggerhead	164	99	2	1	1
Leatherback	35	100	0	0	2
Olive ridley	10	100	0	0	0
Green	5	100	0	0	0
Unknown hardshell	1	100	0	0	3
<b>Post-regulations 3 May 2004 – 31 March 2007</b>					
Combined species	52	100	0	0	3
Loggerhead	38	100	0	0	2
Leatherback	13	100	0	0	0
Olive ridley	0		0		0
Green	0		0		0
Unknown hardshell	1	100	0	0	1

<sup>1</sup> Typically indicates that the caught turtle came free of the gear before getting close enough to the vessel for the observer to determine the turtle's condition.

Table 4 and Fig. 5 summarize the proportion of hooked turtles that were released with vs. without terminal tackle (hook and possibly line and wire trace if used) remaining attached to the turtle for the periods before and after sea turtle regulations came into effect. Pre-regulations, 40% of hooked turtles (combined species) were released after removing all terminal tackle (hook, line, and wire trace if used) (N = 178). Post-regulations, 74% of hooked turtles were released after the removal of all terminal tackle (N = 47). There was a highly significant difference in the proportion of turtles released with terminal gear attached between the periods before vs. after the sea turtle regulations came into effect (Chi-square test,  $X^2 = 17.25$ ,  $DF = 1$ ,  $P < 0.01$ ; Fisher's exact test  $P < 0.01$ ; odds ratio test, odds ratio = 4.29 [ $> 4$  - fold significantly greater odds of being deeply hooked in the pre-turtle regulations period vs. the post regulations period], 1.67 – 11.07 99% CI,  $P < 0.01$ ). During the first quarter of 2007, 13 of the 14 (93%) caught sea turtles were released after removal of all terminal tackle (one of the two caught leatherbacks was released hook and line attached to its wing/front flipper).

Table 4. Proportion of hooked turtles caught in the Hawaii-based longline swordfish fishery that was released after removal of the hook and line vs. released with the hook and line remaining attached.

	Terminal Tackle Attached or Removed to Released turtles		
	Released with no terminal tackle attached	Released with terminal tackle attached <sup>a</sup>	Unknown <sup>b</sup>
<b>Pre-regulations 2 March 1994 – 20 Feb 2002</b>			
Combined species	72	106	45
Loggerhead	65	89	13
Leatherback	0	10	27
Olive ridley	2	7	1
Green	5	0	0
Unknown hardshell	0	0	4
<b>Post-regulations 3 May 2004 – 31 March 2007</b>			
Combined species	35	12	8
Loggerhead	31	4	5
Leatherback	4	8	1
Olive ridley	0	0	0
Green	0	0	0
Unknown hardshell	0	0	2

<sup>a</sup> Terminal tackle may include a hook, monofilament line, and possibly wire trace and a weighted swivel.

<sup>b</sup> Turtle came free of the gear before getting close enough to the vessel for the observer to determine the turtle's condition or otherwise there was no information recorded in the observer program database of whether or not terminal tackle was attached to the released hooked turtle. Prior to 22 August 2003, managers of the Hawaii longline observer database did not input information on what type of terminal tackle, if any, was attached to released turtles. Observers have always recorded this information, thus this more detailed information is likely available in the hard copy observer files.

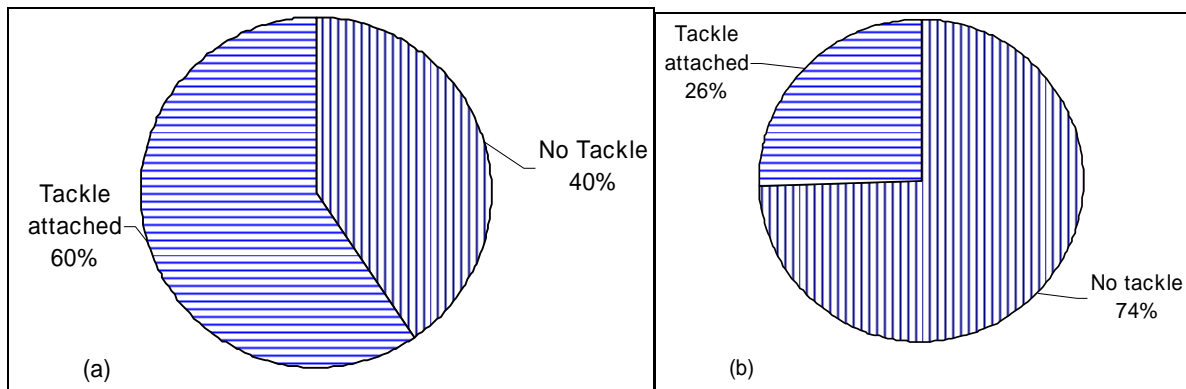


Fig. 5. Proportion of sea turtles combined species caught in the Hawaii longline swordfish fishery that were released after removal of all terminal tackle vs. released with some terminal tackle remaining attached (a) before and (b) after sea turtle regulations came into effect.

#### 4. References

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