

Report of the Workshop on Marine Turtle Longline Post-Interaction Mortality

Bethesda, Maryland, USA
15-16 January 2004

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U.S. Department of Commerce
National Oceanic and Atmospheric Administration
National Marine Fisheries Service

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EXECUTIVE SUMMARY

The National Marine Fisheries Service (NMFS), Office of Protected Resources (OPR), was charged with conducting a review of the NMFS post-hooking mortality criteria, established in February 2001, and determining whether, and if so, how, those criteria should be modified. As part of this review, OPR convened a Workshop on Marine Turtle Longline Post-Interaction Mortality (Workshop) in Bethesda, Maryland on 15-16 January 2004. Seventeen experts in the areas of sea turtle biology, sea turtle anatomy/physiology, sea turtle veterinary medicine, sea turtle satellite telemetry, and longline gear deployment participated in the workshop. Consideration of the workshop discussion, along with a comprehensive review of all of the information available on the issue, led OPR to establish revised post-hooking interaction mortality criteria. Despite the refinement of the criteria, knowledge of the effects of sea turtle interactions with longline gear remains limited and is unlikely to be elucidated further in ways that will be particularly relevant to sea turtle recovery. What is certain is that reducing sea turtle interactions with longline gear is necessary for the long-term survival and recovery of these highly migratory species. A summary of the key changes to the 2001 criteria follows.

Categories: The February 2001 injury categories have been expanded to better describe the specific nature of the interaction. The February 2001 criteria described two categories for mouth hooking: (1) hook does not penetrate internal mouth structure, and (2) mouth hooked (penetrates) or ingested hook. The revised criteria (Appendix 1) divide internal hooking events into three categories that reflect the severity of the injury and account for the probable improvement in survivorship resulting from removal of gear, where appropriate, for each injury. The new criteria also separates external hooking from mouth hooking, eliminates the ‘no injury’ category, and adds a new category for comatose/resuscitated turtles.

Probable Improvement in Survivorship When Gear is Removed: The new criteria recognize that in most cases removal of all or some of the gear (except deeply ingested hooks) may improve the probability of survival. The categories for gear removal are: (1) released with hook and with line that is greater than or equal to half the length of the carapace; (2) released with hook and with line that is less than or equal to half the length of the carapace; and (3) released with all gear removed. Turtles that have all or most of the gear removed, depending on the nature of the interaction, are expected to have, on average, a higher probability of survival.

Species Difference: Species differences between hard-shelled turtles and leatherbacks likely play a role in post-interaction survivorship. The new criteria takes this into consideration and assigns slightly higher rates of post-interaction mortality for leatherback turtles.

PART I. OBJECTIVES AND OVERVIEW

Workshop Objectives

The objective of the Workshop was to bring together a group of relevant experts to present recent information on post-interaction mortality of marine turtles incidentally captured in longline fisheries, review the best scientific information available on the topic, and receive individual, technical input from invited participants on whether, and how, NMFS should modify the February 2001 criteria for estimating post-hooking mortality. The Workshop goal was not to reach consensus, but to share information that could be used by OPR to revise, if appropriate, the February 2001 criteria.

Workshop Introduction and Overview

The two day Workshop was convened by NMFS-OPR with the assistance of facilitators Dr. Scott McCreary and Dr. Eric Poncelet, from Concur, Inc. Participants were invited based on their expertise in five specific fields: sea turtle veterinary medicine, sea turtle anatomy/physiology, sea turtle biology, sea turtle satellite telemetry, and longline fishing technical operations (Appendix 2). A packet of information materials, including the Workshop Agenda and Background Information Documents, was provided to each participant in advance of the Workshop (Appendices 3 and 5). NMFS asked participants to provide individual input based on their expertise in these respective areas. The Workshop was also open to observers. Participants were informed that the focus of the Workshop was narrowly defined to the objective above and was not convened to include discussions on fishery closures, gear modifications, research to investigate gear modifications, development of gear research plans, status of turtle populations, determining bycatch rates, or the jeopardy standard pursuant to the Endangered Species Act.

The first day of the workshop and the morning of the second day were dedicated to reviewing background material on the best available scientific information relating to post-interaction mortality, through both formal presentations and moderated, topic-driven discussion. Participants spent the afternoon of the second day individually responding to a structured feedback instrument. A review and compilation of the feedback instruments indicated that there was no unified assessment on whether the February 2001 criteria should be amended, and if so, how NMFS should do this. However, for those individuals who felt that modifications were necessary, there was convergence around a number of important issues including expansion of the injury categories, improvement in survival probabilities when gear is removed, and recognition of differences in survival probabilities between hardshelled turtles and leatherbacks.

PART II: SUMMARIES OF FORMAL PRESENTATIONS

Current NMFS Marine Turtle Post-Hooking Mortality Criteria – Background Presentation

Barbara Schroeder, NMFS Office of Protected Resources

The process by which the February 2001 criteria were developed was summarized. In December 2000, NMFS-OPR was tasked with reviewing existing information and preparing a recommendation on evaluating post-hooking mortality of marine turtles. During January 2001, OPR sought input on the topic from agency, academic, and industry experts. OPR took the responses under advisement and issued a memorandum in February 2001 recommending the adoption of post-interaction mortality criteria and providing supporting documentation for the proposed criteria. The Office of Sustainable Fisheries (OSF) subsequently suggested revised criteria. In mid-February, the Directors of OPR, OSF, and Science and Technology met to discuss the various recommendations and produced a Decision Memorandum (February 16, 2001) establishing guidelines for estimating post-interaction mortality. These criteria established four categories for determining post-hooking mortality and attributed mortality risk to each of these categories as follows:

1.	No hooking, no injury, disentangled completely	0%
2.	Hooked externally or entangled, line left on animal (hook does not penetrate internal mouth structure, e.g., lip hook)	27%
3.	Mouth hooked (penetrates) or ingested	42%
4.	Dead	100%

Following the background presentation, four presentations were made on recent research on marine turtle post-interaction mortality. The presentations and the group discussions that followed are summarized below.

Post-Hooking Dive Behavior and Movement Patterns of Oceanic Stage Loggerhead Turtles

Alan B. Bolten, Brian Riewald, and Karen A. Bjorndal (Presented by Alan Bolten)

Data were presented from a study using satellite telemetry to assess post-hooking mortality of loggerhead turtles captured in the Azores longline fishery. The study involved 6 turtles that had ingested J hooks and 12 hand captured control animals not related to the longline fishery but captured in the same area and of the same size classes. The treatment animals were released with the hook in place and approximately 18" of the leader attached to the eye of the hook.

Key points from the presentation included the following:

Post-Hooking Behavior

- Composite dive depth and dive duration histograms indicated that the hooked turtles made more shallow and longer dives than the control animals. Deep dives were rare in the hooked animals. Additionally, the hooked turtles used only a fraction of the water column; they spent the vast majority of their time just below the surface (2-5 meter depth range). Hooked turtles were absent from 40-150 meters where they would normally be expected to forage.
- The hooked turtles appeared to stop orienting and all moved in nearly the same direction, away from the location where they were hooked. It was assumed that these animals were floating with the current, since the direction of travel was consistent with the direction of movement of the main Azorean current. Conversely, the control animals continued to orient in the area where they were released, presumably to remain in rich foraging areas.
- Hooked turtles moved with greater “straightness” suggesting that they were floating with the prevailing current.

Sublethal Effects of Hooking

Data were presented showing that half of the hooked turtles in the study began to show movement and dive patterns characteristic of orientation approximately 8-10 months after they were released, indicating that some turtles may take many months to recover from a hooking incident. Although these later movements and behavior were more consistent with that of the control turtles, there are likely sublethal effects resulting from the loss of or reduction of foraging for 8-10 months of the oceanic juvenile stage. Changes in location and nutrition may decrease growth and productivity during these periods, potentially resulting in longer term reproduction impacts at the population level. Although this study provides the first direct evidence of sublethal effects, the effects cannot be quantified at this time.

PARTICIPANT DISCUSSION KEY POINTS:

- The surface layer is a dynamic environment, as are the layers beneath the surface. It is possible that water temperature factored into the behaviors exhibited by treatment animals. However, since the control animals were released into the same waters, this alone would not account for the subsequent difference in behavior. In reference to water temperature, it was also noted that reptiles tend to seek out warmth when they are injured and that this may be a choice to fight infection.
- It would be normal to see diving in the range the treatment turtles were avoiding. Several participants noted that deeper portions of the water column were required for foraging and that these animals could not have survived for 8-10 months without feeding.
- It was suggested that the straight movements of the treatment animals might actually be directed, rather than passive travel, and that turtles were orienting their travel based on

currents, SST fronts, or bathymetry. However, in this study, non-hooked turtles have not exhibited straight movements as observed in the treatment group.

- On the long, inactive dives, treatment animals may exist a few meters down in a less traumatic medium and float in a healing mode. It was noted that there was no predation on these animals; thus, they may not be acting like prey due to their inactive behavior.
- In this study, the recorded satellite data immediately showed anomalies that could be interpreted as impacts from the hooking event. One of the physiologists noted that this could be due to either altered behavior or a physical inability to dive.
- It can be difficult to discern behavioral differences between hooked and control turtles brought on board. Hooked turtles often show no visible signs of stress at the time, but may be experiencing undetected injuries. In this study, the turtles appeared strong and robust and there was no immediate apparent difference between the treatment and control groups on deck. This contrasts with the findings of different diving behavior and movements between the two groups after release. It was noted that the history of the interaction may be a factor in understanding these behaviors. Even though the animals can get to the surface, physiological impacts may happen during the time that the animal is still on the hook, and this could be compounded by acute injury. The real trauma may have already occurred. Lactic acid sampling of boarded animals might provide additional information on this issue.
- Transmitter failure and attachment failure are two different potential sources of error in this and other telemetry studies. There was some discussion of keeling and compression relative to attachment failure and of ghost hits. Frequent ghost hits can be due to dying batteries or failing tags and ghost hits can be received from transmitters that have expired or are no longer in existence. This can confound data interpretation.

Post-hooking Mortality - Atlantic Pilot Study

Sheryan Epperly, Christopher Sasso, Eric Prince, Alan Bolten, and Carlos Rivero (Presented by Sheryan Epperly)

Data were presented from a pilot study directed at assessing post-hooking mortality of loggerhead turtles captured in the pelagic longline fisheries. The study was conducted from 2001-2003 in the Northeast Distant (NED) statistical reporting area. It involved 4 entangled, 5 flipper hooked, 10 mouth hooked, and 10 ingested hook treatment animals, as well as 10 control animals dipnetted in the NED. In addition, the study also involved 4 free floating tags (not attached to turtles) deployed in the Azores. All gear, except-swallowed hooks, was removed from the treatment animals. All turtles were fitted with PAT2 or PAT3 pop-up archival transmitting (PAT) satellite tags.

Key points from the presentation included the following:

- The results of the study are preliminary, since tags are still deployed and researchers are still working on interpreting data received to date.
- A key issue is the duration of the study. A short study (< one year) could fail to detect longer term post-hooking mortality. A study that is too long has the potential for confounding results due to natural mortality. Consequently, researchers decided to conduct a year long study, which would also allow for analyzing seasonal effects. Confounding effects due to the long study duration are accounted for by also conducting a study of control turtles for comparison. The decision to conduct a long-term study dictated the type of PAT tag used.
- Preliminary findings suggest that the location of the hook on the turtle is a factor in post-hooking survival. The satellite tags on deeply hooked turtles failed to transmit more often than tags on turtles that were externally hooked or hooked in the mouth.
- The data showed similar dive patterns for deeply hooked turtles and turtles externally or mouth hooked.
- Performance of PAT tags has been a significant hurdle in this study. Performance of PAT 3 tags was superior to that of PAT 2 tags.
- There are numerous potential sources of error including: tagging induced mortality (not likely to be significant and accounted for in the comparison with control turtles), tag shedding (see study mentioned below), tag failure, and data interpretation. The researchers are currently in the process of evaluating the tag attachment, tether, and pin over the course of a year on captive turtles to evaluate the probability of tag shedding. They are also working with Wildlife Computers to improve tag performance and to improve the ability to interpret the transmitted data.

PARTICIPANT DISCUSSION KEY POINTS:

- Some turtles continue to swallow hooks when they are on deck. Therefore, it is important to process and sample the turtles as soon as possible. There was some discussion on whether turtles should be processed right-side up or upside-down. The physiologists supported working up the turtles right-side up (carapace up) for optimal ventilation. This is not currently the practice in the NED experiment.
- Based on information presented from both the Azores and NED studies, there was preliminary discussion about expanding the mouth hooked category to differentiate the lower jaw from the upper jaw and roof of the mouth. A number of participants felt the need to better understand how hooks behave in the mouth of a turtle and the resultant damage from different hook types. Participants suggested approaching the issue

anatomically, considering the location of the injury instead of focusing on hook type. It should be possible to categorize injuries without focusing on gear type, since gear type is reflected in the description of the injury. The afternoon session commenced with a gear demonstration and characterization and a description of the anatomy of the mouth and jaw.

Modeling Post-release Mortality of Pelagic Loggerhead Sea Turtles Exposed to the Hawaii-Based Pelagic Longline Fishery

Milani Chaloupka, Denise Parker, and George Balazs (Presented by Milani Chaloupka)

Findings were presented from analyses of an existing data set of 40 marine turtles captured in the Hawaii-based pelagic longline fishery and outfitted with satellite tags prior to release. This project re-analyzed data from a study that lacked rigorous scientific design. The objectives of the project were to evaluate post-hooking mortality using satellite telemetry data from turtles captured by the Hawaii-based longline fishery, applying nonparametric survival probability and hazard rate modeling with left, right, and interval censored data. This study looked exclusively at location data since no dive data were collected.

Key findings and major points from the research and analysis include the following:

- In the Hawaii study, there were significant differences in transmission time between light and deeply hooked turtles within the first 90 days post-hooking. There was no difference in transmission time between these two hooking classes for turtles that transmitted beyond the first 90 days post-hooking.
- The survival function is the probability of the ARGOS network recording a signal from the transmitter at least to time (t) for any specified time (t) post-release. The hazard function results, presenting risk of failure at any point in time, showed a bathtub or “U” shape, suggesting an early failure period followed by a more constant failure period and then an accelerating period of failure. It was concluded that early failures were most likely due to defects or poor attachment while later failures were more likely due to dying batteries.
- The Hawaii-based study included only 40 tags. While this is a relatively small number of tags, this remains the largest study of its kind in the world. Additional studies with much larger data sets are needed, since enough tags have not yet been deployed to draw conclusions with any degree of certainty.
- Study design issues that are unavoidable in the analysis of this (and other) studies included the following:
 - ▶ Inference of death is extremely problematic.
 - ▶ When death is inferred, it is difficult to determine from these types of data whether mortality is due to natural causes or longline hooking.

- ▶ It is not possible from this or other similar studies to infer post-release mortality unless the cause of each transmitter failure is known with certainty. Various modes of transmitter failure exist. Ultimately, these types of satellite telemetry projects provide data on time until transmitter failure, not survivorship of turtles.
- ▶ Biases introduced by observer assignment of tags to turtles have not yet been fully evaluated.
- ▶ Study results were confounded by using different duty cycles that were changed in the middle of the experiment.
- ▶ Study results were confounded by year effects, since the data were not collected during the same period.
- ▶ If the study is longer than 90 days, the effects of natural mortality and longline related mortality may be confounded. This requires a well reasoned control group to overcome.
- ▶ At present, no unequivocal studies on post-hooking mortality of marine turtles exist. The current studies are most useful as stepping stones toward conducting better studies.

PARTICIPANT DISCUSSION KEY POINTS:

- Participants with veterinary expertise generally felt that the majority of turtles released alive with lethal injuries would likely die within 90 days post-release. It was noted that recovery from non-lethal injuries may encompass a longer term period (e.g., over many months or even years). However, this long term recovery is a best case scenario with veterinary treatment. It was also noted that recovery from comparable trauma proceeds more slowly in reptiles than in warm blooded animals.
- There was considerable discussion over the selection of a 90 day time limit within which hooking induced mortality could be distinguished from other mortality: what it means and what it was based on. A number of participants felt that a 90 day time frame would underestimate mortality in the Hawaii study, since mortality likely exists after that, even if it is not possible to detect. Others felt that the 90 day benchmark should apply only to the Hawaii study - with its inherent design and technology issues - rather than to limit how future studies are conducted. Other studies could look beyond 90 days, using other methods for determining death, or if there is an appropriate control group. It was also noted that drawing inferences is complicated by the fact that natural mortality may vary seasonally. In concluding this part of the discussion, it was noted that distinguishing between natural and fisheries mortality will continue to be a problem that will need to be addressed.
- It was noted that experimental controls to date for post-hooking studies have been “quasi-controls” rather than true controls. Controls only serve as true controls when all of the

turtles in both the control and test sets remain in the same habitat (e.g., in the Azores, the control group went off to a totally different habitat). Better control studies are needed to help differentiate between natural mortality and hooking-induced mortality, but these controlled studies are very difficult to conduct. However, it is possible to have control groups for certain behaviors (e.g., movements) and it was reiterated that what is needed for these studies is not true “classic” controls, but controls that characterize normal behavior in the wild. The problems associated with the non-randomized and biased treatment groups were also identified. Generally, participants felt that the current studies provide stepping stones to better studies, but until we can design better studies we need to be circumspect in our conclusions.

Survivorship and Movements of Sea Turtles After Their Release from Longline Fishing Gear in the Pacific

Yonat Swimmer, Randall Arauz, Lianne McNaughton, Mike Musyl, Rich Brill, and Anders Neilson (Presented by Christofer Boggs)

Research findings were presented from a pop-up archival satellite tag (PSAT) study conducted in cooperation with local fishermen off the Pacific coast of Costa Rica from November 2001 through June 2003. The objectives of the study were to examine diving behavior and survivorship following interactions with longline gear. Pop-up satellite tags were deployed on 9 olive ridley turtles and one green turtle captured on longline fishing gear and an additional 5 control animals (olive ridleys) captured by hand while free swimming. Turtles were hooked either externally or in the mouth and all gear was removed with the exception of one deeply throat hooked olive ridley where the hook remained in place. The satellite tags were set to release at a pre-set pop-up date. The tags were also set to release if they stayed at a constant depth for 4 days or exceeded 1,500 meters in depth (both events suggest death of the turtle, as these parameters exceed the range expected in live turtles). Behavior (movements and survivorship) of longline captured and control turtles were compared.

Key findings and major points included the following:

- In this study, short term survival appeared high. PSATs remained on control and longline captured turtles for an average of 61 and 54 days, respectively (range 26 to 115 days) and on the green turtle for 26 days.
- The high incidence of premature tag shedding indicates that refinements are needed in the attachment method.
- The researchers felt that they conclusively verified the death of one of the control turtles that sank 66 days after being tagged.
- Both treatment and control olive ridleys spent nearly all of their recorded time within the top 60 m, with very few dives exceeding 100 m.
- Olive ridleys spent over 90% of their recorded time in water temperatures of 22-28° C and horizontal movements appeared to correlate with oceanographic variables.

- There were few clear differences between the behavior of longline captured and control turtles.

PARTICIPANT DISCUSSION KEY POINTS:

- It would be helpful to evaluate post-hooking behavior along with other behaviors that might not appear in a control set, such as reproductive behavior.
- Olive ridleys in this experimental area are there to mate, not forage and dive. Hence, they cannot be readily compared to animals that are feeding in the Azores.
- Several participants noted that a slide of an olive ridley showing purported hooking scars from previous longline gear interactions may have been mating-related scars.

PART III: MODERATED DISCUSSIONS

Topic Area 1: Marine Turtle Veterinary Medicine, Physiology, and Anatomy

The objective of this moderated discussion was to seek input on how injuries resulting from longline hooking or entanglement may alter behavior and/or lead to infection, resulting in mortality or reduced fitness. The discussion would help to inform post-hooking mortality estimates, address problems in distinguishing lethal and sublethal injuries, and contribute to our understanding of the potential for recovery in the wild. Participants discussed the following four questions:

Question 1: What injuries may occur from forced submergence, hook ingestion, external hooking, entanglement, and hook removal that may result in mortality?

Participants with expertise in veterinary medicine, sea turtle anatomy, and sea turtle physiology suggested categorizing injuries according to the mortality risk level to help direct the discussion. They suggested the following list of ideas for turtle bycatch injuries that may result in immediate or future mortality. The list was considered as a gradient of risk and was based on their experience with necropsy findings, knowledge of sea turtle anatomy and vulnerable structures, and consideration of issues such as soft palate injuries, esophageal separation, vascular function, hemorrhage, laceration of trachea, esophageal abscess, forced submergence effects, sepsis, and hooking. The anatomy of sea turtles and the proximity of the hook to certain anatomical structures was considered very important in developing the list. This preliminary working exercise did not take into account whether the gear was removed.

Higher Risk:

1. Comatose and resuscitated
2. Hook embedded at or below the level of the heart (i.e., hook not visible through mouth)
3. Cervical esophagus hooking (this category was added during discussion)
4. Released with external entanglement
5. Hook in glottis and/or jaw joint hooking (very sensitive structures in turtles)
6. Hook in soft palate (e.g., coming out of eye)
7. Line trailing at greater than half the carapace length

Lower Risk:

8. Line trailing at less than half the carapace length
9. Hook in lower jaw (not jaw joint) or adnexa other than glottis
10. Any external hook with no line attached
11. No hooking, no injury, disentangled completely

It was emphasized that the jaw joint is a very sensitive structure in turtles and there could be residual edema, joint injury, or arthritis even if the hook were removed. The veterinarians

generally thought the likelihood of a hook entering the brain cavity was low. Three of the categories - “release with external entanglement,” “line trailing at greater than half the carapace length,” and “line trailing at less than half the carapace length” - are qualitatively different from the other categories. While the other categories indicate injury resulting from gear interaction, these three categories pertain to the state of the turtle as it is released from the boat. Thus, they serve more as compounding factors to the existing injuries.

Role of gear removal: Several participants noted that when gear can be removed without inducing further injury, removing hooks and other gear could have a significant positive effect on the recovery of an individual turtle. However, one participant noted that removing gear would not have equal effect for each of the listed injuries and that equal “benefits” could not be assumed across the gradient of injuries. It was also emphasized that surgical removal under laboratory conditions is a much different scenario from de-hooker removal on-board a vessel. Under on-board conditions, the potential for future infection and other complications would also be expected to be higher. While hook removal was advocated for most hooks, several participants identified that additional injury can result from the act of removing hooks from certain locations (e.g., deeply ingested hooks). Additionally, several participants opined that sufficient information does not exist to quantitatively determine the decrease in risk of mortality associated with hook/gear removal.

Other post-interaction injuries: Participants also discussed other potential post-interaction injuries not captured in the list above. These included: osteoarthritis, penetration of skin, soft tissue injury, eye puncture, line strangulation of limbs and subsequent infection/amputation or fused joints, and water inhalation leading to lung infection. Forced submergence and the incidence of asphyxiation and hypoxia were also discussed, but it was acknowledged that given the current tools, there is no way to assess this on board a vessel.

Uncertainties are inherent in forecasting: Participants noted that sea turtles tend to be inherently robust animals; when subjected to severe stress, mechanical damage, and risk of infection they will become survival-oriented in their behavior and physiology. The effect that this may have on the outcome of a post-hooking injury is unknown.

Question 2: What sublethal effects may occur from forced submergence, hook ingestion, external hooking, entanglement, and hook removal?

Participants discussed potential sublethal effects that might have an impact on sea turtles. These included: loss of growth, delayed development, diminished productivity, and delayed time to maturity. Any significant amount of trailing line can always present the risk of later effects. Sublethal impacts were documented in the Azores study and this is the best available research to reference on this issue. Participants generally agreed that sublethal effects were an important consideration, but they remain very difficult to quantify with the information currently available. Several participants noted that it can be difficult to distinguish between lethal and sublethal injuries, as an injury can cause a pathology that later leads to death. One participant noted that sublethal effects may outweigh lethal effects due to impacts at the population level. Some participants noted a need for additional studies in this area.

Question 3: Are there inherent physiological differences among marine turtle species relevant to their response to: forced submergence, hook ingestion, external hooking, entanglement, and hook removal?

Participants felt that species (in particular, hard-shelled versus leatherback turtles), size, and sex were most relevant to physiological differences in response to trauma associated with longline interaction events.

Leatherbacks versus hard-shelled turtles - Participants noted and discussed the following relative to the differences between leatherbacks and hard-shelled turtles and how those differences may affect their respective risk for post-interaction mortality:

- Field and laboratory observations indicate that loggerheads and olive ridleys appear to be less susceptible to trauma than leatherbacks, which have more friable skin and softer bones. One participant felt that a leatherback brought along side a vessel would sustain greater external damage than a hard-shelled turtle.
- Necropsy findings indicate that internal hooks inflict greater damage in leatherbacks due to the fragility of both soft and hard tissue structures.
- In reference to the above observations, circle hooks in the mouth/throat may be more damaging to leatherbacks.
- In the U.S. northeast distant shallow set swordfish fishery, loggerheads should be able to get to the surface when hooked, if they are not entangled. Since leatherbacks are more likely to be entangled, they will be less likely to be able to get to the surface to breathe. Lab studies also suggest that leatherbacks may take longer to recover from acidosis.
- Based on experience with three live leatherbacks entangled in gillnet gear in the Atlantic, one participant observed that leatherbacks may be more vulnerable to the ecological impact associated with displacement from their normal foraging area; higher rates of travel and a longer time period to resume normal dive behavior were documented.

Size of turtles - Participants discussed the following differences between larger and smaller turtles that might influence their susceptibility to injury and mortality:

- Larger turtles have greater lung capacity than smaller turtles.
- The bigger the turtle, the greater chance it has of reaching the surface after being hooked or entangled.
- Larger turtles are more susceptible to injury if dropped on deck or when coming into contact with the vessel while in the water.

Sex of turtles - Participants generally noted that it is very difficult to evaluate sex differences relative to mortality rates, since it is impossible for observers to determine the sex of immature turtles. It was noted that in the Pacific studies to date, virtually all of the olive ridleys and green turtles that have been caught have been females, suggesting either a skewed sex ratio or the gear taking a disproportionate number of females due to the location and timing of the fishery.

Question 4: For marine turtles that are moderately or severely injured, over what time period would you anticipate effects from the injury to persist?

After reviewing the most recent information presented, participants generally agreed that an injured turtle can die relatively quickly (a matter of hours) to over nine months or more following the injury. Turtles may take a long time to recover from forced submergence.

Topic Area 2: Gear Materials

The objective of this moderated discussion was to seek individual input how (and if) different materials used for longline hooks might affect mortality, since different materials corrode at different rates. Participants briefly discussed the effect of gear materials on post-interaction mortality. Key discussion points included the following:

- Current regulations already stipulate the use of corrodible hooks. It was noted that carbon steel hooks are still legal and they are as enduring as the prohibited stainless steel hooks.
- Corrodible hooks generally corrode very slowly. Corrosion has toxic effects, but these corrosion materials are typically not that toxic to sea turtle gastrointestinal tracts. Therefore, the gradual rusting process shouldn't be a significant concern for sea turtles.
- Corrosion can also cause inflammation that may increase hook expulsion.
- Little research on this topic has been conducted with sea turtles. More research is being done on fish and this could have some application to sea turtles.

Topic Area 3: Satellite Telemetry

The objective of this moderated discussion was to seek individual input on the potential for satellite telemetry to inform the issue of post-interaction mortality and to discuss some of the problems and limitations inherent to satellite telemetry studies relative to post-interaction mortality. Participants discussed the following four questions:

Question 1: What types of data do satellite tags provide?

Participants listed the following categories of data that, depending on manufacturer and configuration, can be provided by conventional (standard Argos-linked satellite tags, periodically sending data via Argos) and pop-up archival satellite tags (configured to store data and transmit once the tag releases from the turtle): location, dive duration, dive profile, deepest dive, surface time (dry time), sea temperature profile, and sea temperature at depth. Conventional tags provide higher resolution location data, whereas pop-up tags provide less finely resolved location data. Conventional tags report the above data according to a prescribed duty cycle (which can be near real time), while pop-up tags report only after the tag has been released and floats to the surface. Pop-up tags have the capability to report premature release, since the release function can be

programmed for a set time. Several participants noted that the data reported by the two primary tag technologies are both important in addressing the issue of post-interaction survivorship.

Question 2: What are the advantages and disadvantages of the different types of satellite tags?

Participants discussed the following respective advantages and disadvantages of conventional and pop-up satellite tags:

Conventional Tags

Key advantages:

- Duty cycle permits regular data transmission
- Higher resolution geolocation data

Key disadvantages

- Difficult to determine mortality

Pop-Up Tags

Key advantages:

- Can potentially report data on turtle mortality, though not yet fully operational
- Can be designed to release under various conditions (e.g., when the preset pop-up date is reached, when the tag is at constant depth for 4 days, when the tag is at 1,500 m depth)

Key disadvantages:

- Delay in receiving data
- Less reliable attachment to date
- Less reliable geolocation
- Difficulties receiving all stored data through the Argos link if tag is not recovered
- Extremely high failure rates to date

Some disadvantages apply to both tag types:

- Satellite coverage diminishes at lower latitudes
- Hardware problems
- Expensive technology

Question 3: What post-deployment transmission characteristics may be used as a proxy for mortality?

Participants suggested the following as proxies that may indicate mortality and commented that studies with large sample sizes are most reliable:

Conventional Satellite Tags

- Complete transmission failure post-release.
- Cessation of transmissions, coupled with an understanding of previous transmissions, diving profiles, or other sensor data.

Pop-Up Satellite Tags

- Aberrant deep dive or tag depth followed by activation of release mechanism due to exceeding of pre-set maximum depth point.
- Constant depth for several days followed by activation of release mechanism per pre-set parameters.
- Participants also noted that while uncertainty will still exist, it may also be helpful to look for patterns of consistency (e.g., of battery power). However, this requires larger sample sizes.

Participants reinforced that they are still investigating their ability to interpret these data and discussed the need to explore alternative methods other than relying on interpreting location and dive data as a means of determining marine turtle mortality. Although constant depth may be indicative of a dead turtle, this also involves some speculation. There is also the problem of correctly interpreting tags that release prior to the programmed release date. Cessation of transmissions cannot simply be assigned as tag failure. Subsequent fisheries interactions, predator encounters, or other acute events unrelated to the original longline hooking event can confound interpretation of the data. Participants who have been involved with post-interaction telemetry studies agreed that at this stage, very few conclusions can be drawn with confidence.

Question #4: What can be learned from existing satellite telemetry data?

Satellite telemetry technology has greatly improved in recent years. Transmitters can be built with more data sensors and data resolution has improved for certain types and models of tags. Marine turtle scientists have taken advantage of these advances and our knowledge of movements, behavior, and ecology have improved. However, applying this technology to address post-interaction mortality still presents numerous challenges. Participants generally agreed that the satellite telemetry data that exist are insufficient for drawing clear conclusions or implications for post-interaction mortality. Simply put: it is still difficult to figure out what a turtle is doing and relate that behavior to a specific event. There is a lot of variability among tags. Too many unknown variables prevent robust statistical treatment of the data. Participants noted that at present only limited conclusions can be drawn from recent studies. These included the following:

- 1) Evidence of a difference in behavior between hooked and non-hooked turtles (Azores study results). However, when examining dive data to distinguish post-interaction

impacts, autocorrelation is a concern, since dive patterns are not necessarily independent events.

- 2) A pattern of early tag failure for deeply hooked turtles (Hawaii-based and northeast distant area Atlantic study results).

Several participants recommended that post-release studies performed to date be viewed as “pilot studies” that suffer from small sample sizes, presumed high failure rates of pop-up tags, and variation among tag manufacturers and tag batches. Pop-up tags in particular have a wide range of performance and there were significant differences of opinion regarding their reliability. It was agreed that hundreds of tags would need to be deployed to achieve the sample sizes necessary to attempt to resolve mortality events and to investigate patterns. Several participants opined that a summary report on all of the pop-up tags that have been deployed to date is desperately needed to help us to better understand the performance and utility of these tags.

Telemetry experts at the Workshop agreed that we need to work with telemetry companies to develop next generation tags that might provide more useful data to inform the question of post-hooking effects. Further, data from these tags need to be more directly comparable among studies. In the future it would also be beneficial to build information on the condition of the instrument into the tag itself. In spite of the potential advancements, it was noted that there are still significant obstacles to overcome and this will continue to be an issue.

Topic Area 4: Current NMFS Post-Hooking Mortality Criteria

The objective of this moderated discussion was to seek individual input regarding the February 2001 post-hooking mortality criteria. The discussion would help inform NMFS whether modifications to the current criteria are needed, and if so, how such modifications might be structured. Key comments on the existing criteria included the following:

- **Restatement of criteria** - While the current criteria are titled “*Post-Hooking* Mortality Criteria,” several participants noted that “*Post-Interaction* Mortality Criteria” would be more accurate, since this broader designation could include factors other than hooking and would also extend to sublethal effects.
- **Revised categorizations** - Participants suggested a variety of alternative ways to revise the injury categories in the existing post-hooking mortality criteria. Most suggestions were directed at re-defining the types of injuries listed within categories, or to dividing the existing four categories into a greater number of sub-categories. Several participants specifically mentioned adopting the categories discussed during the moderated discussion under Topic Area 1. Several participants offering this suggestion also proposed adding the category “hooked in cervical esophagus” to the high risk category.
- **Comments on Existing Category 1** - *No hooking, no injury, disentangled completely.* Nearly all of the participants expressed support for the view that any fisheries interaction with sea turtles results in a greater than zero probability for risk of mortality in the future. However, most agreed that the mortality risk would be small - likely less than 1%.

- **Comments on Existing Category 2** - *Hooked externally or entangled, line left on animal (line does not penetrate internal mouth structure, e.g., external beak hook)*. Several participants suggested that 27% is probably high for the injuries now included in that category.
- **Comments on Existing Category 3** - *Mouth hooked (penetrates) or ingested*. Participants generally felt that mouth hooking should not be in the same category as ingested hooks and they viewed lower jaw hooking as having a lesser relative risk than a hook in the roof of the mouth (soft palate) or an ingested hook. Several participants recommended that this category be broken down to distinguish between lower jaw, roof of mouth (soft palate), and ingested hooks.
- **Comments on Existing Category 4** - *Dead*. Several participants noted that the dead category was not really needed, since it is clear that dead animals constitute a 100% mortality rate.

Additional topics of discussion included the following:

- **Absolute versus relative risk** - While most participants felt comfortable stating that some injuries are relatively worse (or less worse) than others, they also opined that assigning specific risk percentages to different gear interaction possibilities is difficult without better data. Many participants, while acknowledging NMFS' requirement to develop quantitative criteria, felt more comfortable ascribing relative risk (e.g., low, moderate, high), rather than absolute risk (i.e., quantifying risk in percentage terms).
- **Effects of gear removal** - Participants recommended that NMFS modify the criteria to allow for reduced risk in cases where gear is safely removed. However, it was also noted that there are cases when removing the gear can worsen the magnitude of the injury (e.g., hooks in the cervical esophagus at or below the level of the heart). There were divergent opinions on when it is appropriate to attempt removing hooks from certain locations. However, there was general agreement that if the insertion point is not visible when viewed through the mouth, the hook should not be removed.
- **Precision of assigned mortality rates** - Many participants noted that given the limited and uncertain data available, post-interaction mortality rates should not reflect a precision that does not exist. For example, instead of assigning rates like 27% or 42%, rates should be in increments of 5% or 10%.
- **Species differences** - Participants generally agreed that the current criteria apply more readily to hard-shelled turtles than to leatherbacks, which were viewed as more vulnerable because of their friable skin, softer tissue, bone structure, and increased susceptibility to both entanglement and anoxia. Participants felt that the risk for most injury categories would be greater for leatherbacks.

PART IV: FEEDBACK INSTRUMENT

To provide an opportunity for participants to organize their thoughts and input, the workshop conveners prepared a feedback instrument (Appendix 4). The instrument was organized around a series of eight questions, all of which provided the opportunity for open-ended, qualitative response, and did not force answers into a quantitative scale. On the afternoon of the second day, participants were asked to provide individual input using the feedback instrument as a guide. A summary of the responses to the feedback instrument is provided below.

Participants made a serious effort to engage in the material presented and this was reflected in their responses. Although some respondents provided more detail and rationale for their feedback than others, a number of general comments summarized:

- For most questions there was a range of responses, as well as a notable degree of convergence. Specifically, the majority of the respondents supported expanding and refining the number of injury criteria categories. However, respondents were mixed in their ability to assign quantitative mortality rates to the revised categories.
- Respondents conveyed varying degrees of willingness to draw inferences based on the existing data that are available on this issue. Some respondents were willing to be normative and prescriptive, while others were uncomfortable making recommendations.
- On question 8, which asked for additional comments and recommendations, several respondents noted the difficulty of accurately assessing the effects of post-interaction effects and several respondents called for additional studies focused on this issue.

Summary of Feedback Instrument Responses

Question 1) *When a trained fishery observer is present to record and characterize an interaction what information relative to the gear should be considered in determining post-hooking mortality?*

- Location of hook*
 - Fate of hook (removed or left intact)*
 - Nature of line entanglement (for example: number of appendages involved, number of wraps, etc.)*
 - Fate of line (completely removed, partially removed, or left intact)*
 - Length of line and/or leader left on turtle*
 - Hook material (corrosiveness/degradability)*
 - Other (describe)*
- Participants showed strong support for recording and characterizing information on: location of the hook, fate of the hook, nature of line entanglement, fate of line, and length of line and/or leader left on turtle. Participants placed less importance on hook material,

since little information exists on the relative rates of decay for various hook materials currently used.

- Question 2)** *Which of the following non-gear parameters do you believe would make a meaningful difference in the probability of mortality?*
- a. *Size of turtle*
 - b. *Species*
 - c. *Nature or extent of visible injuries (for example: extensive tissue damage, minor abrasions, etc.)*
 - d. *Behavior (while on deck, in the water, and/or post-release)*
 - e. *Oceanographic factors (for example: water temperature, currents)*
 - f. *Other (describe)*

- The two non-gear parameters that received nearly unanimous support for consideration were: species and nature or extent of visible injuries.
- A strong majority of respondents stated that behavior would make a meaningful difference in the probability of mortality. However, it was noted that the behavior of turtles on deck can be deceiving and may not be indicative of the true condition of the animal.
- A majority of respondents also stated that the size of the turtle would make a meaningful difference in the probability of mortality, since larger turtles are at greater risk of injury during boarding or when handled on or adjacent to a vessel.
- A few respondents felt that oceanographic factors would be relevant. Supporters noted that water temperature can affect healing rates and appetite, while one opponent noted that temperature is unlikely to make a difference if the turtle is taken and released in the same water temperature.

- Question 3)** *Considering the existing conventional and pop-up archival satellite telemetry studies, do you believe that quantitative or qualitative assessments of post-hooking mortality can be made?*

- Most participants noted that there have been some improvements since 2001 in the quality of data available to inform post-interaction mortality determinations. Some participants were willing to make inferences from the most recent data, while others were not. At the same time, participants widely acknowledged that substantive improvements in the quality of data are still needed.
- Approximately ten respondents expressed the view that some qualitative or quantitative assessment of post-hooking mortality could be determined based on satellite telemetry studies that have been conducted to date. However, these respondents noted that any quantitative assessments that could be made would be limited. Seven respondents did not

believe that satellite telemetry studies could produce definitive answers regarding post-interaction mortality. When examining the same data sets, participants had differing interpretations on the ability to draw meaningful inferences or conclusions.

Question 4) *Are there sublethal effects (e.g., reduced fitness or delayed maturation due to depressed growth rates) that should be factored into an assessment of post-hooking mortality?*

- Approximately half of the respondents stated that sublethal effects should be factored into an assessment of post-hooking mortality, but most of these respondents noted that they had no clear idea of how this could be done. Several respondents noted that there is very little data to support factoring sublethal effects into post-hooking mortality assessment.

Question 5) *Based on available information from archival and/or conventional satellite telemetry, what behavioral factors, if any, should be considered and evaluated as an indicator of altered or compromised post-release behavior?*

- a. Diving patterns*
- b. Movement patterns*
- c. Other*

- Nearly all respondents expressed the view that both diving and movement patterns should be considered and evaluated as an indicator of compromised post-release behavior. Of these two factors, dive patterns were seen as more critical. Several respondents noted that the quality of this information is dependent on the presence of good controls (a feature that has been lacking in a number of studies to date). It was also noted that when assessing diving behavior, autocorrelation is a real concern. Several respondents were unclear as to how these behavioral factors could be applied to the issue.

Question 6) *In considering how to evaluate post-release mortality, how would you recommend expanding or contracting current post-hooking criteria categories of interaction?*

- Many respondents noted that there are multiple sub-categories that could be separated out from the current injury categories to better characterize the risk associated with specific injuries. Conversely, two respondents stated that there was insufficient new data to warrant changing the existing four criteria categories and that there were benefits to keeping the same categories.
- Approximately two-thirds of respondents proposed expanding or refining the existing criteria categories. Respondents recommended a variety of approaches, generally recognizing that the categories need to be practical for NMFS to use. Many expressed support for using the high/low risk list of injuries presented during the Workshop to

expand the existing categories. Few of the respondents proposed altering the relative ordering of the list of injuries as initially discussed during the Workshop. However, respondents differed in their approach as to how these injuries should be grouped. Some respondents felt that all eleven injuries could be grouped under as few as two or three broad strata, while others suggested as many as six categories. Still others suggested that rather than adjusting the number of categories, a preferable course would be to add precision to the types of injuries and group them into three broad categories of high, medium, and low risk (plus the 100% dead category). Among the specific revisions suggested were:

1. Disaggregate the existing “mouth hooked or ingested hook” category into subcategories (e.g., lower jaw, upper jaw (soft palate), hook embedded in esophagus at or below heart).
2. Create a specific category called “comatose and resuscitated”.
3. Subdivide categories by considering whether the hook/line was removed. This could include adding detail to length of attached line (one-half the carapace length was suggested).
4. Subdivide categories further by considering species (leatherback versus hard-shelled turtles).

Several respondents suggested retaining the existing categories based on the following rationale:

- Given existing data, expanding categories might be premature.
- The existing categories are simple and adequately match the mouth/external and deep-hooked categories already used in most existing studies, further expansion would be uninformative.

Based on the injury categories discussed during the Workshop, a number of respondents ranked the different injury categories relative to other classes of injury. Generally these ranking schemes closely paralleled the ranking scheme discussed during the Workshop, originally suggested by the participating veterinarians. Many of the respondents noted that their perceptions of mortality probabilities are affected by other compounding factors. Some of these involved the condition of the turtle at release. Key among these were:

- Whether hooks/line are removed
- The length of line remaining on the turtle
- Whether removal of gear caused additional injuries

Other additional compounding factors unrelated to gear included: 1) whether the turtle was injured while being brought or handled on board; and 2) whether the turtle was experiencing stress due to severe entanglement.

Respondents viewed several of the injuries as posing approximately equivalent risks and grouped these together for assigning post-injury mortality rates by category. This provided input on how injury categories might be grouped differently from the February 2001 criteria. Observations from this exercise included the following:

- No respondents viewed the categories of “Dead/comatose and not resuscitated” and “Comatose and resuscitated” as equivalent.
- Seven respondents viewed the categories of “comatose and resuscitated” and “hook embedded at or below level of heart” as somewhat equivalent. Three respondents placed them at different levels of risk.
- Approximately two-thirds of respondents viewed the categories of “hook embedded at or below level of heart” and “hooked in cervical esophagus” as approximately equivalent.
- Approximately half of respondents viewed “hooked in cervical esophagus” as approximately equivalent to “hook in glottis/jaw hinge.” Several (2-3) participants saw these as significantly different.
- Slightly more than half of 11 respondents viewed “hook in glottis/jaw hinge” as equivalent in risk to “hook in soft palate.”
- Approximately two-thirds of respondents viewed “hook in soft palate” as a higher degree of risk than “hook in lower jaw.” Approximately 3 respondents viewed these two categories as similar risks of mortality.
- Approximately half of the respondents viewed “hook in lower jaw” as nearly equivalent to “external hook with no line attached.” Approximately 6 respondents viewed these categories as qualitatively different risks.

(Note that the term “approximately” as used above relates to situations where there was some question regarding how a respondent interpreted and responded to a particular question).

Question 7) *Please provide a post-hooking mortality rate or range or ranking for each proposed category you identified in Question 6 above and provide an explanation of your rationale for assigning either a quantitative rate or a qualitative rate.*

Five respondents stated that they could see merit in qualitatively ranking risks of mortality by sources of injury, but preferred not to, or could not, assign quantitative percentiles. Nine respondents recommended revising the criteria and offered specific, quantitative suggestions on how to do this. Most of the respondents who suggested quantified mortality rates appear to have based their percentages, at least in part, on the numbers presented in the February 2001 criteria. Within this last grouping, key considerations included the following:

- The current “No hooking, no injury, disentangled completely - 0%” category should be revised upward to a percentage greater than 0. Suggestions for modifying this ranged from .05 - 5%.
- Hook/gear removal, consistent with NMFS guidance, should be treated as lowering the risk of mortality.
- Mortality rates presented in multiples of 5% or 10% are more appropriate than absolute numbers that imply precision.
- There is merit to having relatively fewer groupings of injuries (3-5) for ease of administration.
- Leatherbacks are at greater risk in all categories of injury and 5-10% should be added to the mortality rate for leatherbacks for each category of injury.
- Sublethal effects are a factor, but given the lack of knowledge in this area it is not possible to address this quantitatively.
- Suggestions for the appropriate mortality rate for high risk injuries ranged from 40-70%, with a cluster of responses in the 40-50% range.

Question 8) *Please provide any additional comments and recommendations.*

Participants emphasized the need to conduct additional research specifically targeting this issue. Suggestions in this area included:

- Research on species differences
- Research on the physiological effects of hooking
- Improved experimental design with larger sample sizes
- Continuing work on tag development that will better enable the confirmation of mortality versus tag or attachment failure

The need to disseminate clear handling and release protocols to longline fishermen was also reinforced.

PART V: REVISION OF FEBRUARY 2001 CRITERIA

Following the Workshop, OPR reviewed the information presented formally and during directed discussions, the feedback instruments completed by participants, and all of the available information relevant to the issue. Based on this detailed review, OPR concluded that changes to the existing criteria were appropriate and necessary. The revised criteria (Table 1) reflect the information presented at the Workshop, the detailed discussions among expert participants, the expert feedback received from individual participants at the Workshop, peer reviewer comments (Appendix I), and OPR's review of all other relevant information.

Summary of Recommended Changes

Categories: The February 2001 injury categories have been expanded to better describe the specific nature of the interaction. The February 2001 criteria described two categories for mouth hooking: (1) hook does not penetrate internal mouth structure, and (2) mouth hooked (penetrates) or ingested hook. The new criteria divide the mouth hooking event into three components to reflect the severity of the injury and to account for the probable improvement in survivorship resulting from removal of gear, where appropriate, for each injury. The new criteria also separate external hooking from mouth hooking, eliminate the 'no injury' category, and add a new category for comatose/resuscitated turtles,

Probable Improvement in Survivorship When Gear is Removed: The new criteria recognize that in most cases removal of all or some of the gear (except deeply ingested hooks) is likely to improve the probability of survival. The "release condition" of turtles interacting with longline gear are divided into four categories: (1) released with hook and with trailing line greater than or equal to half the length of the carapace (line is trailing, turtle is not entangled); (2) released with hook and with trailing line that is less than or equal to half the length of the carapace (line is trailing, turtles is not entangled); (3) released with hook and entangled; and (4) released with all gear removed. Turtles that have all or most of the gear removed are expected to have, on average, a higher probability of survival.

Species Difference: Species differences between hard-shelled turtles and leatherbacks likely play a role in post-interaction survivorship. The new criteria take this into consideration and assign slightly higher rates of post-interaction mortality for leatherback turtles.

Table 1: Criteria for assessing marine turtle post-interaction mortality after release from longline gear. Percentages are shown for hardshelled turtles (i.e., loggerhead, Kemp’s ridley, olive ridley, hawksbill, and green turtle), followed by percentages for leatherbacks (in parentheses).

Injury Category		Release Condition			
		Released with hook and with trailing line greater than or equal to half the length of the carapace (line is trailing, turtle is not entangled)	Released with hook and with trailing line less than half the length of the carapace (line is trailing, turtle is not entangled)	Released with hook and entangled (line is not trailing, turtle is entangled ¹)	Released with all gear removed
		Hardshell (Leatherback)	Hardshell (Leatherback)	Hardshell (Leatherback)	Hardshell (Leatherback)
I	Hooked externally with or without entanglement.	20 (30)	10 (15)	55 (65)	5 (10)
II	Hooked in upper or lower jaw with or without entanglement. Includes ramphotheca, but not any other jaw/mouth tissue parts (see Category III).	30 (40)	20 (30)	65 (75)	10 (15)
III	Hooked in cervical esophagus, glottis, jaw joint, soft palate, tongue, and/or other jaw/mouth tissue parts not categorized elsewhere, with or without entanglement. Includes all events where the insertion point of the hook is visible when viewed through the mouth.	45 (55)	35 (45)	75 (85)	25 (35)
IV	Hooked in esophagus at or below level of the heart with or without entanglement. Includes all events where the insertion point of the hook is not visible when viewed through the mouth.	60 (70)	50 (60)	85 (95)	n/a ²
V	Entangled only, no hook involved.	Released Entangled 50 (60)			Fully Disentangled 1 (2)
VI	Comatose/resuscitated.	n/a ³	70 (80)	n/a ³	60 (70)

¹ Length of line is not relevant as turtle remains entangled at release.

² Per veterinary recommendation hooks would not be removed if the insertion point of the hook is not visible when viewed through the open mouth.

³ Assumes that a resuscitated turtle will always have the line cut to a length less than half the length of the carapace, even if the hook remains.

APPENDIX 1: PEER REVIEW OF REVISED CRITERIA

Upon completion of the Report of the Workshop and the draft revised criteria, the Office of Protected Resources contacted three external reviewers with expertise in the areas of marine turtle veterinary medicine, pathology, and epidemiology and requested their independent review of the revised criteria for assessing post-interaction mortality. While the Workshop Report provided the necessary background on the issues, workshop discussions, and participant feedback, reviewers were asked to comment specifically on the revised criteria.

The reviewers were:

Dr. Robert A. Morris MS, DVM who has had a private veterinary practice - The Makai Animal Clinic in Kailua, HI for 27 years, is a graduate of Cornell University. Dr. Morris served as a contract veterinarian for the NMFS monk seal program and has been under contract with the NMFS Pacific Islands Fisheries Science Center sea turtle program for the past 11 years, evaluating all live sea turtle strandings in Hawaii. To date, he has observed and evaluated over 500 sea turtles.

Dr. Charles Manire, DVM, a veterinarian and research scientist who focuses specifically on marine veterinary medicine and is a graduate of Texas A&M University. Dr. Manire is the Chief Veterinarian and a Staff Scientist at Mote Marine Laboratory and Aquarium in Sarasota, Florida. He oversees the Sea Turtle Rehabilitation Hospital and the Dolphin and Whale Hospital at Mote Marine Laboratory and has been involved in sea turtle rehabilitation for over 13 years.

Dr. Elliott Jacobson, Ph.D., DVM, has extensive research experience in health assessment of reptiles, reptile immunology, and infectious and noninfectious diseases of reptiles. A graduate of both the Veterinary and Zoological Medicine programs at the University of Missouri, Dr. Jacobson has been a professor of Wildlife and Zoological Medicine with the College of Veterinary Medicine at the University of Florida since 1990 and has extensive experience with sea turtle health and disease issues.

Comments on the Revised Criteria

The reviewers generally felt that the revised criteria did a good job of defining the post-hooking injury categories as well as the possible release conditions. One of the reviewers felt that NMFS did not have sufficient data to accurately estimate the mortality rates associated with the various injury categories, but that our best capability at this time is to determine the relative mortality of each category compared to the other categories. However, he did feel that the revised criteria accurately reflects and estimates that relative mortality. Another reviewer also expressed reservations about whether there is adequate data to have confidence in the actual percentages assigned to injury categories and indicated that he would feel more comfortable assigning a range (e.g., 0-20%) rather than an actual percentage (e.g., 10%) to each category. However, he noted

that if there is a need for an actual number for calculation purposes then each number in the table probably falls near the middle of the expected range for each category. A third reviewer also felt that the mortality figures would make more sense if presented as a range, since this would better reflect our imperfect knowledge. As noted above, the post-interaction mortality estimates presented in the revised criteria are necessary for mortality calculation and represent the best estimate of actual mortality based on all of the available information. This reviewer also felt that the mortality percentages might have been high in some cases. He also emphasized that both entangling and ingested lines can cause serious injuries (flipper fractures, amputations and intussusceptions), implying that perhaps these mortality criteria categories underestimated post-interaction mortality. We believe that the revised criteria have adequately estimated the severity of injuries caused by lines. One reviewer suggested modifying the category heading for the nature of the interaction to a more simplified term: “Injury Category.” This term has been changed in the revised criteria. It was also suggested that the comatose/resuscitated category should be listed as a subcategory under each injury category. We note however, that the creation of this category as a stand alone category does take into account all of the other injury categories, and the associated estimated mortality rate reflects the serious nature of this condition.

In addition to the specific comments on the revised criteria, each of the reviewers identified other issues that mirrored some of the discussions that occurred during the workshop and are captured in the Workshop Report, most notably, the difficulty in assessing post-interaction mortality given the current state of knowledge. While these points are important, we believe they were adequately considered and addressed during the development of the criteria.

Suggestions for Further Research

The reviewers had a number of constructive suggestions for additional research and improved studies that could help to better inform the issue of post-hooking mortality. One reviewer suggested that a comprehensive survey of sea turtle rehabilitation facilities be conducted to review the available medical records on hooked sea turtles to establish how many turtles with hooks removed survived, how many died despite treatment and, for the ones that died, how long after arrival at the facility they died. Another reviewer noted a recently developed technique to estimate mortalities in various categories from tag/recapture data. He felt that this approach, initially used for sharks, might be applicable to sea turtles, although the need for a large number of recaptures may preclude its use.

Another reviewer highlighted the need to establish criteria to enable inference of death of sea turtles via post-hooking telemetry studies. He suggested that all hooked turtles that die in rehabilitation facilities be fully necropsied to obtain data on the pathological consequences of hooking. This same reviewer suggested that an epidemiologist could help design an improved study to determine post-interaction mortality and that there may be some epidemiological models that can be applied to this issue. While developing new studies or improving on studies conducted to date was not an objective of the Workshop, these recommendations may help guide future efforts directed toward these questions.

APPENDIX 2: PARTICIPANT LIST

Workshop Facilitators - CONCUR, Inc.

Dr. Scott McCreary

Dr. Eric Poncelet

Workshop Participants

Mr. Nelson Beideman - Blue Water Fisherman's Association

Dr. Christofer Boggs - NMFS Pacific Islands Fisheries Science Center

Dr. Alan Bolten - University of Florida

Dr. Milani Chaloupka - University of Queensland

Dr. Scott Eckert - Duke University Marine Laboratory

Ms. Sheryan Epperly - NMFS Southeast Fisheries Science Center

Dr. Joe Flanagan - Houston Zoo

Dr. Craig Harms - College of Veterinary Medicine, North Carolina State University

Mr. Mike James - Dalhousie University

Mr. John LaGrange - Hawaii Longline Association

Dr. Molly Lutcavage - University of New Hampshire

Dr. Peter Lutz - Florida Atlantic University

Dr. David Owens - College of Charleston

Mr. Earl Possardt - U.S. Fish and Wildlife Service

Ms. Barbara Schroeder - NMFS Office of Protected Resources

Dr. Thierry Work - U.S. Geological Survey

Dr. Jeanette Wyneken - Florida Atlantic University

Workshop Rapporteurs

Therese Conant - NMFS Office of Protected Resources

Kristy Long - NMFS Office of Protected Resources

Cheryl Ryder - NMFS Office of Protected Resources

Workshop Observers

Marydele Donnelly - The Ocean Conservancy

Rachael Littman - Oceana

George Mannina - O'Connor & Hannan

Chris Sasso - NMFS Southeast Fisheries Science Center

Sierra Weaver - The Ocean Conservancy

AGENDA

**Workshop on Marine Turtle Longline Post-Interaction Mortality
Convened by NMFS - Office of Protected Resources
January 15-16, 2004**

**Bethesda Hyatt Regency, Laliqie Room
Bethesda, MD**

Day 1: January 15, 2004

- 9:00** Welcome, Purpose of Workshop, Ground Rules and Logistics
- 9:15** Introduction of Participants
- 9:45** Introductory/Background Presentation on Current NMFS Sea Turtle Post-Hooking Mortality Criteria - Barbara Schroeder
- 10:30** BREAK
- 10:45** Presentations (each presentation includes 15 minutes for clarifying questions)
- 10:45** Post-Hooking Dive Behavior and Movement Patterns of Oceanic-stage Loggerhead Turtles - Alan B. Bolten, Brian Riewald, and Karen A. Bjorndal
- 11:25** Post-Hooking Mortality - Atlantic Pilot Study - Sheryan Epperly, Eric Prince, Chris Sasso, Alan B. Bolten
- 12:15** LUNCH
- 1:30** Presentations ((each presentation includes 15 minutes for clarifying questions)
- 1:30** Modeling Post-Release Mortality of Pelagic Loggerhead Sea Turtles Exposed to the Hawaii-Based Pelagic Longline Fishery - Milani Chaloupka, Denise Parker, George Balazs
- 2:20** Survivorship and Movements of Sea Turtles after their Release from Longline Fishing Gear in the Pacific Ocean - Yonat Swimmer, Randall Arauz, Lianne McNaughton, Mike Musyl, Rich Brill, Anders Neilson (presented by Chris Boggs)

APPENDIX 3 (continued)

3:15 BREAK

3:30 Moderated Discussion - Veterinary Medicine/Physiology

- What sublethal effects may occur from forced submergence, hook ingestion, external hooking, entanglement and hook removal?
- What injuries may occur from forced submergence, hook ingestion, external hooking, entanglement and hook removal that may result in mortality?
- Are there inherent physiological differences among marine turtle species relevant to their response to: forced submergence, hook ingestion, external hooking, entanglement and hook removal?
- For marine turtles that are moderately or severely injured, over what time period would you anticipate effects from the injury to persist?

5:00 Moderated Discussion - Day 1 Topics

6:00 Adjourn

Day 2: January 16, 2004

9:00 Recap and Questions

9:15 Moderated Discussion - Satellite Telemetry

- Is satellite telemetry a viable method for assessing post-interaction mortality?
- What factors (e.g. transmitter manufacturer, transmitter model) are relevant to the question of evaluating post-interaction mortality via satellite telemetry studies?
- What post-deployment transmission life should be used, if any, as a proxy for mortality?
- Can satellite telemetry studies elucidate any sublethal effects of sea turtle/longline interactions?

10:30 Break

10:45 Moderated Discussion - Current NMFS post-hooking mortality criteria

12:00 Feedback Instrument Walk-Through

12:30 Lunch

2:00 Participants Complete Feedback Instrument

4:00 Adjourn

APPENDIX 4: PARTICIPANT FEEDBACK INSTRUMENT

1. When a trained fisheries observer is present to record and characterize an interaction, what information relative to the gear should be considered in determining post-interaction mortality (underline and expand on all that apply)

1. Location of hook
2. Fate of hook (removed or left intact)
3. Nature of line entanglement (for example: number of appendages involved, number of wraps, etc.)
4. Fate of line (completely removed, partially removed, or left intact)
5. Length of line and/or leader left on turtle
6. Hook material (corrosiveness/degradability)
7. Other (describe):

For each item selected above, please provide additional written comments supporting your selection(s):

2. Which of the following non-gear parameters do you believe would make a meaningful difference in the probability of mortality? (underline and expand on all that apply)

1. Size of turtle
2. Species
3. Nature or extent of visible injuries (for example: extensive tissue damage, minor abrasions, etc.)
4. Behavior (while on deck, in the water, and/or post-release)
5. Oceanographic factors (for example: water temperature, currents)
6. Other (describe):

(A) For each item selected above, please provide additional written comments supporting your selection(s):

(B) For each item selected above, please discuss whether data exist to either quantify or qualify* in a meaningful way, the effect(s) that these non-gear parameters may have on the probability of mortality:

*{Quantify for example would be: likely to increase (or decrease) mortality by X%) and qualify would be: highly likely to increase (or decrease) mortality, somewhat likely to increase (or decrease) mortality}

APPENDIX 4 (continued)

3. Considering existing conventional and archival satellite telemetry studies, do you believe that quantitative or qualitative assessments of post-interaction mortality can be made? Please describe:
4. Are there sublethal effects (for example: reduced fitness, delayed maturation due to depressed growth rates, etc.) that should be factored in to an assessment of post-interaction mortality? If so, how would you incorporate sublethal effects into the post-interaction mortality criteria?
5. Based on available information from archival and/or conventional satellite telemetry what behavioral factors, if any, should be considered and evaluated as an indicator of altered or compromised post-interaction behavior?
 1. Diving patterns
 2. Movement patterns
 3. Other (describe):

Please provide additional written comments supporting your above response:

6. In considering how to evaluate post-interaction mortality, how would you recommend expanding or contracting the current post-hooking criteria categories of interaction? (see February 16, 2001 memo for current criteria)
7. Please provide a post-hooking mortality rate (or range) or ranking for each proposed category you identified in #3 above and provide an explanation of your rationale for assigning either a quantitative rate (for example: X% or X-Y%) or a qualitative ranking (for example: high probability of mortality, moderate probability of mortality, low probability of mortality):
8. Please provide any additional comments or recommendations you may have relative to the issue of post-interaction mortality.

APPENDIX 5: BACKGROUND DOCUMENTS PROVIDED TO PARTICIPANTS

NMFS Documents on Post-Interaction Mortality Criteria

1. January 4, 2001 Knowles Memorandum to Powers: F/PR recommended criteria for post-hooking mortality including comments received on strawman
2. February 8, 2001 Knowles Memorandum to Hogarth: F/PR response to internal comments and associated documents
3. February 16, 2001 Fox/Knowles/Morehead Memorandum to Hogarth: Decision memorandum establishing post-hooking criteria

Additional Background/Information Documents

- Aguilar, R., J. Mas, and X. Pastor. 1992. Impact of Spanish swordfish longline fisheries on the loggerhead sea turtle *Caretta caretta* population in the western Mediterranean. *In*: J.I. Richardson and T.H. Richardson (compilers). Proceedings of the Twelfth Annual Workshop on Sea Turtle Biology and Conservation. NOAA Tech. Memo. NMFS-SEFSC-361, pp 1-6.. AND Eric Hawk electronic mail to B. Schroeder *et al*, January 31, 2001. "Conversation with Aguilar and Pont." [e-mail clarifies several issues in the 1992 study].
- Balazs, G.H. 1994. Satellite Monitoring: A potential method for evaluating post-release survival of hooked sea turtles in pelagic habitats. *In*: Research Plan to Assess Marine Turtle Hooking Mortality: Results of an Expert Workshop held in Honolulu Hawaii, November 16-18, 1993. NOAA-Tech. Memo. NMFS-SWFSC-201.
- Balazs, G.H., D.R. Kobayashi, D.M. Parker, J.J. Polovina, and P.H. Dutton. 2000. Evidence for counter-current movement of pelagic loggerhead turtles in the north Pacific Ocean based on real-time satellite tracking and satellite altimetry. *In*: H.Kalb and T. Wibbels (compilers) Proceedings of the Nineteenth Annual Symposium on Sea Turtle Conservation and Biology. NOAA Tech. Memo. NMFS-SEFSC-443, p 21.
- Bjorndal, K.A., A.B. Bolten, and B. Riewald. 1999. Development and use of satellite telemetry to estimate post-hooking mortality of marine turtles in the pelagic longline fisheries. NOAA Fisheries Southwest Fisheries Science Center H-99-03C.
- Chaloupka, M., D. Parker, and G. Balazs. Modeling post-release mortality of pelagic loggerhead sea turtles exposed to the Hawaii-based longline fishery. Submitted to Fishery Bulletin.

APPENDIX 5 (continued)

- Eckert, S.A. 1994. Evaluating the post-release mortality of sea turtles incidentally caught in pelagic longline fisheries. *In: Research Plan to Assess Marine Turtle Hooking Mortality: Results of an Expert Workshop held in Honolulu Hawaii, November 16-18, 1993.* NOAA-Tech. Memo. NMFS-SWFSC -201.
- Jacobson, E. 1995. Veterinary experiences with hooked sea turtles. Edited transcript of verbal presentation. *In: Guidelines for Handling Marine Turtles Hooked or Entangled in the Hawaii Longline Fishery: Results of an Expert Workshop Held in Honolulu, Hawaii, March 15-17, 1995.* NOAA Tech. Memo. NMFS-SWFSC-222
- Parker, D.M., G.H. Balazs, S.K.K. Murakawa, and J.J. Polovina. 2005. Post-hooking survival of sea turtles taken by pelagic longline fishing in the north Pacific. *In: M.S. Coyne and R.D. Clark (compilers) Proceedings of the Twenty-first Annual Symposium on Sea Turtle Biology and Conservation.* NOAA Tech. Memo. NMFS-SEFSC-528, pp 50-52.
- Parker, D.M., G.H. Balazs, and J.J. Polovina. 2001. Estimation and Comparison of time spent on surface for pelagic sea turtles using the Telonics ST10/18 surface-time-counter function. NOAA Fisheries Southwest Fisheries Science Center.
- Riewald, B., A.B. Bolten, and K.A. Bjorndal. 2000. Use of satellite telemetry to estimate post-hooking behavior and mortality of loggerhead sea turtles in the pelagic longline fishery in the Azores. Final Contract Report to National Marine Fisheries Service, Honolulu Laboratory.
- Swimmer, Y., R. Brill, and M. Musyl. 2002. Use of pop-up satellite archival tags to quantify mortality of marine turtles incidentally captured in longline fishing gear. *Marine Turtle Newsletter* 97:3-7.
- Work, T.M., and G.H. Balazs. 2002. Necropsy findings in sea turtles taken as bycatch in the north Pacific longline fishery. *Fish. Bull.* 100: 876-880.