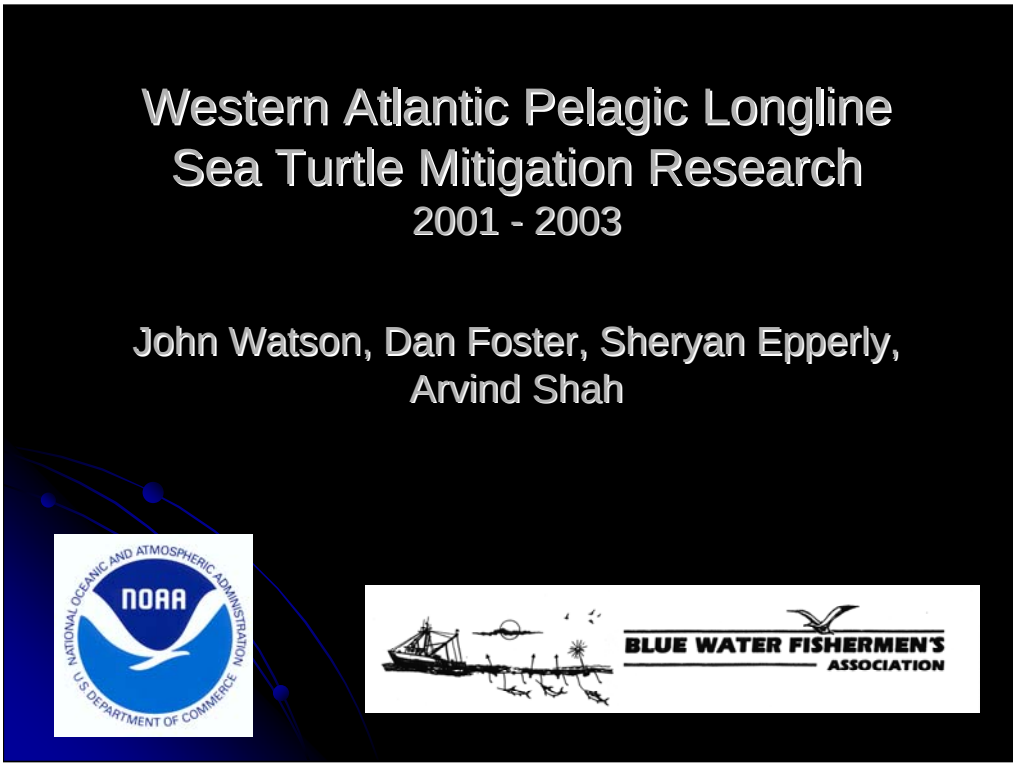
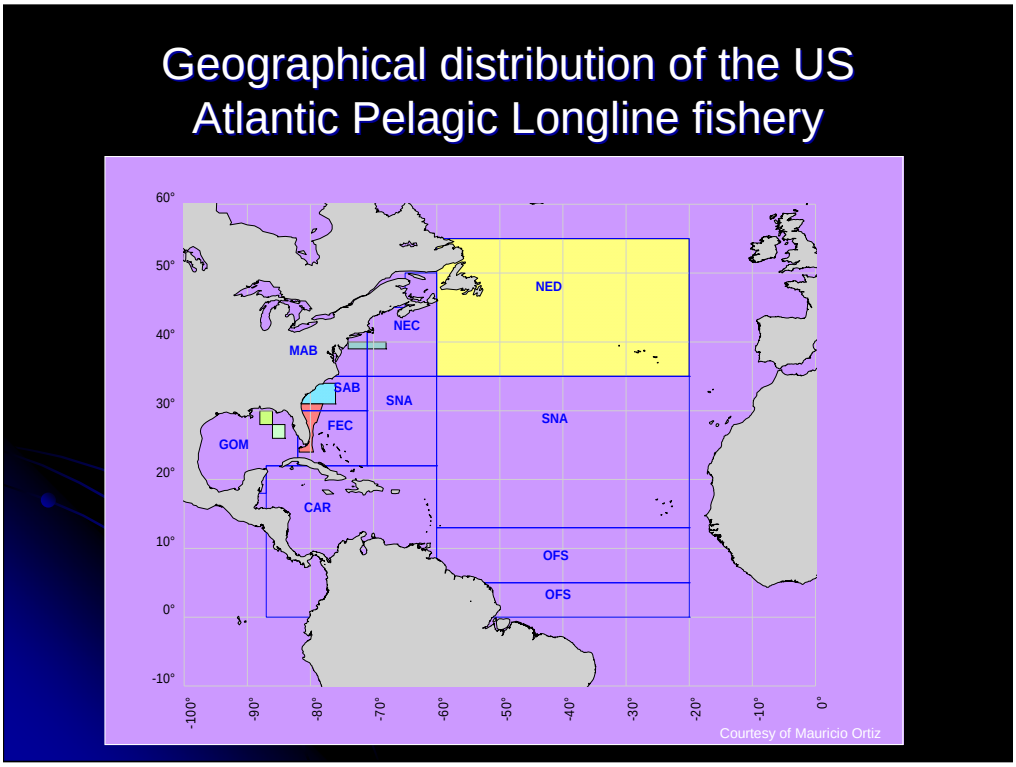
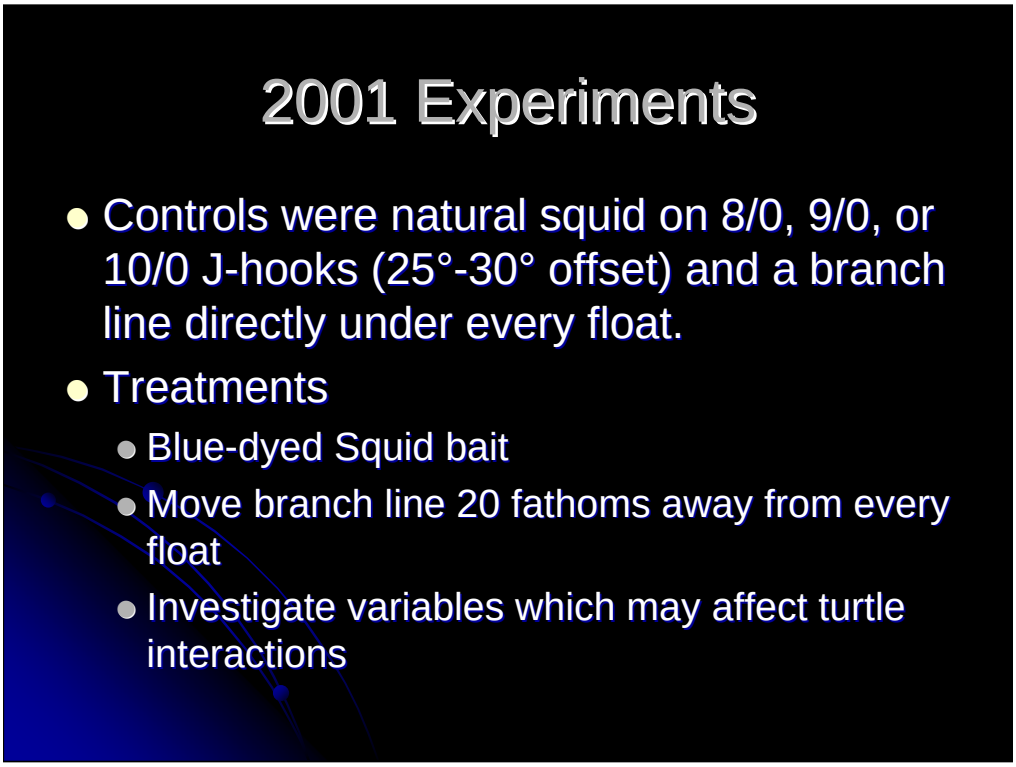


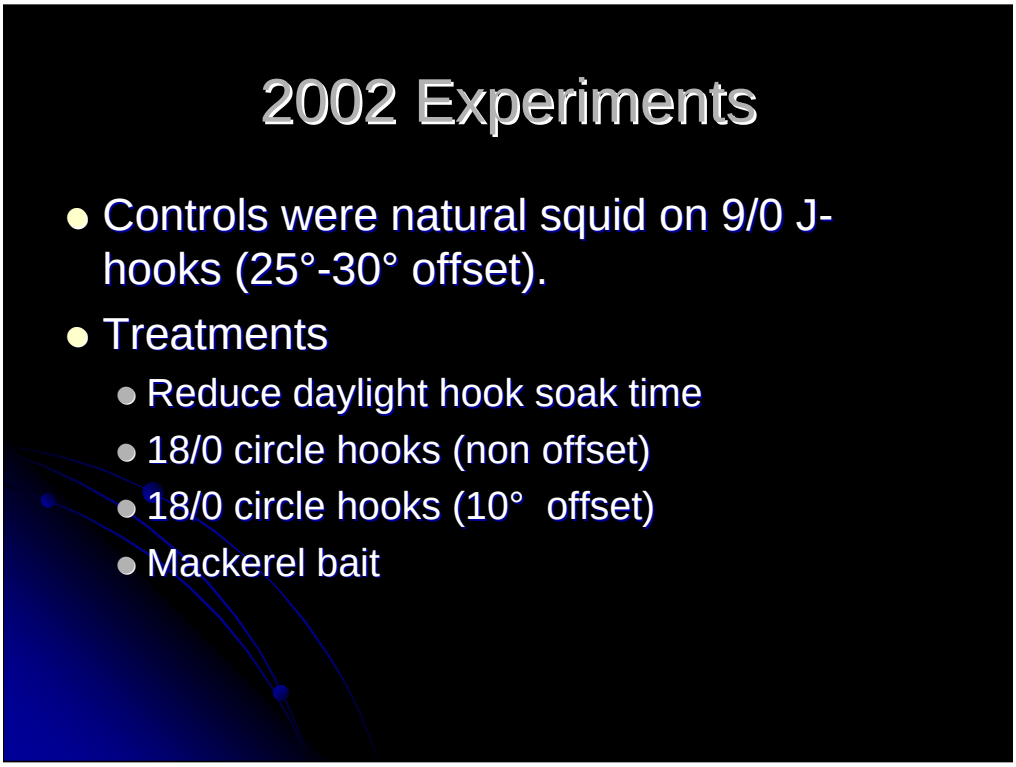
NOAA Fisheries in cooperation with the Blue Water Fishermen's Association conducted research in the Western Atlantic Ocean to develop and evaluate fishing gear modifications and tactics to reduce the incidental capture of endangered and threatened sea turtle species by pelagic longline fishing gears. A three year project was initiated in 2001 and was completed in 2003. The following presentation is a summary of the results of this research.



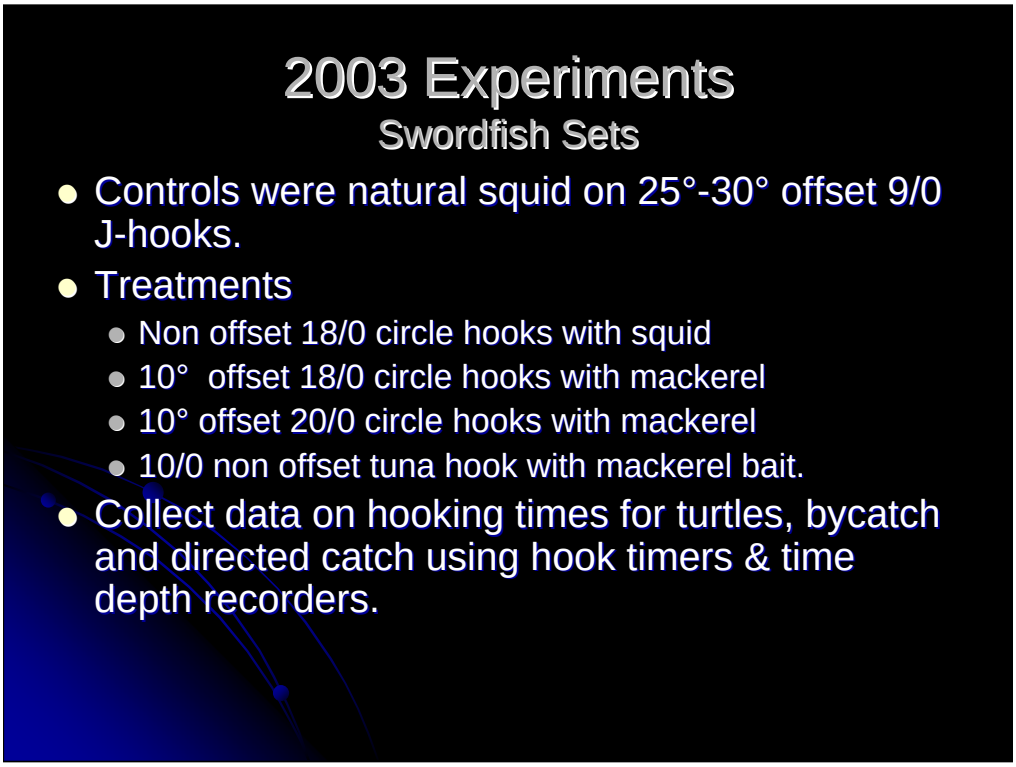
The area of operation was the Northeast Distant Waters (NED) statistical reporting zone in the Western Atlantic Ocean. The NED area is closed to pelagic longline fishing by U.S. flag vessels by regulation with the exception of the experimental fishery.



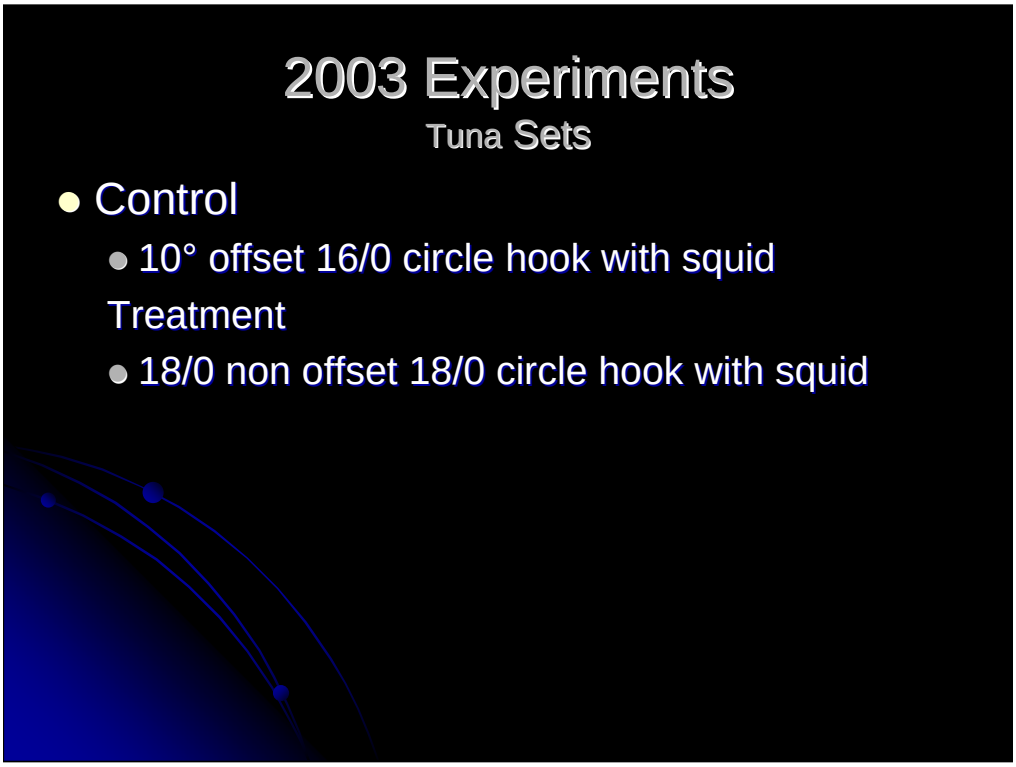
In 2001 the research experimental design was to test the effect of moving hooks that are normally deployed very near floats to 20 fathoms away from floats as historical data indicates a higher turtle take proportion on the hooks nearest floats. The design also tested the effect of using blue dyed squid rather than the standard squid as bait. Data on eighteen other variables were also collected to determine their effect on turtle capture rates.



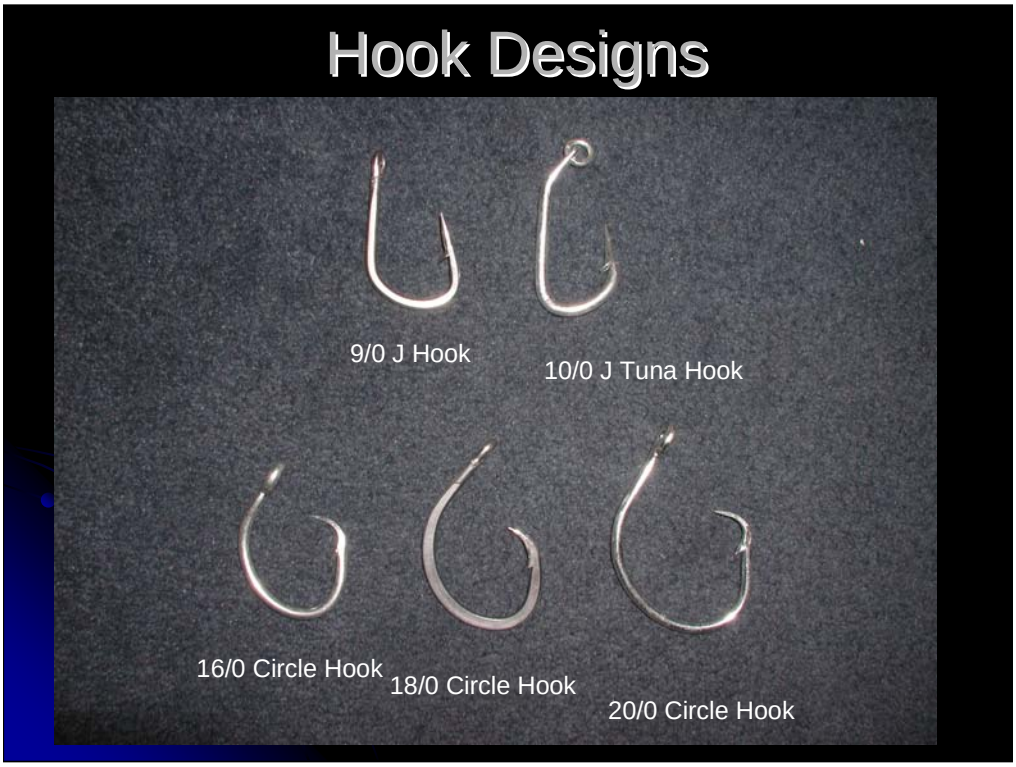
In 2002 the experimental design evaluated the effect of reducing daylight hook soak time, the use of 18/0 circle hooks both offset and non offset with squid bait, and the use of mackerel bait on both J hooks (control) and 18/0 circle hooks in reducing sea turtle interactions with pelagic longline gear.



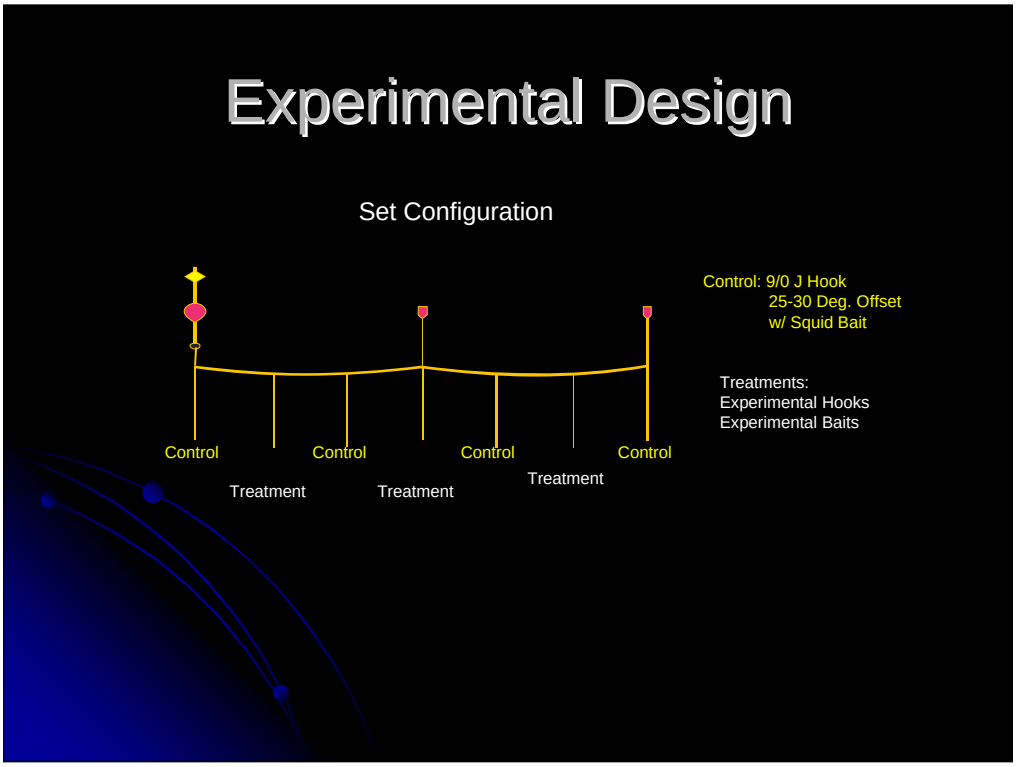
The control hook was a 25° - 30° offset “J” hook and the control bait was squid. Treatments were non offset 18/0 circle hook with squid bait, 10° offset 18/0 circle hook with mackerel bait, 10° offset 20/0 circle hook with mackerel bait, and non offset 10/0 Japanese tuna hook with mackerel bait. Data was also collected on hooking times and depths for target and bycatch species using hook timers and time depth recorders.



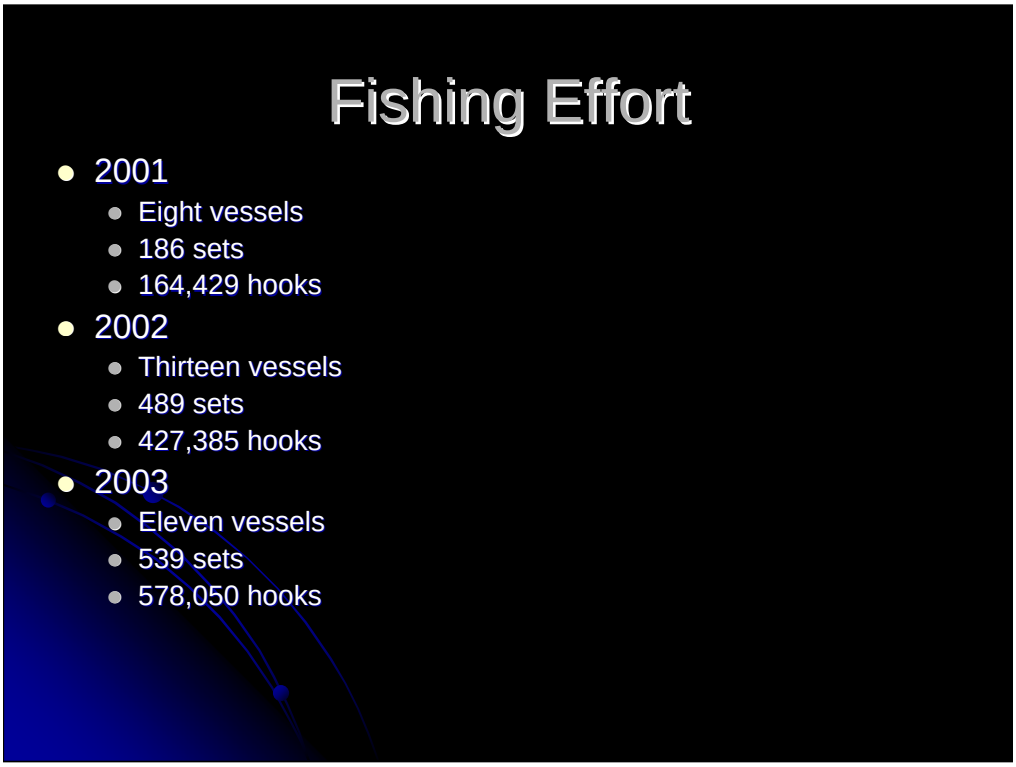
The control hook for tuna directed fishing sets was a 10° offset 16/0 circle hook and the control bait was squid and the treatment hook was a non offset 18/0 circle hook and the treatment bait was squid.



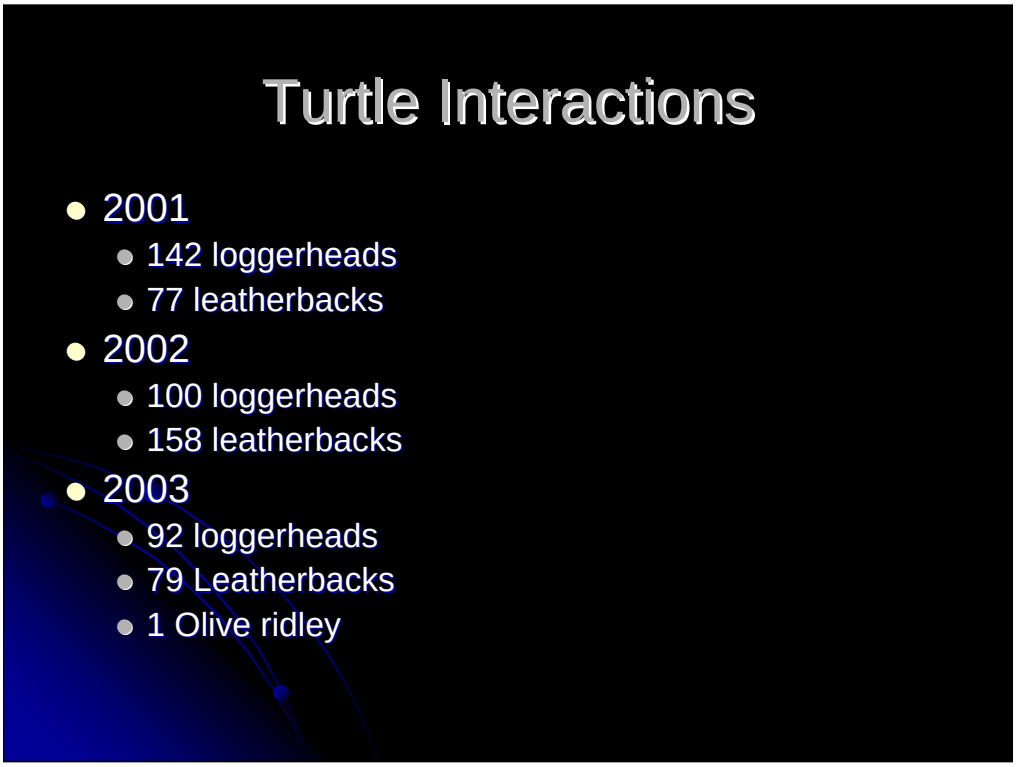
Control and treatment hooks designs tested.



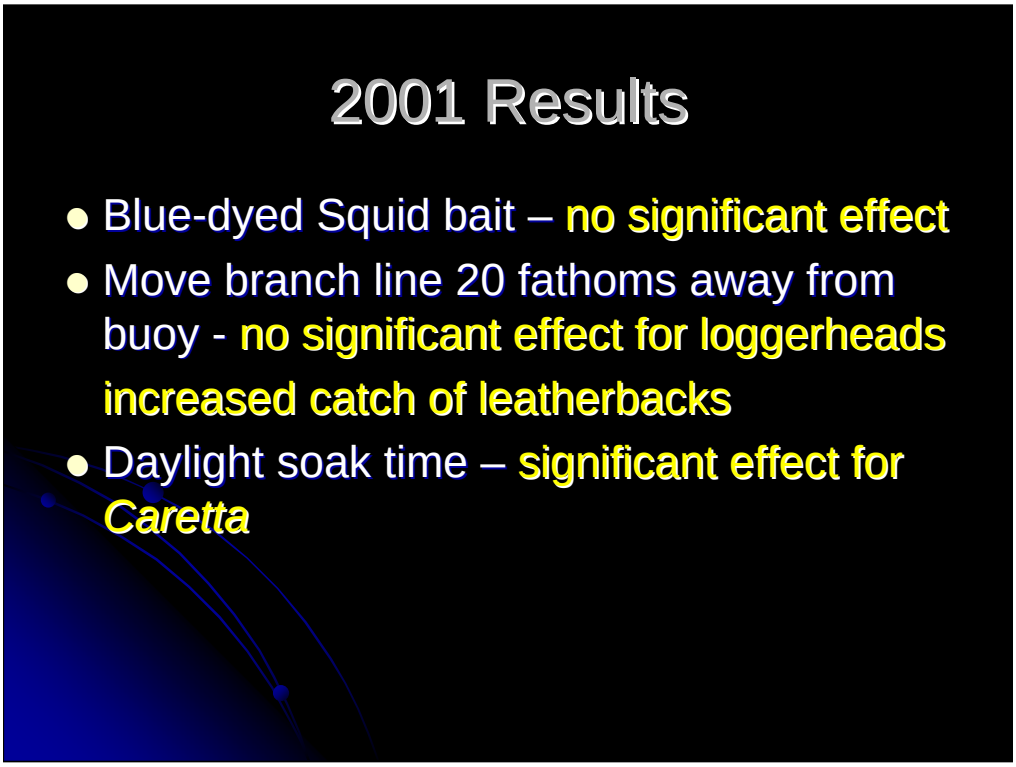
The experimental design was to evaluate the treatment hooks and baits using a randomized block design alternating control hooks and experimental hooks and bait along the entire set. Bait types (ie squid or mackerel) were not mixed on a set.



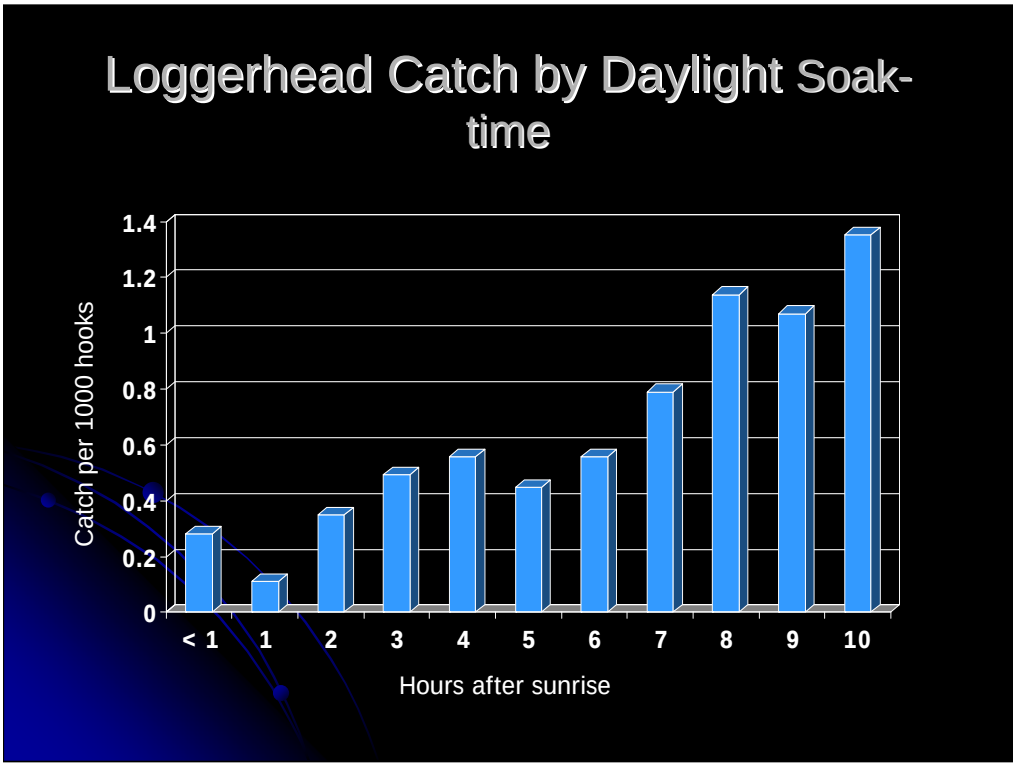
In 2001 eight commercial pelagic longline vessels made 186 sets fishing 164,429 hooks. In 2002 thirteen vessels made 489 sets fishing 427,385 hooks, and in 2003 eleven vessels made 539 sets fishing 578,050 hooks.



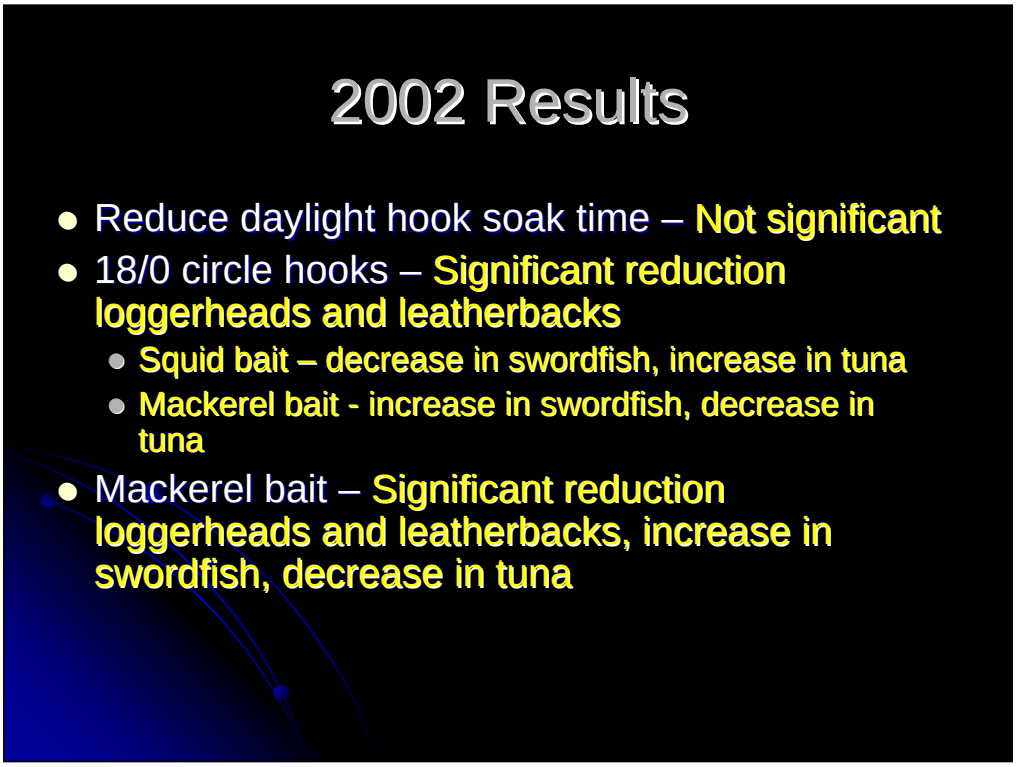
There were 142 loggerhead and 77 leatherback caught in 2001, 100 loggerheads and 158 leatherbacks in 2002, and 92 loggerhead, 79 leatherbacks, and 1 olive ridley in 2003.



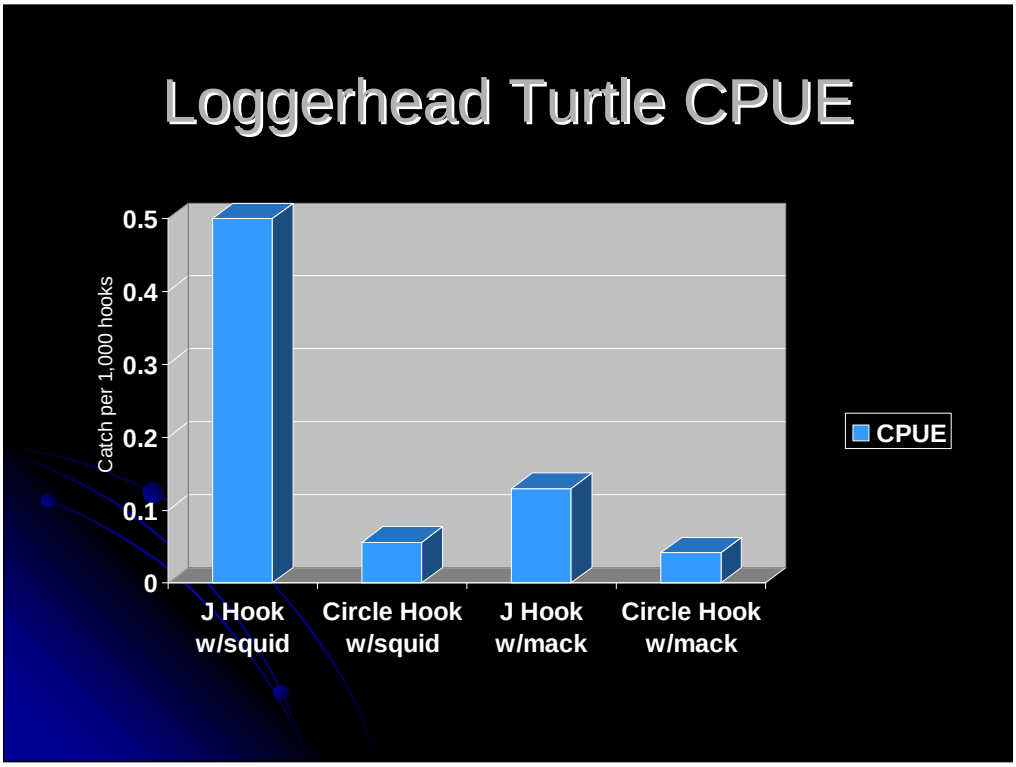
Analysis of the data collected in 2001 indicated that there was no significant effect of blue dyed squid on turtle capture rates and that there was an increase capture rate for leatherback turtles on the hooks placed 20 fathoms from floats. A general linear model indicated that daylight hook soak time (the amount of time the hooks are in the water during daylight hours) was the only variable which effected loggerhead turtle capture rates, but there was no effect of daylight soak time for leatherback turtle captures.



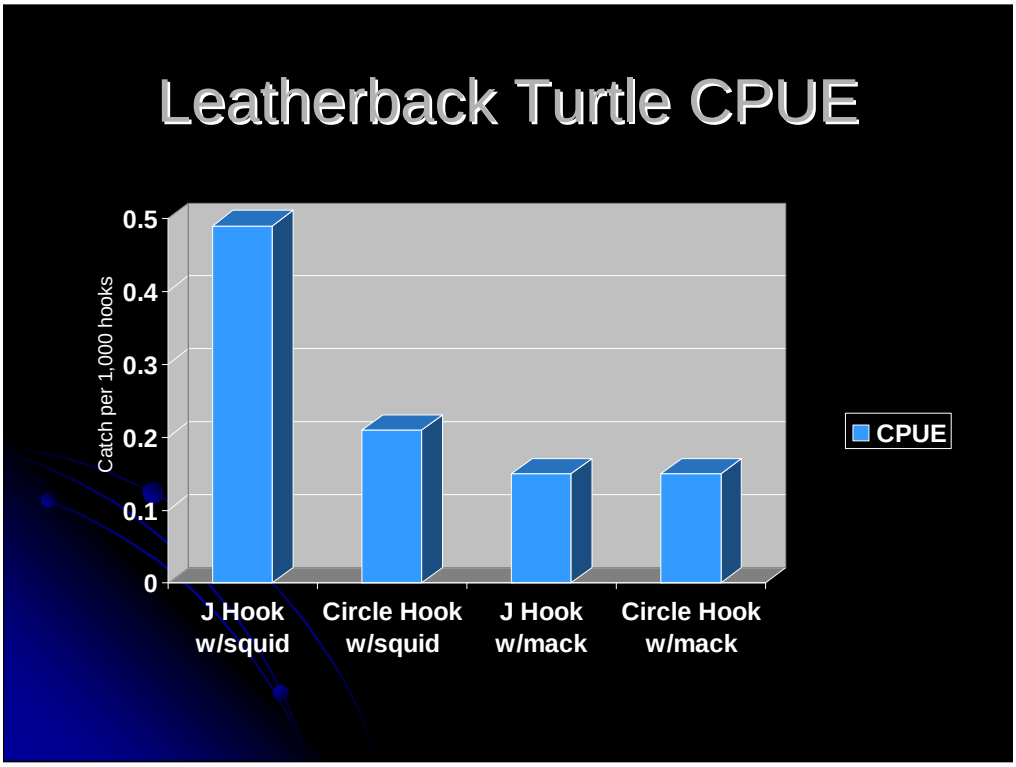
Loggerhead cpue increases significantly with increased daylight hook soak time indicating that loggerhead interaction with longline gear in the NED is a daytime interaction.



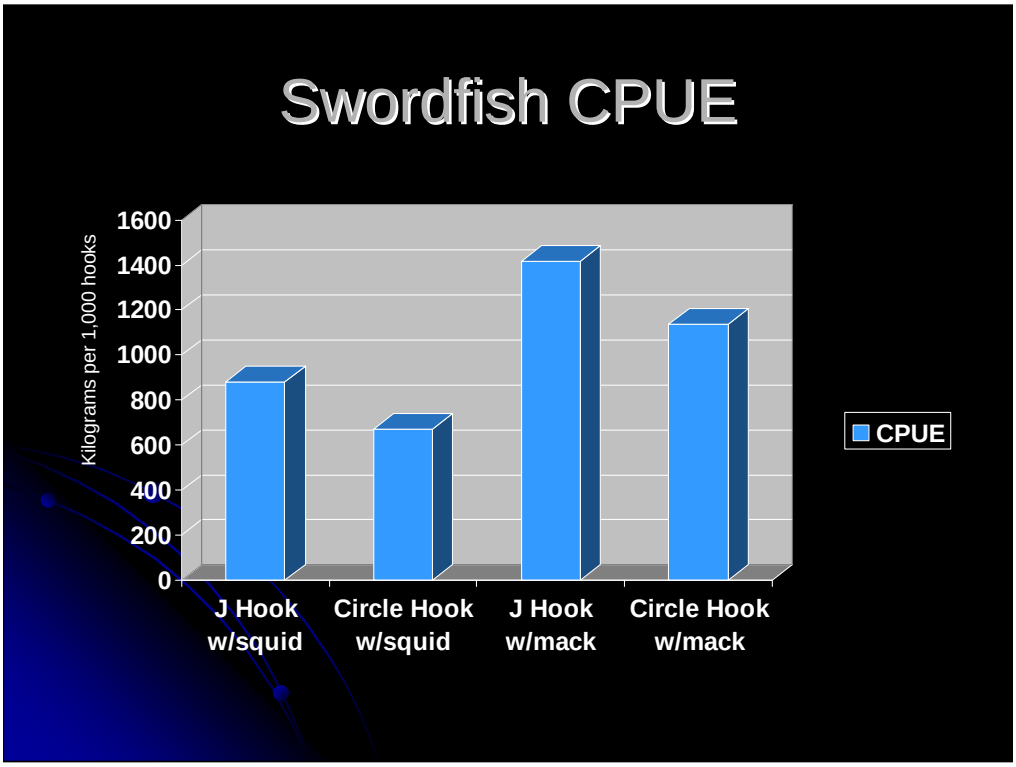
Logistic regression models indicated that daylight soak time was not a significant variable in determining turtle interactions with longline gear. 18/0 circle hooks were found to significantly reduce both loggerhead and leatherback interactions when compared to J hooks. 18/0 circle hooks with squid bait reduced swordfish catch, but increased tuna catch. 18/0 circle hooks with mackerel bait had the highest reduction in loggerhead turtle interactions and increased swordfish catch, but decreased tuna catch. J hooks with mackerel bait significantly reduced both loggerhead and leatherback interactions, increased swordfish catch, and reduced tuna catch.



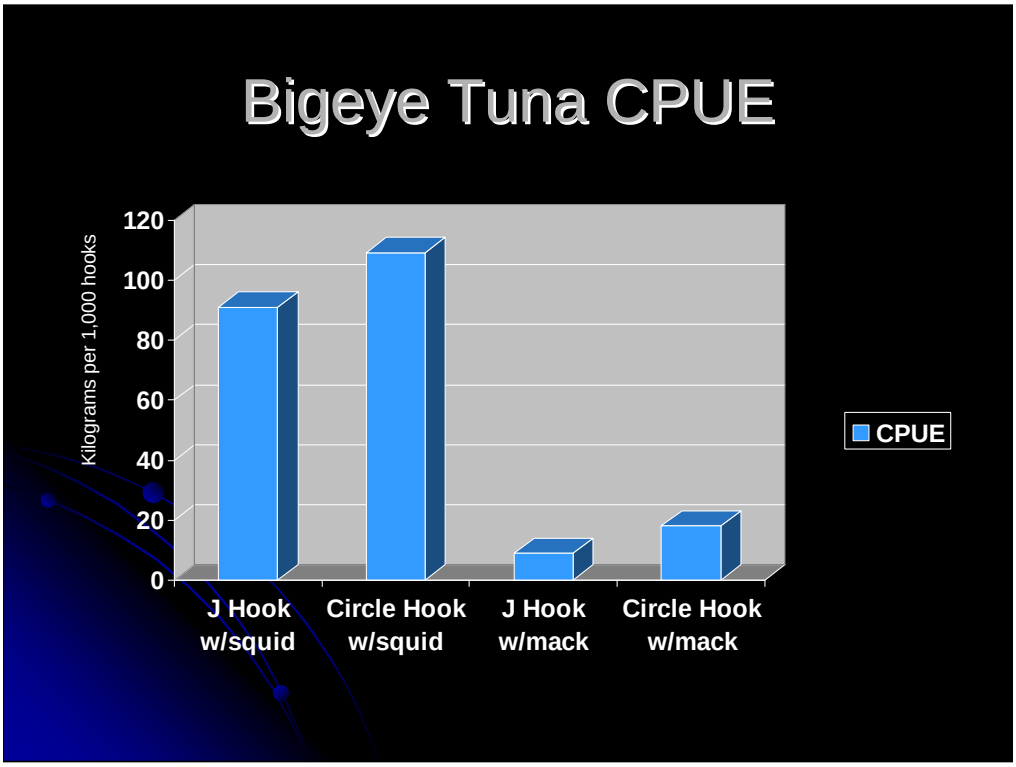
Circle hooks with squid bait reduced loggerhead catch by 86% (CI= 73%-93% $p<0.0001$), mackerel bait with “J” hooks reduced loggerhead catch by 71% (CI = 42%-86%, $p=0.0005$), and circle hooks with mackerel bait reduced loggerhead catch by 90% (CI= 70%-97%, $p<0.0001$).



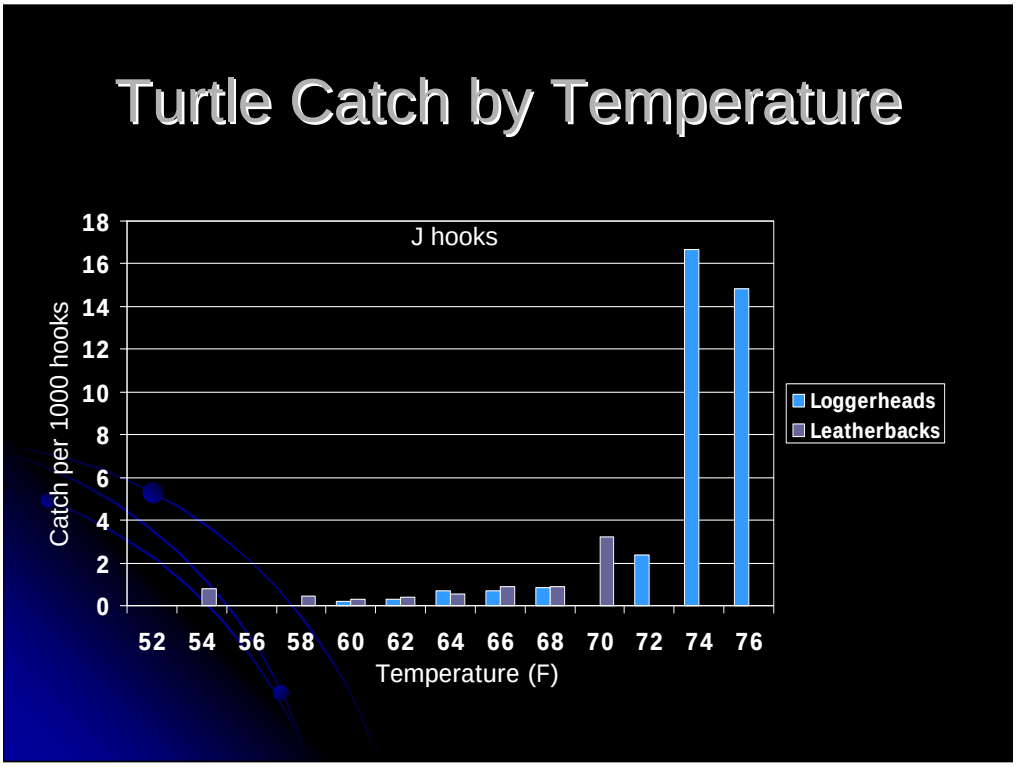
Circle hooks with squid bait reduced leatherback catch by 57% (CI=34%-72%,P<0.0001), “J” hooks with mackerel bait reduced leatherback catch by 66% (CI=37%-81%, p = 0.0006), and circle hooks with mackerel bait reduced leatherback catch by 65% (CI=36%-81%, p=0.0006).



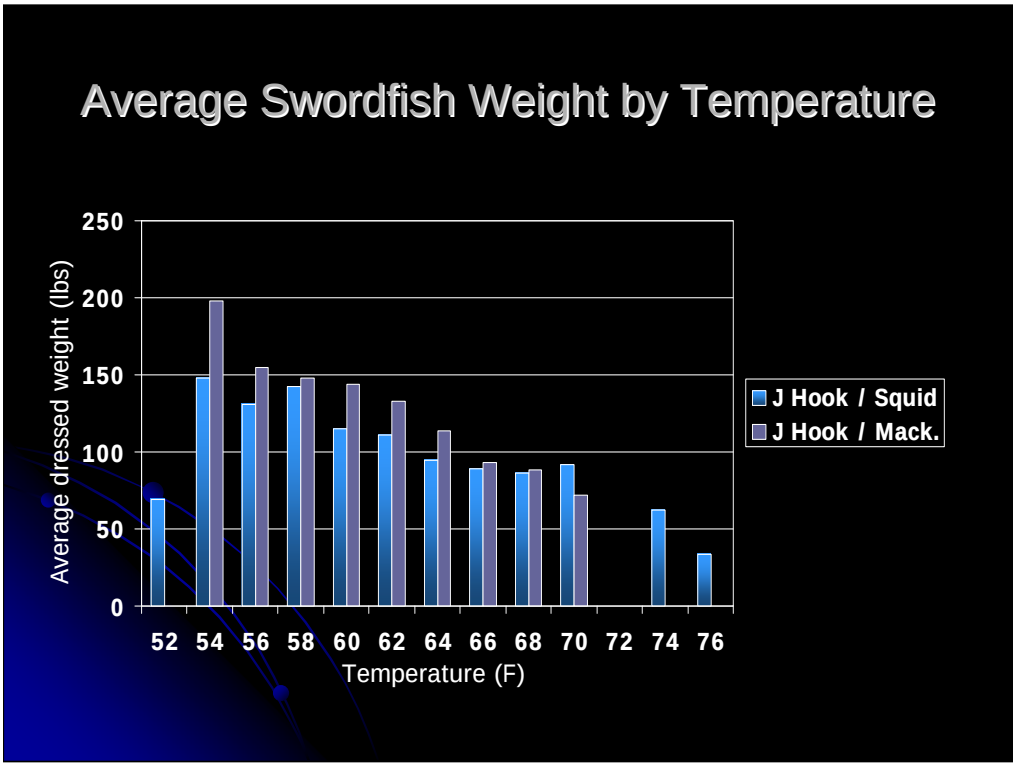
Circle hooks with squid bait reduced swordfish catch by 29% (10° offset) and 33% (non offset) (CI=14%-44%, p=0.0002 and 19%-46%, p<0.0001), “J” hooks with mackerel bait increased swordfish catch by 63% (CI= 46-81%, p<0.0001), and circle hooks with mackerel bait increased swordfish catch by 30% (CI = 14%-46%, p =0.0002).



Circle hooks with squid bait had a nominal increase in tuna catch of 26%. Mackerel bait reduced tuna catch by 81% (CI = 49% - 100%, $p<0.0001$) on circle hooks and 90%, CI = 58%-100%, $p<0.0001$) on “J” hooks.

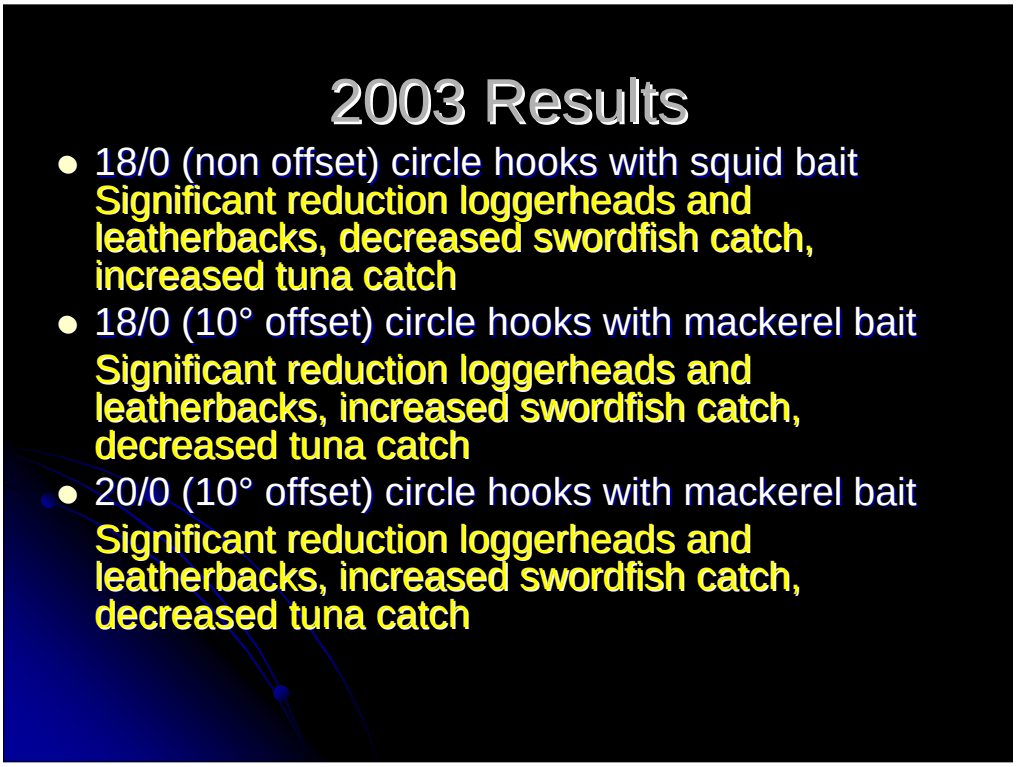


Both loggerhead and leatherback turtle catch rates varied with the surface water temperature. There was a dramatic increase in loggerhead catch rates for water temperature over 72 degrees (F). There was also an increase in leatherback turtle catch rates for water temperatures over 68 degrees (F). This data indicates that turtle interaction rates can be reduced by fishing in cooler water temperatures.

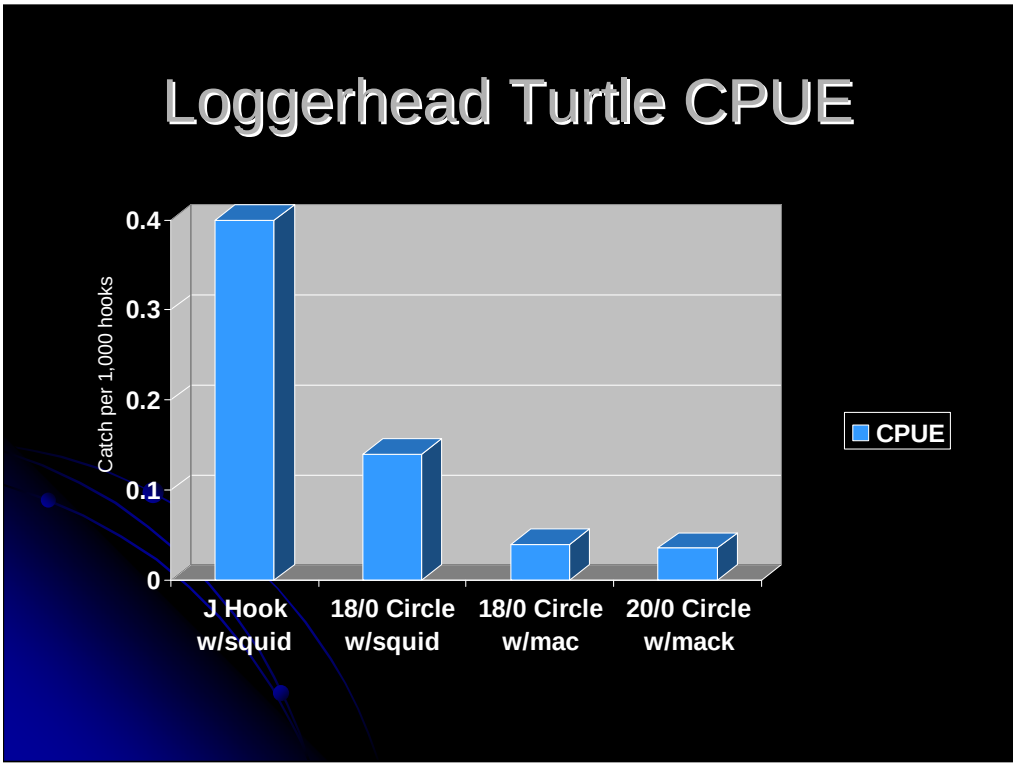


The effect of surface water temperatures was the reverse for swordfish catch by weight. The average dressed weight increased with cooler water temperatures (below 68 degrees (F).

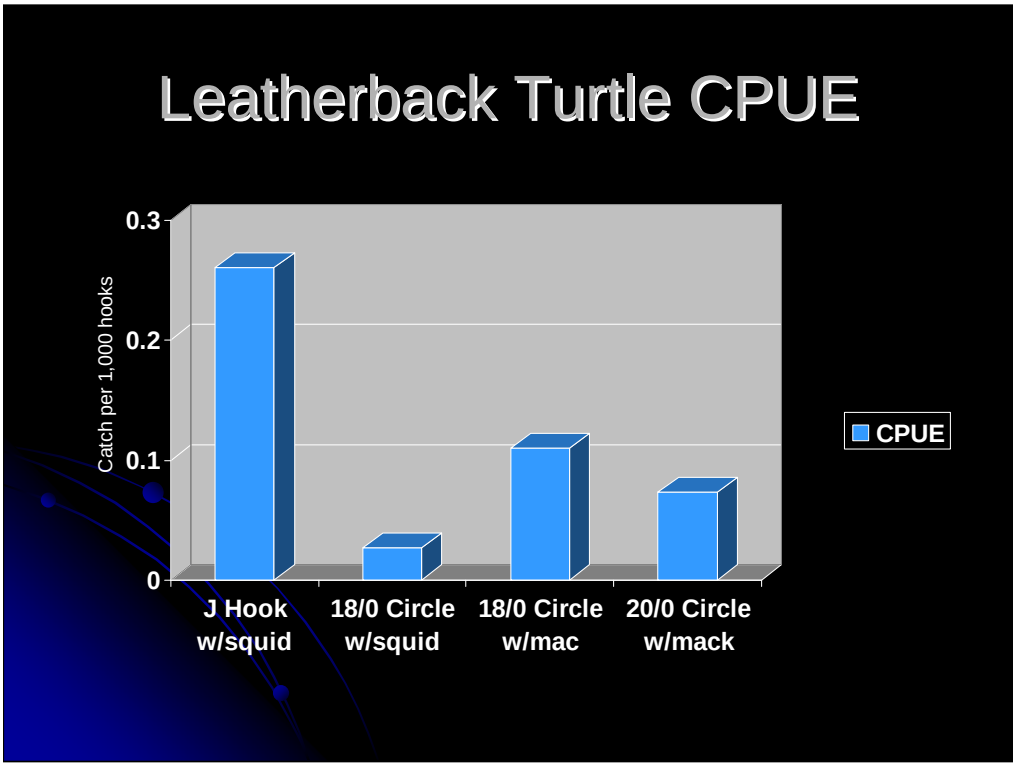
This data indicates that a fishing water temperatures below 68 degrees (F) can significantly reduce loggerhead turtle interactions while increasing target catch rates.



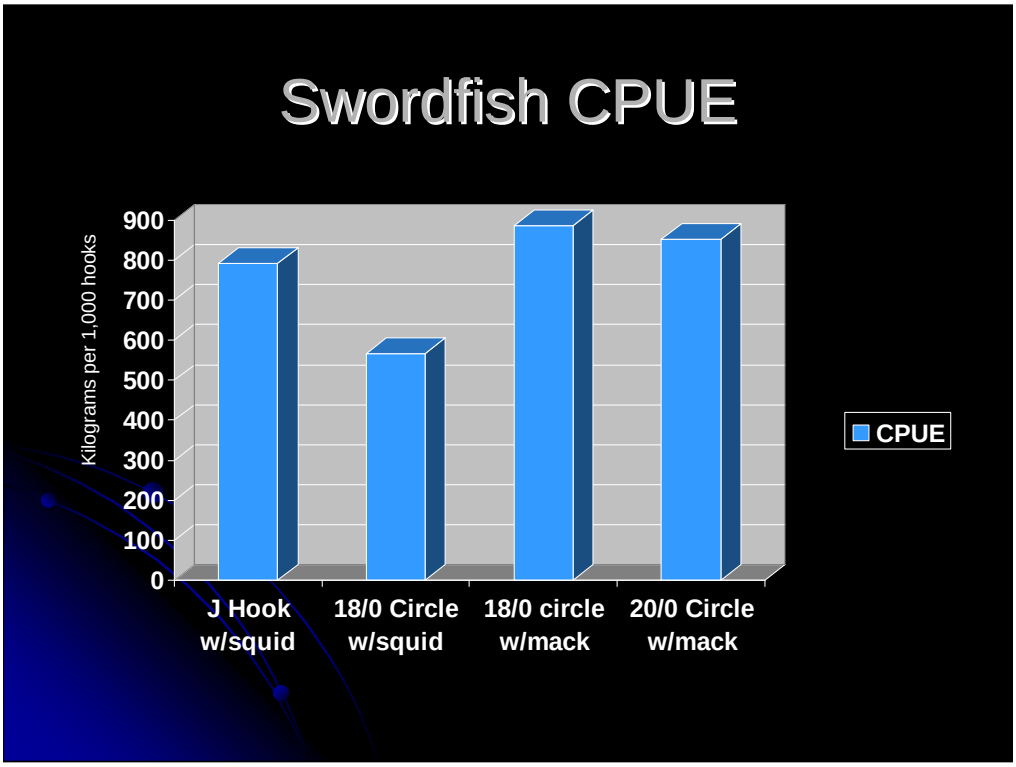
The 18/0 non offset circle hooks with squid bait had significant reductions in loggerhead and leatherback catch when compared to the control “J” hook and squid bait, and an increased tuna catch, but had a significant reduction in swordfish catch. The 18/0 10° offset circle hook with mackerel bait also had a significant reduction in catch of loggerhead and leatherback turtles compared to the control hook and bait and an increase in swordfish catch, but a significant decrease in tuna catch. The 20/0 10° offset circle hook also had a significant reduction in loggerhead and leatherback catch, a slight increase in swordfish catch and a significant decrease in tuna catch.



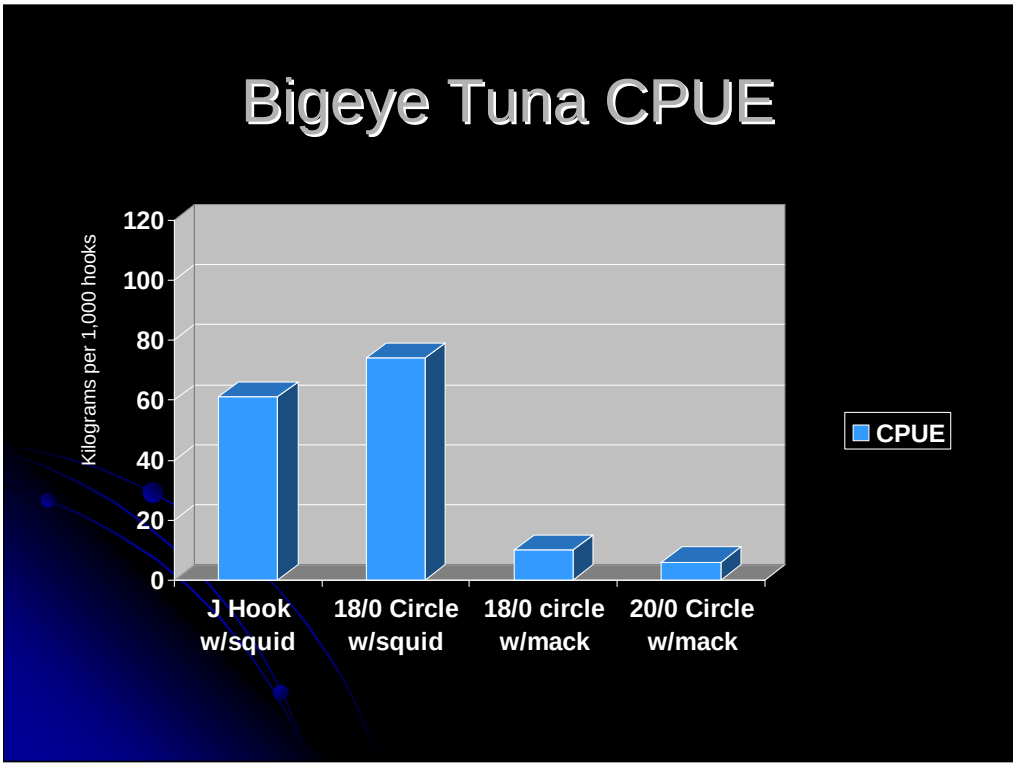
18/0 (non offset) circle hooks with squid bait reduced loggerhead catch by 64% (CI = 37% - 80% p = 0.0002), 18/0 (10° offset) circle hooks with mackerel bait reduced loggerhead catch by 89% (CI = 76%-95% p <0.0001) and 20/0 (10° offset) circle hooks with mackerel bait reduced loggerhead catch by 91% CI = 77%-96% p=<0.001).



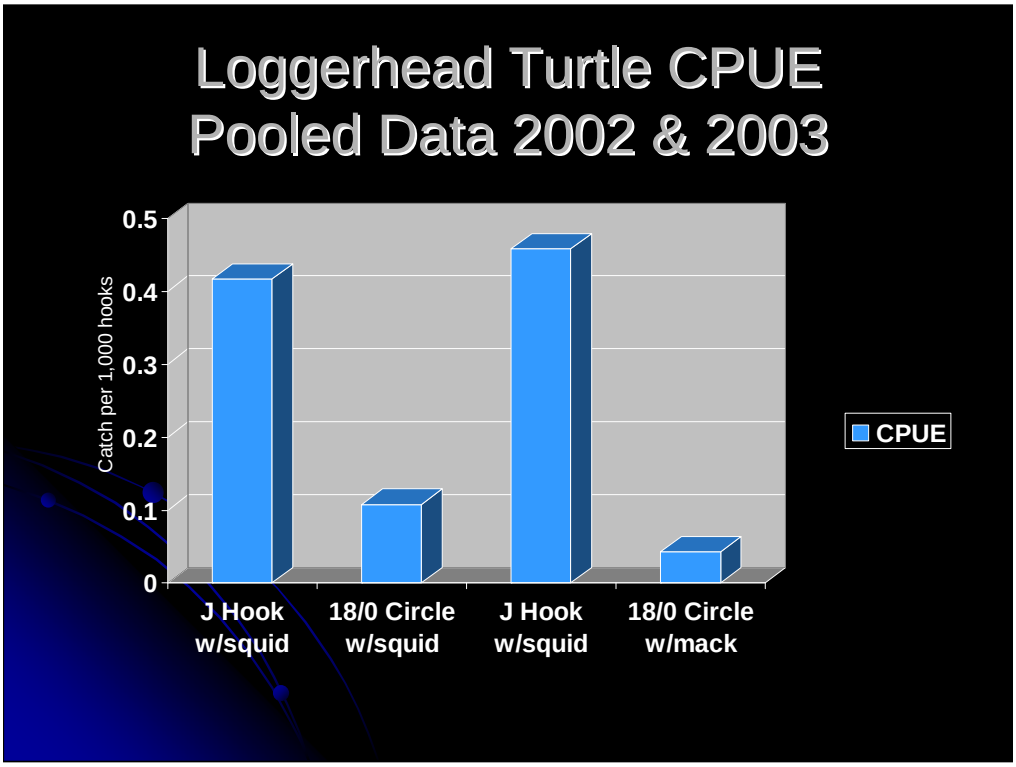
18/0 (non offset) circle hooks with squid bait reduced leatherback catch by 90% (CI = 66%-97% $p<0.0001$), 18/0 (10° offset) circle hooks with mackerel bait reduced leatherback catch by 56% (CI = 22%-76% $p=0.0043$), and 20/0 (10° offset) circle hooks reduced leatherback catch by 72% (CI = 42%-86% $p=0.0002$).



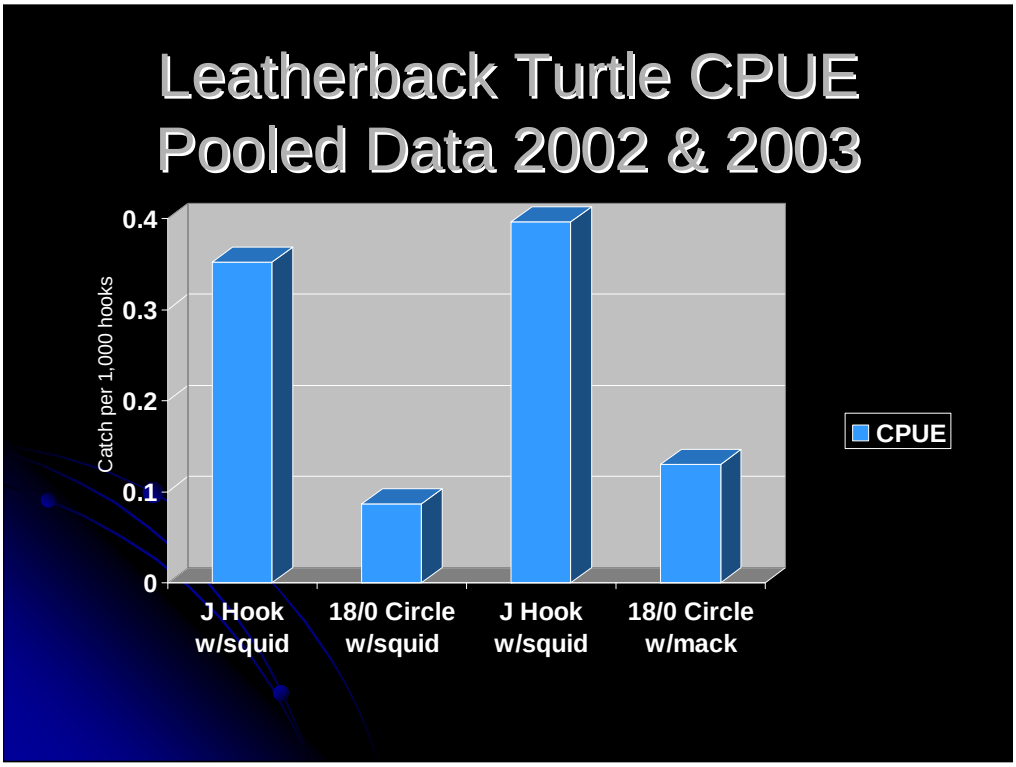
18/0 (non offset) circle hooks with squid bait reduced swordfish catch by 29% (CI = 21%-36%). 18/0 (10° offset) circle hooks with mackerel bait increased swordfish catch by 12% and 20/0 (10° offset) circle hooks increased swordfish catch by 8%.



18/0 (non offset) circle hooks with squid bait increased bigeye tuna catch by 20%, 18/0 (10° offset) circle hooks with mackerel bait decreased bigeye tuna catch by 83% (CI = 56%-100%) and 20/0 (10° offset) circle hooks with mackerel bait decreased bigeye tuna catch by 90% (CI = 62%-100%).



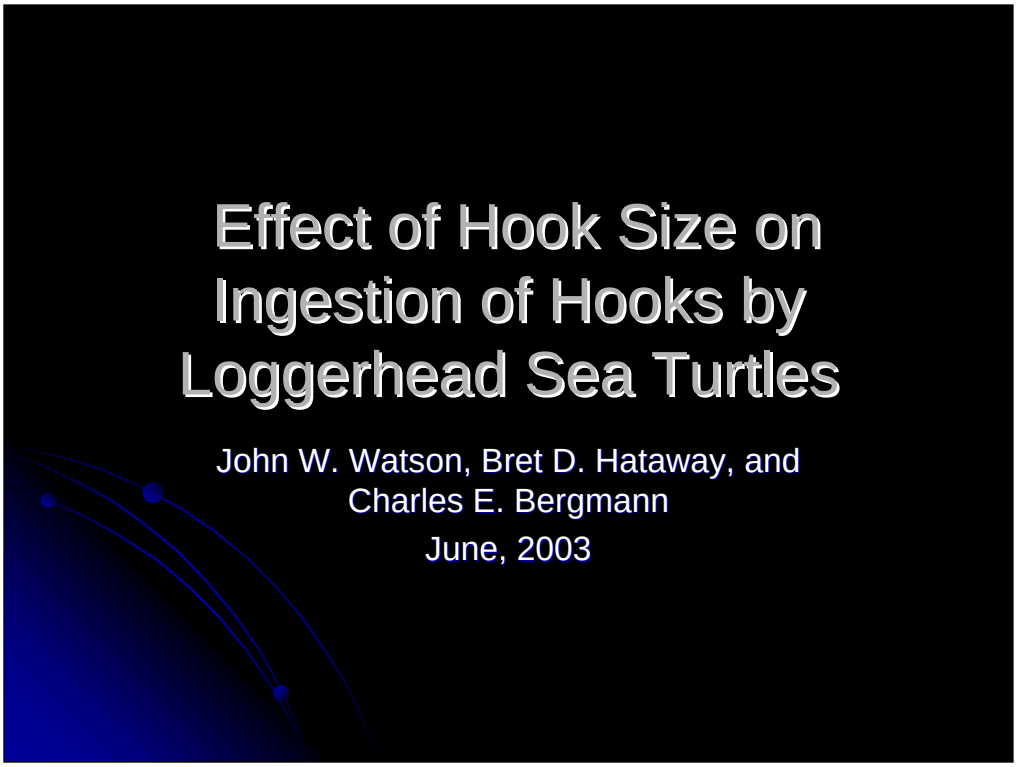
18/0 circle hooks with squid bait reduced loggerhead CPUE by 74% (CI = 58%-84%), and 18/0 circle hooks with mackerel bait reduced loggerhead CPUE by 91% (CI = 82%-95%) for pooled data from 2002 and 2003.



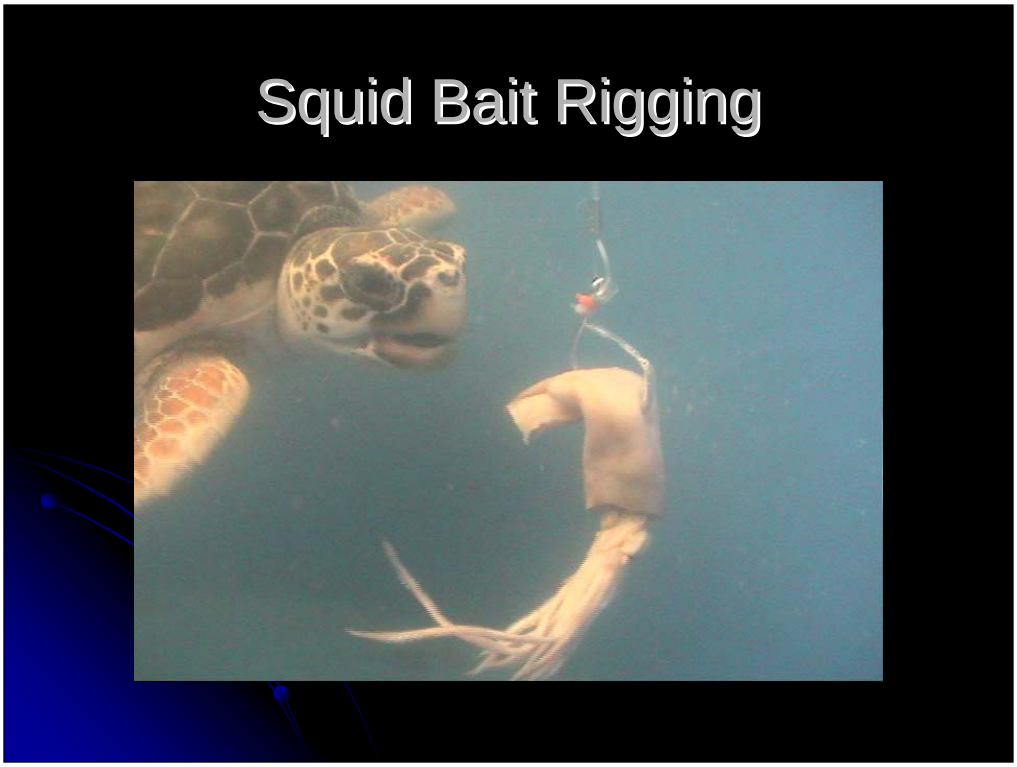
The 18/0 circle hook with squid bait reduced leatherback CPUE by 75% (CI = 57%-86%) and the 18/0 circle hook with mackerel bait reduced leatherback CPUE by 67% (CI = 51%-78%) for 2002 and 2003 pooled data.

Tuna Directed Research Results

- Sample size is too small to determine effect, but preliminary numbers indicate reductions in both loggerhead and leatherback turtles with 18/0 circle hooks compared to 16/0 circle hooks. Bigeye tuna catches were similar and there was a slight increase in yellowfin tuna catch with 18/0 circle hooks versus 16/0 circle hooks



NOAA Fisheries Southeast Fisheries Science Center conducted feeding studies using captive reared loggerhead (*Caretta caretta*) sea turtles to investigate the effect of hook size on ingestion of hooks used in the pelagic longline fishery. This research was conducted in conjunction with research being conducted in the Western Atlantic Ocean to develop mitigation measures to reduce the capture and mortality of sea turtles by pelagic longline fishing gear (http://www.mslabs.noaa.gov/watson2.pdf). The turtles used in these experiments were reared at the NOAA Fisheries Galveston, Texas Laboratory. The turtles are used in annual shrimp trawl turtle excluder device certification tests at the NOAA Fisheries Panama City, Florida Laboratory by the NOAA Fisheries Mississippi Laboratories in Pascagoula, Mississippi. In June of 2003, NOAA Fisheries investigated potential longline mitigation techniques including hook design and size effect on ingestion of hooks, which is the primary cause of mortality associated with pelagic longline gear. Turtles between 44 cm. and 58.8 cm. in straight line carapace length (size of loggerhead turtles encountered in pelagic longline fisheries in the Western Atlantic is 40-65 cm) were used for these experiments.

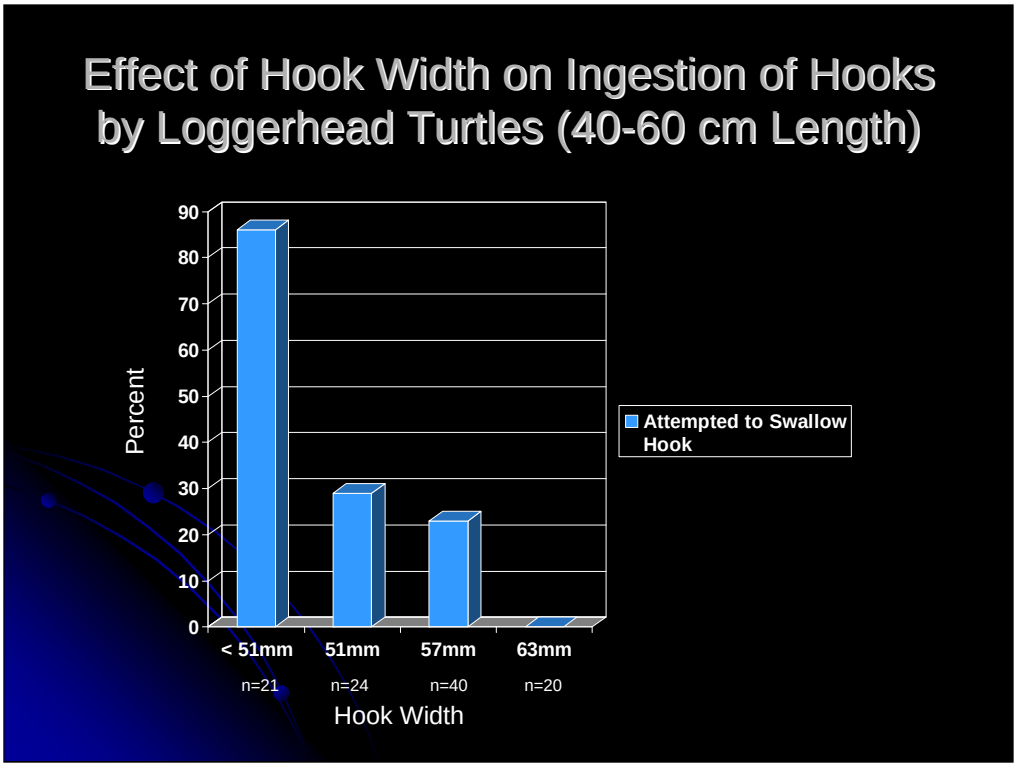


Squid baiting method used in the experiments. Squid bait was the primary bait used in the experiments and was used on all hook types. Squid used in the experiments were 150 to 250 gram weight.

The experimental procedure was to present turtles a baited hook. The turtle response was recorded by an observer as four categories. The categories were:

1. Did not take the hook into mouth.
2. Took the hook partially into mouth.
3. Took the hook fully into mouth.
4. Attempted to swallow the hook.

Turtles were observed carefully by the researchers and once the hook was fully in the mouth and the turtle continued to swallow the bait, the hook and bait were pulled out of the mouth. Turtles were not allowed to actually swallow the hook.



Hook size had significant effect on the ingestion of hooks by loggerhead turtles between 40 and 60 cm in length. Ingestion of hooks and impact of associated leader material on loggerhead sea turtles is the most significant cause of mortality of the turtles which are incidentally captured by pelagic longline fishing gear. The predominant hooks used in pelagic longline fisheries are less than 51 mm in width. Using hooks larger than 51 mm in width has the potential to significantly reduce mortality of loggerhead sea turtles incidentally captured by pelagic longline fisheries.

Summary of Logistic Regression Analysis on Hook Swallowing Attempts

Explanatory Variable	Coefficient (SE)	Odds Ratio (90% CI)	*p value*
Turtle Size CCL (mm)	0.015 (0.006)	1.015 (1.004-1.026)	0.0196
Hook Width (mm)	-0.157 (0.045)	0.855 (0.794-0.921)	0.0005
Hook Length (mm)	-0.043 (0.024)	0.958 (0.920-0.997)	0.0772

Squid Bait only, n=105
Stepwise technique used with a sig level of 0.1 for model entry and retention
Hosmer and Lemeshow Goodness-of-Fit Test: Chi-Sqr=8.38, df=7, p = 0.2998

Logistic modeling focused on the variables turtle size (mm), hook width (mm), and hook length (mm) as predictors of swallowing attempt. The terms turtle size and hook width are significant (p=0.0196 and p-0.0005, respectively) and hook length is a marginally significant (p=0.0772) predictor. This suggests that swallowing attempt should be looked at as a function of these three variables simultaneously.

As expected, the model suggests that the probability of swallowing increases with (increasing) turtle size and decreases with (increasing) hook width and hook length. The table gives the coefficients, standard errors, and odds ratios, and 90% confidence intervals for each variable.

The odds of swallowing increases by a multiplicative factor of 1.5% with one mm increase in turtle size. This means that the odds of swallowing increase by 25% with 15 mm increase in turtle size, by 50% with 27 mm increase in turtle size, and the odds doubles with 47 mm increase in turtle size.

The odds of swallowing decreases by a multiplicative factor of 14.5% with one mm increase in hook width. This means that the odds of swallowing decrease by 37.5% with 3 mm increase in hook width, by 67% with 7 mm increase in hook width, and by 85% with 12 mm increase in hook width.

The odds of swallowing decrease by a multiplicative factor of 4.2% with one mmt increase in hook length. This means that the odds of swallowing decrease by 19% with 5 mm increase in hook length, by 35% with 10 mm increase in hook length, and 50% by 16 mm increase in hook length.

Caution should be exercised in extrapolating beyond the ranges considered here for the predictors.

Hook Dimensions

Hook Type	Hook Width	Hook Length
9/0 J	41 mm	78 mm
9/0 Tuna	33 mm	78 mm
10/0 Tuna	38 mm	86 mm
11/0 J	51 mm	98 mm
16/0 Circle	51 mm	73 mm
11/0 MJ	56 mm	86 mm
18/0 Circle	57 mm	86 mm
12/0 J	57 mm	111 mm
14/0 J	63 mm	130 mm
20/0 Circle	63 mm	100 mm

Length and widths of hook types evaluated.

This success of this research is due to the hard work and dedication of many individuals within the fishing industry and NOAA Fisheries. The principal investigators would like to give special recognition to the vessel captains, crews, owners, and managers from Bluewater Fishermen's Association who's expertise and efforts were invaluable. We would also like to especially thank the NOAA Fisheries observers who "go the extra mile" in collecting enormous amounts of quality data at sea and are the pulse of the research. We would like to thank Aquatic Research Conservation (ARC) for their tireless efforts in developing and modifying turtle release gear used in the experiments and to Lingren Pittman for developing the hook designs used in the experiments. A very special thanks to Charlie Bergmann, Myrto Argyropoulou, Dennis Lee, Cheryl Brown, Larry Beerkircher, Lesley Stokes, Lisa Belskis, Dominy Hataway, Lionel LaForce, Nick Hopkins, Ron Rinaldo, Sari Karaly, Steve Meyers, and the members of the longline mitigation research ad hoc advisory group for their extraordinary efforts. And finally our sincere appreciation to Bill Hogarth for his vision in developing this research program and his unfailing support.