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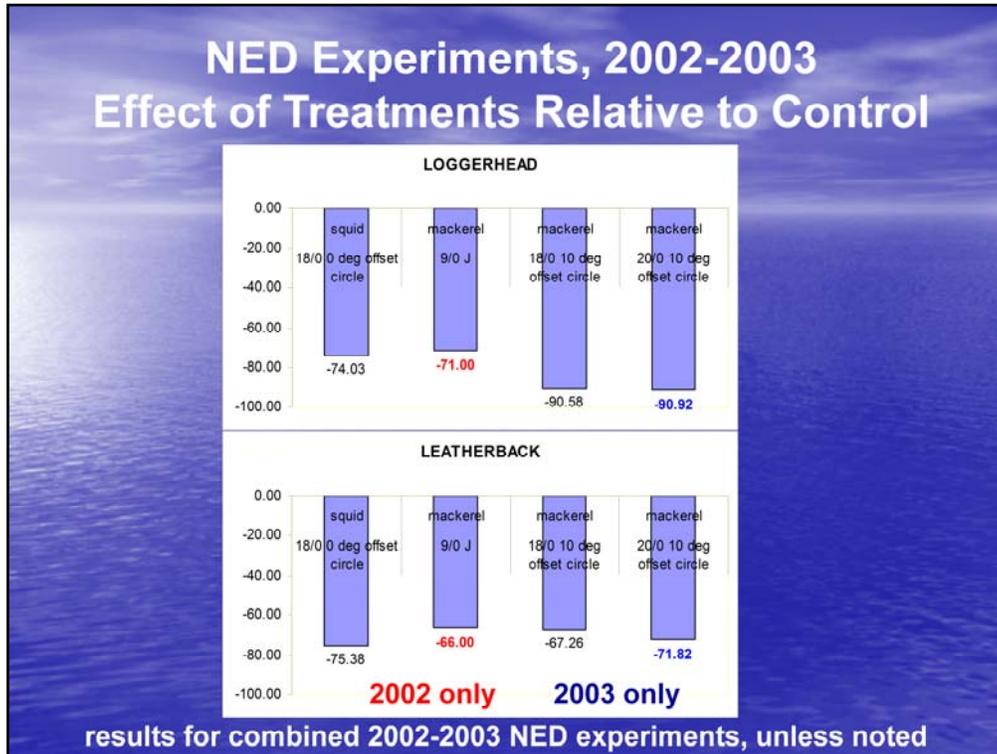


Sea Turtle Bycatch Reduction in the U.S. Atlantic Pelagic Longline Fishery – preliminary analysis

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FISHERIES
SERVICE**

[Note to reader or interpreter – the text in italics is for your information only. It is not part of the spoken narrative.]



Five years ago the NED experiments were completed and we had begun to report the results. They were striking – hook and/or bait changes could effect significant reductions in the catch of loggerhead and leatherback sea turtles.

[In Watson et al. 2005, Canadian Journal of Fisheries and Aquatic Sciences]

We noted that because leatherbacks often are hooked externally – and that probably is not a function a circle hook’s size - we expected circle hooks smaller than 18/0 would be at least as effective as the tested 18/0 hook in reducing foul hooking. Thus, the NED results should be applicable to other areas.

We did not believe the experimental results could be applied outside the NED to different sizes of loggerhead turtles or for different sized hooks because we had evidence to suggest that the ability of a loggerhead to ingest a hook is a function of the hook’s size and the animal’s size

Background:

This shows the detailed results for swordfish-directed sets.

The y-axis is the % difference in CPUE (expressed as catch per hook, calculated on a per set basis, blocking by set when the comparisons were paired) when compared to the control of a 9/0 J hook baited with squid. When the number is negative, that means that the treatment resulted in a reduction in the catch of that species.

Each panel has 4 bars: The first bar is the effect of only the straight circle hook (baited with squid). The second bar is the effect of only mackerel bait (9/0 J hook). The 3rd and 4th bars are the effects of the combination of mackerel and the offset circle hooks: the 3rd bar is for the 18/0 circle hook and the 4th bar is for the 20/0 circle hook.

Data for the 2 years are combined unless noted.

For both species, both treatment individually and in combination resulted in a reduction in the bycatch of turtles.

For loggerheads the reduction ranged from 71% to 91%, with the greatest reduction occurring on circle hooks baited with mackerel.

For leatherbacks, the reduction ranged from 66% to 75%, with the greatest reduction occurring on circle hooks baited with squid, the control bait.

July 6, 2004 Final Rule

- **Within the NED**
 - 18/0 or larger circle hooks
 - offset not to exceed 10 degrees
 - Baits: whole Atlantic mackerel or squids
- **Outside the NED**
 - 16/0 or larger non-offset circle hooks
 - 18/0 or larger circle hooks with offset not to exceed 10 degrees
 - Bait: whole finfish or squids
- **All areas (Reasonable and Prudent Alternative)**
 - possess and use sea turtle release equipment
 - comply with specified sea turtle handling and release protocols

In 2004 the National Marine Fisheries Service promulgated regulations in both the Hawaii-based longline fishery and the Atlantic pelagic longline fishery. The regulations in the Atlantic varied by region.

Within the NED, fishers had to use 18/0 circle hooks or larger with offsets not to exceed 10 degrees. Bait must be squids or whole Atlantic mackerel.

Outside the NED, fishers had to use 16/0 or larger circle hooks – only 18/0 hooks and larger could have an offset, and they had to use squids or whole finfish baits.

In addition, the final rule contained a measure to address post-release mortality. Careful release protocols were mandated.

June 1, 2004 Biological Opinion

Leatherbacks: jeopardy

Other listed species: not-jeopardy

Reasonable and Prudent Alternatives (RPA)

- Improve monitoring of the effects of the fishery,**
- Confirm the effectiveness of the hook and bait combinations that are required as part of the proposed action,**
- Reduce post-release mortality of leatherbacks, and**
- Take management action to avoid long-term elevations in leatherback takes or mortality**

The Biological Opinion stipulated that NOAA Fisheries must undertake management and conservation measures to address and reduce the adverse effects to leatherback populations expected to result from the new rule. There were four Reasonable and Prudent Alternatives specified.

The first required quarterly and annual reports, set deadlines for those reports and identified the necessary content. It also set a minimum level of observer coverage (8%) and specified the details that the observers must record.

June 1, 2004 Biological Opinion

Reasonable and Prudent Alternatives (RPA)

- Improve monitoring of the effects of the fishery,
- **Confirm the effectiveness of the hook and bait combinations that are required as part of the proposed action,**
- Reduce post-release mortality of leatherbacks, and
- Take management action to avoid long-term elevations in leatherback takes or mortality

The second RPA required us to confirm the effectiveness of the hook and bait combinations that were required by the rule.

Questions for this analysis:

- 1) What are the observed changes in bycatch rates associated with regulation ?
- 2) Are these attributable to the management measures (i.e., circle hooks and bait) ?
- 3) Are the bycatch targets being met for each species ?

Remember that:

Bycatch is a function of both bycatch rate (CPUE) and total effort

The regulations were exclusively directed at reducing bycatch rates not controlling fishing effort.

Modeling Bycatch Rates

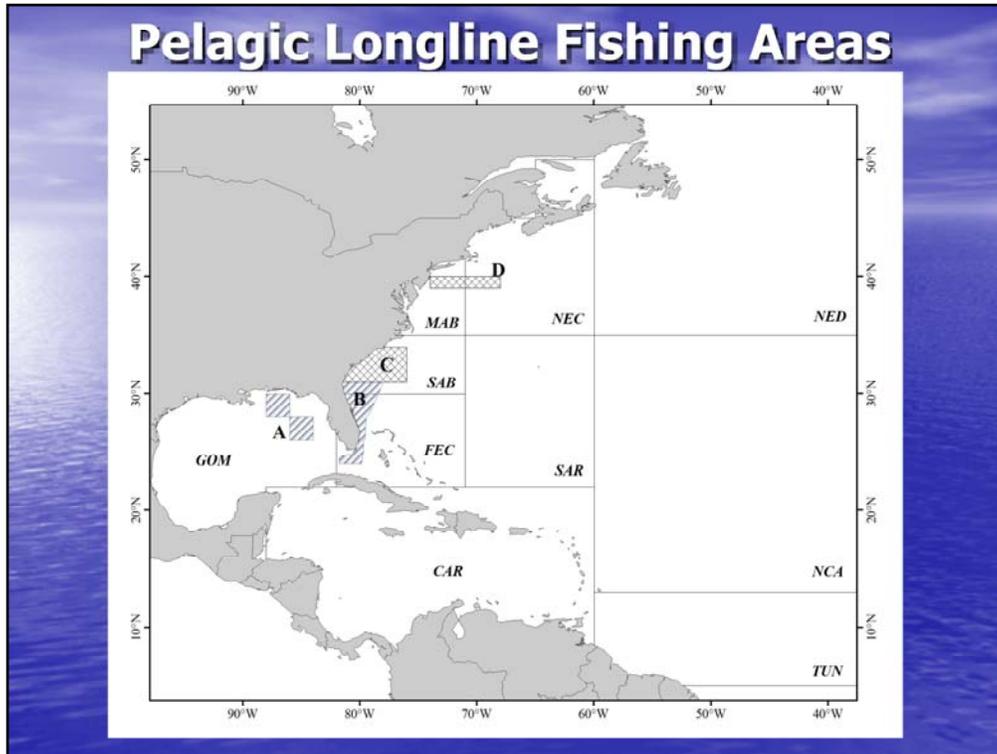
Analysis divided into time periods:

**Outside NED: 2001 – August 2004 = Before
Sept. 2004 – Sept. 2008 = After**

**Within NED: 1998-2000 = Before
2002-2003 = Experiment
June 2004 – Sept. 2008 = After**

METHODS

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The regions were grouped by target species/gear types for analysis:

In addition to the NED (swordfish-directed)

Gulf of Mexico (little swordfish, mostly mixed species and tunas)

Southeast Coastal (FEC and SAB) (mostly swordfish, but some tunas)

Northeast Coastal (MAB and NEC) (swordfish, mixed species, bigeye tuna, yellowfin tuna, other tunas)

Offshore (NCA, SAR, CAR) (swordfish-directly)

Fishery Changes Post-Regulation

- **The fisheries used predominantly J-hooks prior to regulation. Switch to 16/0 circle hooks in the Gulf of Mexico, 18/0 hooks in the remainder of the fishery**
- **Some increases in use of fish bait or fish and squid bait in combination, particularly in offshore areas including the NED**
- **Little change in other fishery characteristics (e.g., hooks fished, mainline length) with exception of NED**
- **In NED, fishing in cooler water with shallower hook depths than in the pre-regulation/pre-experiment period (1998-2000)**

We examined the fisheries for changes in how they operated post-regulation.

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Modeling Bycatch Rates

- Modeling counts of turtles per haul as a function of gear, bait, and fishing variables
- Three alternative model forms used depending on the distributional characteristics of the data
 - Poisson* – base count model assuming variance = rate
 - Negative Binomial* – used in the presence of overdispersion
 - "Hurdle" Models* – a mixed logit and zero-truncated negative binomial in the presence of zero-inflation
- Models were evaluated for fit against observed data and predicted catch per haul was used to evaluate change in bycatch rates.
- Rates multiplied by reported effort to estimate bycatch.

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Model Summaries – Loggerheads

Model Type	Gulf of Mexico	Southeast	Northeast	Caribbean/ Offshore	Northeast Distant	
	Neg. Binom.	Poisson	Neg. Binom.	Neg. Binom.	Logit	Neg. Binom.
Target - Sword	ns	ns	95.1%	-	ns	ns
Target - Mix	ns	ns	ns	-	-	ns
C-16 Hook	-67.6%	ns	ns	-	-	ns
C-18 Hook	-	ns	ns	-68.7%	-75.1%	ns
J & C-18 Hook	-	-	-	-	-56.0%	ns
Fish Only	ns	-74.9%	ns	-	-85.9%	-92.3%
Fish and Squid	ns	ns	ns	ns	-69.3%	ns
Mainline Len. (+ 10 miles)	ns	ns	ns	-54.7%	67.4%	188.3%
Soak Duration	ns	ns	-14.0%	ns	ns	ns
Hook Depth	ns	ns	ns	ns	ns	ns
Haul Temp. (70 to 60 F)	ns	ns	ns	ns	-96.8% (lin.)	ns
# of Hooks (+ 100 hooks)	ns	ns	ns	68.4%	ns	ns
Quarter 2	356.8%	-70.9%	ns	ns	-	-
Quarter 3	ns	-91.2%	ns	-	-	-
Quarter 4	ns	ns	ns	ns	208.1%	153.5%
Other Factors	ns	ns	ns	ns	1123.1%	ns

This table summarizes the findings of the regression models for bycatch rates of loggerhead turtles. Colored cells indicate important explanatory variables and their separate [*independent*] impact on the predicted number of turtles caught per haul.

Each column represents a model fitted to data for each region. For the Gulf of Mexico, Southeast, Northeast, and Offshore regions, there was no evidence of zero-inflation and either Poisson or negative binomial models were used as needed. There was evidence of zero inflation in the NED data, and hence the table shows parameter values for the binary (logit) portion of the model and the truncated negative binomial component of the model.

The rows represent explanatory variables including binary variables coded for target species, circle hooks as compared to J-hooks; fish and combined fish and squid baits vs. squid only baits. In addition, continuous variables for gear characteristics, and fixed effects for each quarter of the year were examined.

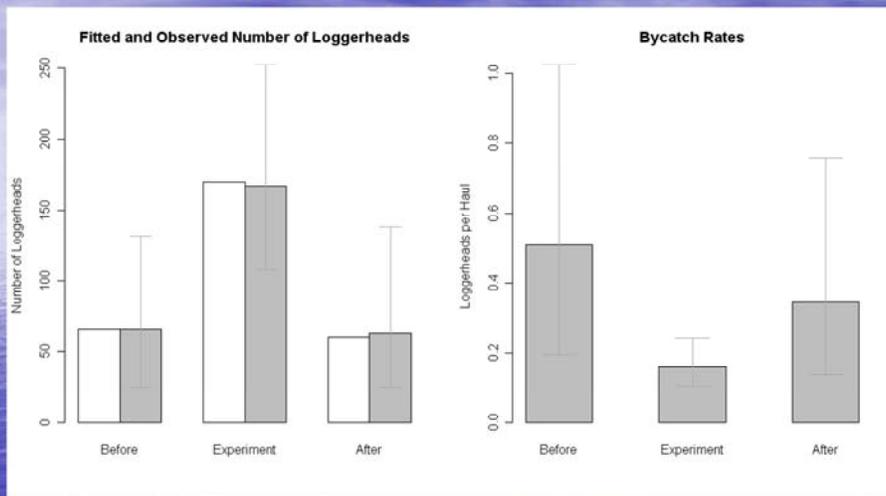
The last variable, "other factors" is a binary variable coded to compare bycatch rates post regulation to those pre-regulation separate [*independent*] of other tested factors. When this variable is important, it suggests that there are temporal changes in bycatch that are not effectively fit using the other variables. This temporal variable may also be confounded with other explanatory variables and thus its inclusion in the models, where needed to adequately fit the data, clouds interpretation of the effectiveness of the variables of interest, particularly the effects of circle hooks and baits on bycatch rate. This is because the circle hook and bait changes occurred simultaneous with the regulation.

For loggerhead turtles, circle hooks were apparently effective in reducing bycatch in the Gulf of Mexico and Caribbean/Offshore regions. Fish baits apparently were effective at reducing bycatch in the Southeast region.

For loggerhead turtles in the NED, the confounded "other factor" effect was highly significant and indicated that the occurrence of sets capturing turtles was approximately 11 times more likely post-regulation compared to pre-regulation. This indicates an important temporally correlated effect that has tended to increase the likelihood of capturing loggerhead turtles in the NED. Despite this, the parameter values for circle hooks and fish and squid baits suggest that these factors reduced the likelihood of loggerhead turtle bycatch. However, the effectiveness of these gear changes was offset to a large degree by the "other factors". Perhaps untested or unknown environmental factors, or changes in population sizes or distributions

may have increased the likelihood of longline gear interacting with loggerhead turtles.

Model Summaries – Loggerheads Northeast Distant Area



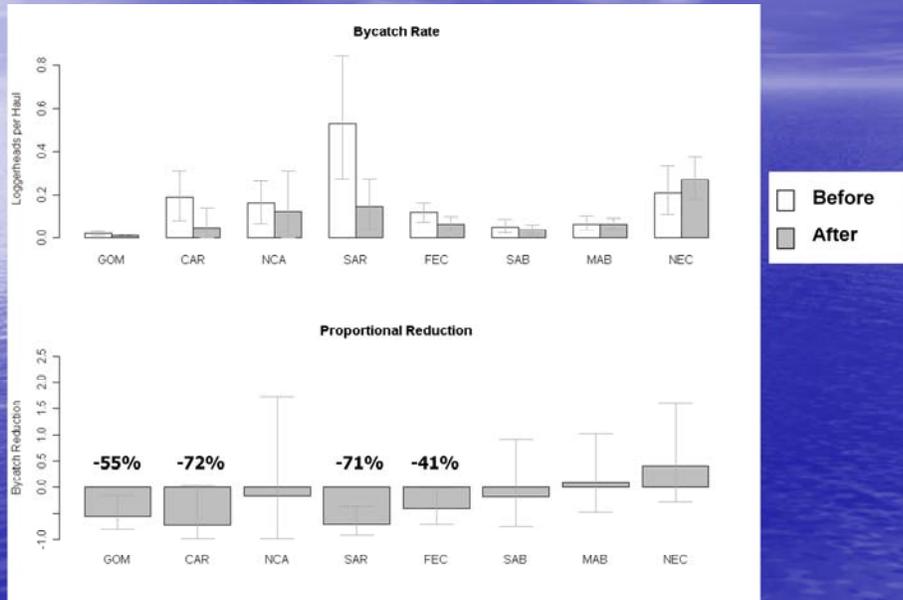
No significant reduction in rate comparing before (1998-2000) to after (2004-2008): Reduction = -18.1% (95% CI -78% to +130%)

Bycatch rates post-reg. significantly higher than expected from experiment

In the NED where our experiments had been based, we see that the models fit the observed data well (*left panel*).

(*Right Panel*) While the post-regulation bycatch rate of loggerheads is less than the pre-regulation rate by 18.1%, the reduction is not significant and the rate is higher than observed during the experiments (2002-2003).

Model Summaries – Loggerheads Bycatch Rates and Proportional Reductions



In the areas outside the NED, the loggerhead bycatch rate was significantly reduced in the GOM, CAR, SAR, and FEC. The reduction was not significant elsewhere.

Model Summaries – Leatherbacks

Model Type	Gulf of Mexico	Southeast	Northeast	Caribbean/ Offshore	Northeast Distant	
	Neg. Binom.	Poisson	Poisson	Poisson	Logit	Neg. Binom.
Target - Sword	-	ns	ns	-	-	-
Target - Mix	-	ns	ns	-	-	-
C-16 Hook	213.4%	ns	ns	-	-	-
C-18 Hook	211.8%	-56.4%	ns	ns	ns	ns
J & C-18 Hook	-	-	-	-	ns	ns
Fish Only	-70.7%	ns	ns	-	-52.7%	ns
Fish and Squid	-48.2%	ns	ns	ns	ns	ns
Mainline Len. (+ 10 miles)	ns	ns	149.9%	ns	ns	ns
Soak Duration	ns	ns	ns	ns	ns	ns
Hook Depth	ns	ns	ns	ns	ns	ns
Haul Temp. (70 to 60 F)	ns	ns	-33.4% (sq.)	1130% (lin.)	-55.5% (sq.)	ns
# of Hooks (+ 100 hooks)	ns	ns	ns	86.8%	ns	ns
Quarter 2	221.9%	-13.5%	ns	ns	-	-
Quarter 3	ns	ns	ns	-	-	-
Quarter 4	300.7%	ns	ns	ns	ns	ns
Other Factors	-89.9%	ns	ns	ns	151.7%	ns

Looking at leatherbacks – this table is structured similar to the one before for loggerheads.

The “other factor” effect was significant for the Gulf of Mexico, and indicated a significant reduction in the bycatch rate of leatherback turtles after the regulations were implemented. This effect was strongly confounded with the circle hook effects and the bait effects because these changes almost exclusively post-regulation. Therefore, it is difficult to interpret their separate [*independent*] impacts on bycatch. The parameter values for bait types are negative, suggesting that they tended to result in additional reductions in bycatch.

Circle hooks had a significant negative effect on bycatch rates in the Southeast region, but not in the other areas. Other effects of note include both quadratic and linear effects of water temperature.

As with loggerhead turtles, there was evidence of zero-inflation in the NED for leatherback turtles and the combined logit and truncated negative binomial model was again necessary.

The use of fish bait was correlated with a reduced likelihood of bycatch of turtles in the NED. However, the “other factor” effect was also important in the NED, suggesting a generally higher than expected likelihood of bycatch in comparison to the experiment and pre-regulation time periods.

Model Summaries – Leatherbacks Northeast Distant Area

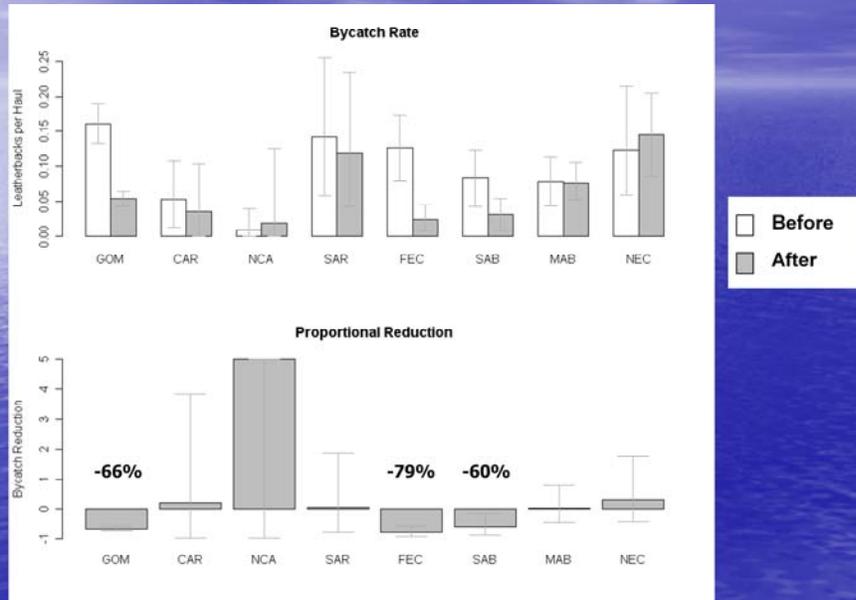


No significant reduction in rate comparing before (1998-2000) to after (2004-2008): Reduction = -22.8% (95% CI -66% to +58%)

In the NED where our experiments had been based, we again see that the leatherback models fit the observed data well (*left panel*).

(*Right panel*) While the post-regulation bycatch rate of leatherbacks in the NED is less than the pre-regulation rate by 22.8%, the reduction is not significant and the rate is higher than observed during the experiments (2002-2003).

Model Summaries – Leatherbacks Bycatch Rates and Proportional Reductions



In the areas outside the NED, the leatherback bycatch rate was significantly reduced in the GOM, FEC, and SAB. The reduction was not significant elsewhere.

Bycatch Reduction

Targets are being met for both loggerhead and leatherback turtles

Loggerheads

BiOp: 575 outside NED + 60 in NED = **545**

Outside NED: Estimated = **384** (95% CI 221-583)

Within NED: Estimated = **157** (95% CI 62-344)

Leatherbacks

BiOp: 481 outside NED + 107 in NED = **588**

Outside NED: Estimated = **482** (95% CI 318-659)

Within NED: Estimated = **113** (95% CI 62-187)

We estimated total bycatch for each species by multiplying bycatch rates by reported effort.

The BiOp authorized an average total take of 545 loggerheads annually and we estimate the annual takes at 541. There were reduced estimated takes in the CAR, FEC, GOM, SAB, and SAR areas, but increased estimated takes in MAB.

The BiOp authorized an average total take of 588 leatherbacks and we estimate annual takes at 595. There were reduced estimated takes in GOM, FEC, and SAB, but increased estimated takes in MAB. There was about a 47% decrease in annual takes of leatherbacks post-regulation.

The bycatch problem is not just about the number of takes, but also about the post-release mortality of animals captured. Most are released alive, but injured.

June 1, 2004 Biological Opinion

Reasonable and Prudent Alternatives (RPA)

- Improve monitoring of the effects of the fishery,
- Confirm the effectiveness of the hook and bait combinations that are required as part of the proposed action,
- **Reduce post-release mortality of leatherbacks, and**
- Take management action to avoid long-term elevations in leatherback takes or mortality

The 3rd RPA is to reduce the post-release mortality of leatherbacks – recall the requirement in the final rule to have specific equipment and to follow careful release protocols when releasing sea turtles.

June 1, 2004 Biological Opinion

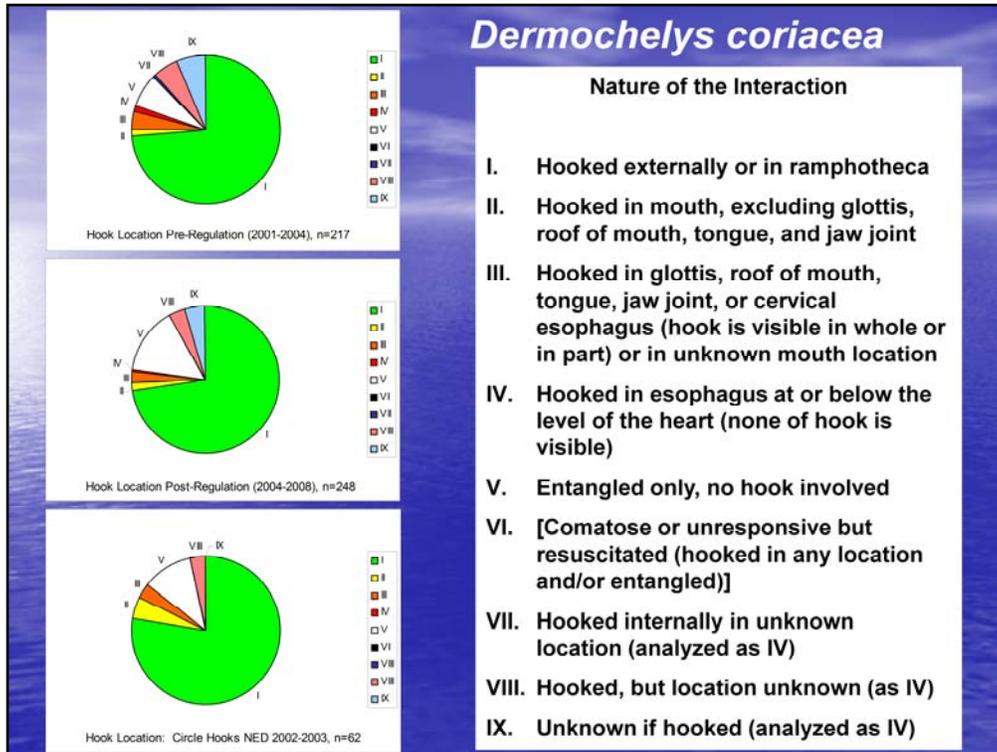
"The SEFSC must use this information [January 2004 draft post-release mortality criteria] to determine the net mortality ratio associated with the observed captures, according to the method of Epperly and Boggs (2004)"

Long-Term Net Mortality Targets (beginning 2007)

- **Leatherbacks (focus of RPA)**
 - A drop in mortality ratio from 32.8% to 13.1% with RPA requiring gear removal (31.9% without RPA)
- **Loggerheads**
 - A drop in mortality ratio from 40.4% to 17.0% (21.8% without RPA)

Overall post-release mortality ratios are dependent upon both the nature of the interaction (i.e., where hooked, whether entangled, whether comatose upon retrieval) and the release situation - gear that was left following the release (hook remaining, amount of line remaining, entangled or not). Therefore, in addition to how the turtle interacted with the gear, the experience, ability, and willingness of the crew to remove gear and the available gear-removal equipment are very important factors in the post-release mortality of sea turtles.

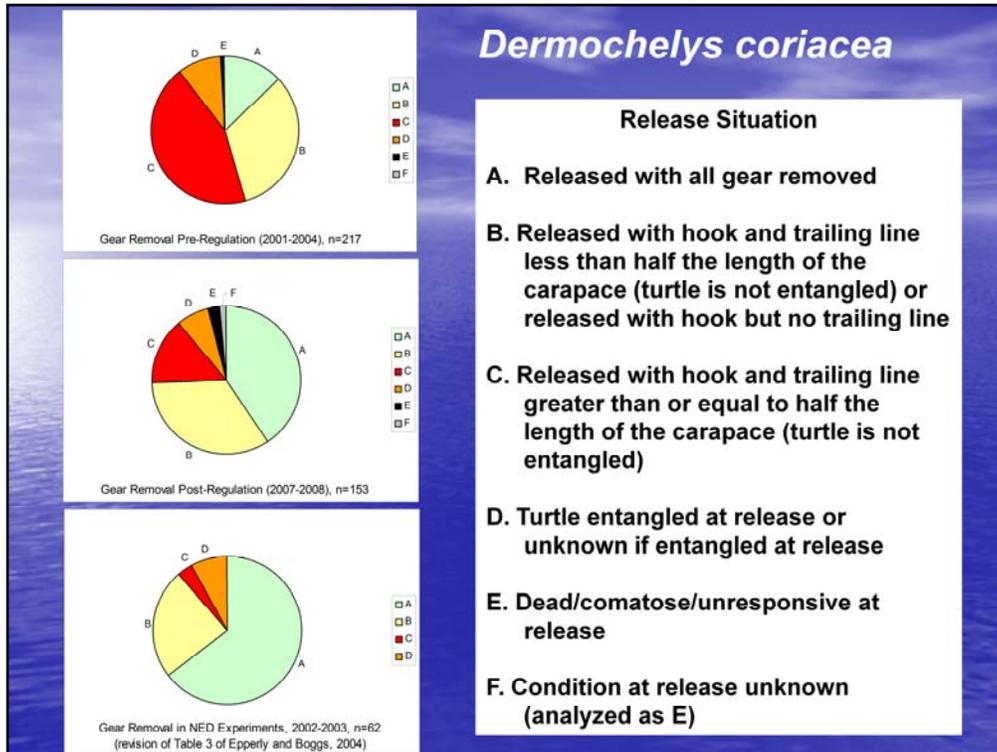
The performance of the fishers in the NED for gear removal and also the hooking locations expected with circle hooks was the basis for the mortality ratio goals set for the remainder of the fishery. The fishers were given 2 ½ years to reach that goal and beginning in 2007 were expected to maintain that level of performance.



LEATHERBACKS [*Emphasize N's*]

We did not see a difference in hooking locations in leatherbacks with J-hooks and circle hooks in the NED experiments.

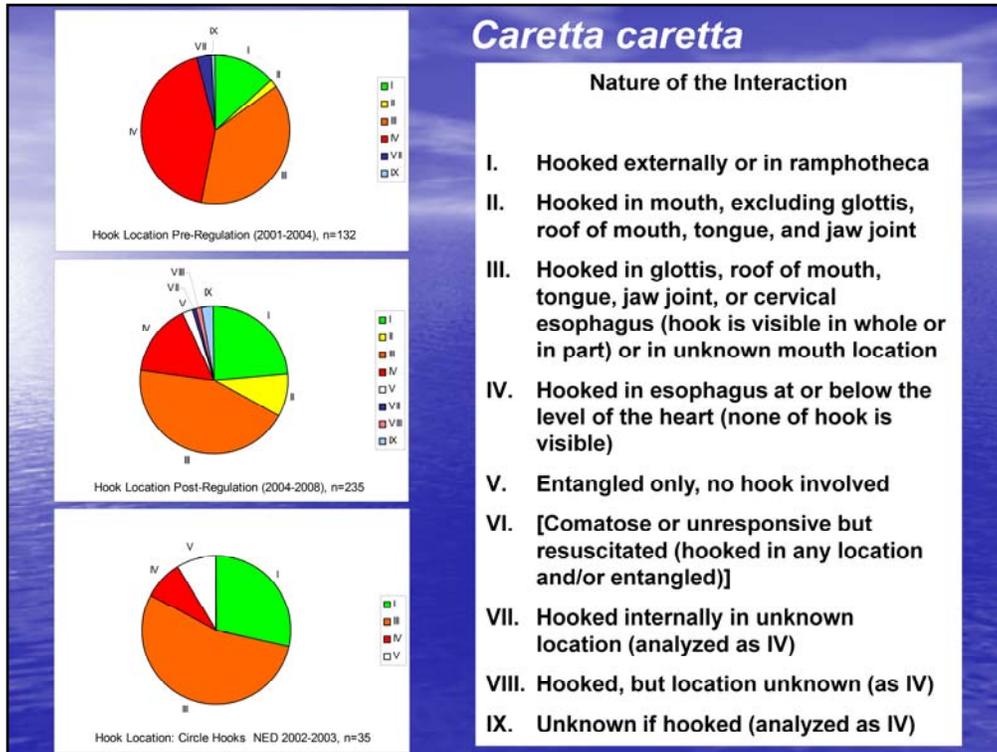
In both the pre-regulation period (*top*) and the post-regulation period (*middle*), leatherbacks were predominately foul-hooked – e.g., hooked externally (*I. green*), which is what we observed in our NED experiments (*bottom*).



In the NED experiments, about 5/8 of all leatherbacks were released with all gear removed and a very small proportion were released with substantial amounts of gear attached (*bottom C. red*).

During the pre-regulation period, most leatherbacks were being released with a substantial amount of gear still attached – more than 1/2 their carapace lengths (*top: C. red*).

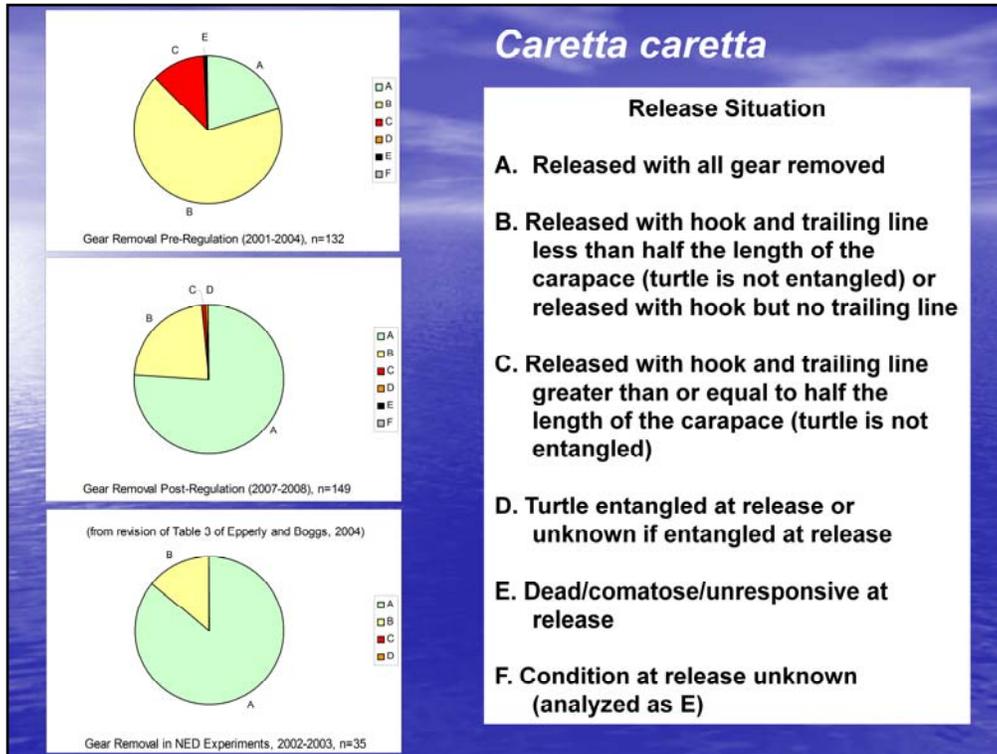
Post-regulation, about 1/8 were still being released with a substantial amount of gear still attached (*middle*).



LOGGERHEADS [*Emphasize N's*]

In the NED experiments we observed significant differences in the hook locations between J-hooks and circle hooks. With circle hooks a very small proportion of the animals swallowed the hooks (*bottom IV. red*).

Pre-regulation, nearly half the animals swallowed the hooks (*top*), but afterwards only about $\frac{1}{4}$ had swallowed the hooks (*middle*). Like we observed in the NED, post-regulation most hooks were external (*I. green*), or in the mouth or cervical esophagus (*II. Yellow and III. Orange*) where the gear could be removed.



Fishers in the NED experiment removed all the gear from nearly all loggerhead turtles (*bottom A. green*).

Pre-regulation, most loggerheads were released with gear, although most often the amount of gear was less than $\frac{1}{2}$ the carapace length (*top B. yellow*)

After the regulations were effective, $\frac{3}{4}$ of all loggerheads were released with all gear removed (*middle, A. green*).

June 1, 2004 Biological Opinion Post-Hooking Mortality Ratios

- **Leatherbacks**
 - Revised NED analysis: goal is 17.0%
 - 2007-2008 fishery: 21.4%
- **Loggerheads**
 - Revised NED analysis: goal is 17.8%
 - 2007-2008 fishery: 23.7%

Looking at the post-release mortality goals, based on a revision of the Epperly and Boggs (2004) estimates, we expected a post-release mortality ratio of 17% for leatherbacks and 18% for loggerheads. For the period beginning January 2007, the fishery fell short of those goals by 4% in the case of leatherbacks and by 6% in the case of loggerheads.

Summary

- **Bycatch rates in the NED are higher than expected for both species for reasons that appear to be due to other factors not measured**
- **Reductions in bycatch were realized in the GOM, Offshore, and Southern Areas, but not in waters of the Mid-Atlantic and Northeast U.S.**
- **Overall bycatch reduction goals for the Atlantic pelagic longline fishery are being met**
- **Mortality ratio goals, based on NED experiment accomplishments (revised), are not quite being met**

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Summary

- Effectiveness of circle hooks was not uniform among the fisheries/areas; there are many confounding factors to consider
- Circle hooks appear to be effective in reducing loggerhead bycatch rates in directed swordfish fisheries in the NED, offshore areas, Caribbean, and in the mixed fisheries of the Gulf of Mexico and appear to be effective in reducing leatherback bycatch in the Southeast
- Circle hooks do appear to be effective in reducing the post-hooking mortality of loggerheads (via hooking locations); furthermore, the careful release protocols also are contributing to an expected lower mortality post-release in both species.
- Fish baits do appear effective, particularly in the NED (both species), the Gulf of Mexico (leatherbacks), and the Southeast (loggerheads); effectiveness of bait for loggerheads corroborated through feeding experiments (Stokes et al. 2006)

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Questions?

Acknowledgements: Larry Beerkircher, Christofer Boggs, Lisa Belskis, and many pelagic longline observers.



