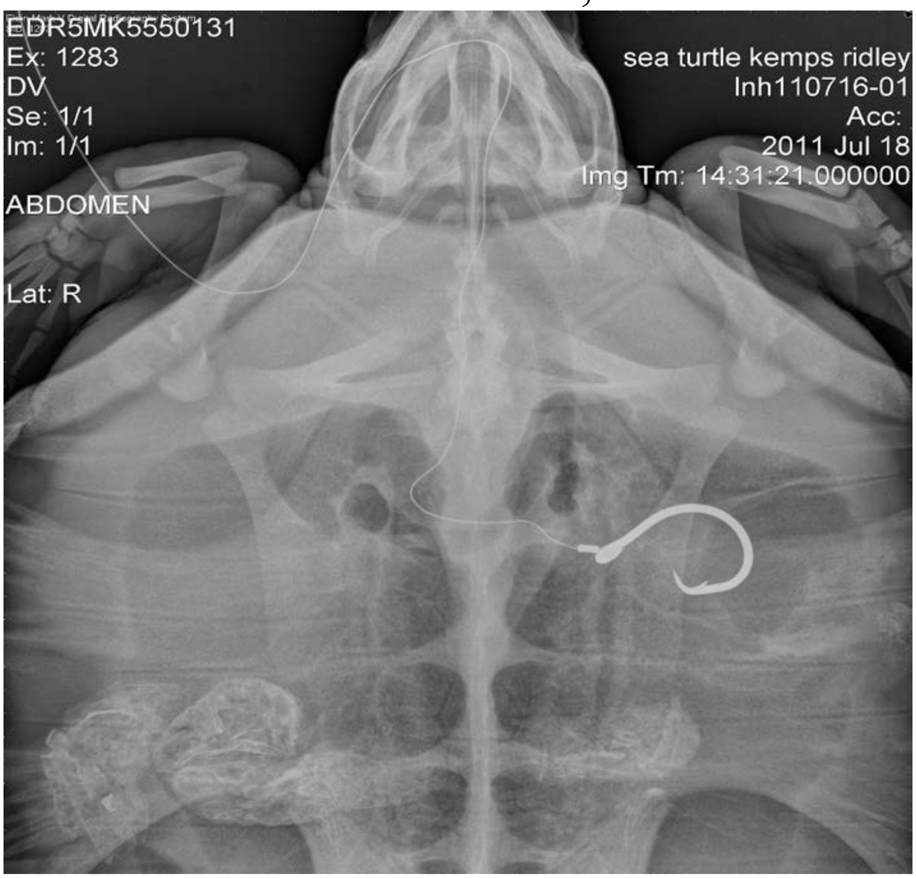
NOAA Technical Memorandum NMFS-PIFSC-34

August 2012

Report of the Sea Turtle Longline Fishery Post-release Mortality Workshop, November 15−16, 2011



Yonat Swimmer and Eric Gilman, Organizers

Pacific Islands Fisheries Science Center
National Marine Fisheries Service
National Oceanic and Atmospheric Administration
U.S. Department of Commerce

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Supplemental material, including pdfs of workshop presentations, are available online at https://sites.google.com/site/turtlepostreleasemortality/

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EXECUTIVE SUMMARY

Background

Incidental capture in longline fisheries is a recognized threat to sea turtles in all major ocean basins. The magnitude of this threat to sea turtle populations is not well understood based, in part, on uncertain rates of sea turtles' post-interaction mortality or the likelihood an injured turtle will die as a result of the interaction after being released alive. In assessing impacts, the National Marine Fisheries Service (NMFS) uses established criteria to determine the post-release mortality level that will be assumed. In November 2011, the Pacific Islands Fisheries Science Center (PIFSC) convened a webinar to review current post-release mortality criteria and to determine whether new scientific information exists in order to recommend modifications.

Estimates of post-release mortality are an essential component of risk assessment and fisheries management. However, methods for estimating the probability of sea turtle mortality following capture and release from longline fishing gear produce results with high levels of uncertainty. Empirically-based field studies of post-interaction mortality are difficult due to highly variable conditions that may influence the outcomes of interactions, challenges in tracking sea turtles released at sea, high costs, and low confidence in determining mortality using available telemetry technology. Due to data deficiencies, high variability, and uncertainties in research findings, government policies predicting the proportion of sea turtles that will die after release as a function of injury type (e.g., hooked in mouth, entangled in line) are largely based upon expert opinion in combination with limited best available science.

Recent research studies have aimed to overcome these challenges and provide more confident estimates of post-release survival of sea turtles after interactions with fishing gear. Despite these attempts, it remains extremely difficult to identify a post-interaction mortality with a high degree of certainty. Continued investment in research and development of methods to improve precision of such estimates is a high priority.

Given the importance of obtaining accurate estimates for fisheries management and species recovery purposes, scientists and managers must periodically review new scientific information to identify any improvements in methods for estimating sea turtle post-release mortality rates and to suggest modifications accordingly. This webinar sought to fulfill this purpose.

Workshop Purpose and Outcomes

In January 2004, the NMFS Office of Protected Resources convened a workshop and expert panel to review NMFS' method for predicting the proportion of sea turtles that are expected to die following their release from longline fishing gear under different categories of circumstances, which was established in 2001. The outcome included revised methods (Ryder et al., 2006). The current webinar was convened by the NMFS' PIFSC to review the current NMFS methods for estimating post-release mortality in light of new scientific information, both published and anecdotal, that has become available after 2004.

There remains high variability and uncertainty in research findings since the 2004 workshop. Major gaps remain in our knowledge of how sea turtle survivability is affected by factors such as hooking location, handling, gear remaining attached after release, species, and size. Despite extensive international efforts using a variety of research methods, the ability to definitively predict a sea turtle's probability of survival remains limited.

Many participants in the 2011 webinar expressed the belief that the current government policy for estimating sea turtle survival after release from longline fishing gear, as described in Ryder et al. (2006), appears reasonable. The best available method for predicting whether a sea turtle will die post-release still must rely on expert opinion in combination with limited best-available science. Although this may not result in the high degree of predictability that fisheries managers often seek, it is the most reasonable method to date and is the basis for the current NMFS policy.

The primary benefits of the webinar were to accomplish the following: 1) conduct a critical review of methods and results from recent research on sea turtle post-release mortality; 2) establish best practice handling and release methods to maximize sea turtles' probability of survival; 3) compare the relative certainty of results from alternative methods to measure/estimate post-release survival; and 4) identify information gaps and future research priorities to improve the accuracy of estimates. This Workshop Report conveys comments offered by one or more workshop participants. As such, each comment does not necessarily reflect the group consensus.

Key Findings and Next Steps

- There have been limited data since the January 2004 workshop to warrant revising the method for estimating sea turtle post-release mortality rates. The extant data sets have resulted in a high degree of variability and uncertainty in estimates. As a result, the best available method to predict post-release mortality must continue to rely upon expert opinion.
- Consistent with previous determinations, specific hooking location, as well as length of line remaining, either from hooking or entanglement, are the most significant explanatory factors of severity of injury and post-release mortality.
- The highest probability of mortality is believed to occur when hooks puncture the stomach, lower esophagus, heart, or lung and when extensive line remains attached to the hook or turtle's body. Under some circumstances, hooks may pass through the turtles' digestive tract and cause minimal damage (as observed from long-term monitoring of longline-caught sea turtles held in captivity).
- Based on necropsies and experience with other vertebrates, it was hypothesized that a line remaining in released sea turtles may cause more serious injury than hooking.
- Mortality after release from fishing gear may be bimodal. Damage to a vital organ can result in rapid death from acute responses (< 30 days). Chronic responses, such as

secondary infections, or slow organ failure, can result in delayed mortality (6 to 9 months) following release.

- Understanding mortality risks associated with specific hooking locations, such as the jaw joint (temporomandibular), tongue, glottis, and esophagus should be a research priority.
- Safe handling of sea turtles, including use of dip nets and line cutters to remove as much line as possible from a hooked or entangled turtle, can play a critical role in their survival. This suggests the importance of education and outreach to longline fishers.
- Given the high variability among turtle handling methods after capture in fishing gear (e.g., if hooks are removed or not), speculation about mortality in the absence of information on how the turtles were handled prior to their release may be misleading.
- Statistical power was identified as a critical component lacking in all studies, largely as a result of small sample sizes and potential sample biases.
- Improved estimates could result from meta-analyses of pooled datasets from individual studies, assuming that pooling is appropriate with the various methodologies. A larger pooled dataset could provide survival estimates with increased power and precision compared to estimates from individual studies.
- Pooling longline fisheries may lead to some error in evaluating mortality risk. For example, the Mediterranean longline fisheries use much smaller hooks than those used in the western Atlantic and some areas of the Pacific. Recording additional information on anatomical hooking location, fishing gear characteristics, fishing methods, and handling and release practices associated with hooking events would allow more accurate estimates of post-release mortality.
- Veterinarians suggested equipping observers with video cameras to improve understanding of sea turtle condition at the time of release or deploying several wildlife veterinarians as observers. Implementing these suggestions could assist in improving accuracy of mortality estimates.
- Current transmitting tag technologies lack the capacity to provide critical information specific to survival that would warrant refining current mortality risk categories. "Daily diary" tags may hold some promise to improve mortality estimates.
- Safe-handling best practices must be encouraged, as proper handling and hook removal largely influence the post-release survival probability. At a minimum, use of dip nets to safely bring turtles on board and line cutters to cut line as close to the hook as possible should be used at all times.

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1. WORKSHOP GOALS, OBJECTIVES AND JUSTIFICATION

Goals

The goals of the workshop were to conduct a scientific review to ensure that the current NMFS criteria for estimating sea turtle post-release mortality in pelagic longline fisheries reflects the current state of knowledge and to incorporate new information and analyses that have become available since the 2004 meeting sponsored by the NMFS' Office of Protected Resources.

Objectives

The primary objective of the workshop was to review information to determine if the current NMFS' criteria should be modified. Specific objectives included:

1) Review the current NMFS' criteria for sea turtle post-release mortality estimates defined in Table 1 (p. 26) of Ryder et al. (2006);
2) Identify, review, and assess relevant research conducted after the 2004 expert workshop; and
3) Discuss the potential effects of hook design (e.g., J, tuna, circle) and size (e.g., narrowest width) on injury and mortality.

Justification

A number of published papers and anecdotal information related to sea turtle post-release mortality since the 2004 workshop have been released, suggesting that reassessing estimates in light of new information could be beneficial. In addition to providing information about anatomical hooking location and trailing gear, this meeting also provided an opportunity to consider the effects of hook types, such as circle, J, and tuna hooks.

2. AGENDA

Day 1 15 November 2011

11:30-11:40		Workshop ground rules (Yonat Swimmer)
11:40-11:45		Introduction (Samuel Pooley)
	1.	<u>Background</u>
11:40-11:55	1.1.	History of NMFS activities related to estimates of post-release mortality and application of estimates in the southeast U.S. (Sheryan Epperly and Lesley Stokes)
11:55-12:10	1.2.	Guidance on estimating longline fishery post-interaction mortality. Applications of estimates of post-release mortality rates: Why are they useful? (Patrick Opay)
12:10-12:25	1.3.	Application of the Ryder et al. (2006) memo in assessing post-release mortality of sea turtles in the Hawaii longline shallow-set fishery (Dawn Golden)
12:25-12:45	1.4.	Questions and discussion
12:45- 1:00		Break
1:00 - 2:00	2.	<u>New scientific information</u> (Mariluz Parga) Review table summarizing methods and findings of relevant publications. Questions and discussion.
2:00-2:15		Break
2:15-2:40	3.1.	<u>Updates on unpublished data:</u> 20 min presentation, 5 min for questions (Yonat Swimmer)
2:40-3:05	3.2.	<u>A year in the life of loggerhead turtles: Estimating survival rates of oceanic and neritic juveniles:</u> 15 min presentation, 10 min for questions (Chris Sasso and Mike James)
3:05-3:30	4.	<u>Estimation methods</u>: Methods to estimate sea turtle post-release mortality in longline fisheries (Eric Gilman). Refer to background document: Methods to estimate sea turtle post-release mortality rates.
3:30 – 4:00	5.	Questions, discussion, recap of Day 1, review Day 2 agenda (Yonat Swimmer)

Day 2 16 November 2011

11:30-11:40		Summary of Day 1 and review Day 2 agenda (Yonat Swimmer)
	6.	<u>Veterinary Perspectives</u> (Brian Stacy, DVM)
11:40-12:00	6.1.	Speaker: Brian Stacy, DVM: 15 min presentation, 5 min for questions
12:00-12:20	6.2.	Speaker: Mariluz Parga, DVM 15 min presentation, 5 min for questions
12:20-12:35	6.3.	Discuss comments in Ryder et al. (2006) regarding the importance of gear removal, likelihood of death within 90 days, potential effects of hook design (J, tuna, circle) on injury and mortality, and more (Brian Stacy)

12:35-12:45	6.4.	Fish hook and line morbidity and mortality: Examples of cases seen in rehab (Terry Norton)
12:45-1:15		Break
1:15 - 2:15	7.	Discuss and critique assumptions and uncertainties in Ryder et al. 2006 (Chair: Jeanette Wyneken); Discussion items: Ryder et al., (2006) separates hard shelled turtles from leatherbacks and apparently attributes higher rates of mortality to same level of injury. Does this seem reasonable based on the best available science?
2:15 - 2:45	7.1.	What do we know now that we didn't know in 2004 that might influence changes in estimates in Ryder et al. (2006) (Chair: Molly Lutcavage); Discussion items: Use of satellite telemetry data for interpretation of mortality: Is there a generally agreed upon preferred tag type (e.g., PSAT, PTT)? Can changes in dive behavior (e.g., depth or distance traveled) be used as a proxy for some effect due to the interaction event (e.g., comparisons of dive behavior of turtle groups with different types of injury)?
2:45 - 3:45	8.	Closing discussion and summary (Yonat Swimmer) Discussion items: Revisiting current NMFS policy – is there more recent best available information since 2004 and thoughts on future meetings.

3. PRESENTATION ABSTRACTS

Note: Abstracts reflect the opinions of the respective authors.

3.1. History of NMFS Activities Related to Estimates of Post-release Mortality and Application of Estimates in the Southeast United States

Sheryan Epperly and Lesley Stokes

In the first consideration of post-release mortality in the pelagic longline fishery in the Atlantic, NMFS Southeast Regional Office (SERO) used a mortality value of 29% of the total takes (1999 and 2000 Biological Opinions). The 2001 Biological Opinion mortality rate estimates were the following: 0% entangled only, disentangled completely; 27% external (includes "lip"), line left on animal, hook does not penetrate internal mouth structure; 42% mouth hooked (penetrates) or ingested. After the 2001 closure of the Grand Banks and the shallow-set Hawaii-based longline fishery and subsequent NED experiments, post-release mortality was once again a focus. In January 2004, the NMFS Office of Protected Resources convened a workshop of a cross-section of experts to discuss post-release mortality. Draft criteria (Epperly and Boggs, 2004) and final criteria (Ryder et al. 2006) were established after the workshop, including a table that recognized differing mortality rates as a function of both hook location or entanglement and gear removal. Because issues still existed in the final criteria table and because observer data forms were revised to collect more detailed hooking location data, revisions to the structure of this table were required. Details of these changes can be found in the updated protocols for categorizing post-release mortality estimates (SEFSC, 2011).

3.2. NMFS Applications of Estimates of Post-release Mortality Rates

Patrick Opay and Dawn Golden

A presentation was made on the application of Ryder et al. (2006) in assessing post-release mortality of sea turtles in the Hawaii longline shallow-set fishery. In 2008, the NMFS Protected Resources Division (PRD) completed a Biological Opinion on the proposed action to increase the effort of the Hawaii shallow-set longline fishery up to 5500 sets. In order to assess the probable effects of the proposed action, we determined how many animals would be affected and what their responses would be (i.e., mortality). Using observer data, we calculated the number of animals that would be exposed. For each turtle that was previously caught in the fishery, we used observer data to determine the location and severity of the hooking/entanglement. We used Ryder et al. (2006) to determine the mortality coefficient for each turtle caught and calculated a mortality rate that was applied to the expected number of turtles that would be caught if the fishery increased to 5500 sets to determine the number that could potentially be killed from the proposed action.

3.3. Updates on Unpublished Data

Yonat Swimmer

Post-release mortality was estimated for loggerhead turtles that had been caught and released from fishing vessels in the S. Atlantic and the N. Pacific Oceans. Turtles from the S. Atlantic (n = 26) were released with platform terminal transmitters (PTTs) attached, while turtles from the N. Pacific (n = 29) were released with pop-up satellite archival tags (PSATs). The strengths and weaknesses of the different technologies were discussed. Data do not support the idea that deep hook ingestion leads to increased mortality rates as inferred from transmission duration and distance traveled, as these were similar among injury classes. Based on expert opinion, criteria were established to interpret data and derive estimates of mortality from data. Specifically, for turtles with either PTT or PSATs, mortality was assumed if a tag reported < 30 days. Under these crude criteria, mortality would be estimated at 10% using data from S. Atlantic turtles (2/21) and 28% for N. Pacific data (7/25). Based on *a priori* assumptions programmed to determine mortality with PSATs, which were a 1200 m depth or 4 days at a constant depth, we were not able to identify any turtle mortalities. This is largely due to 97% of the PSATs reporting prematurely, likely as a result of a weak attachment. Given the limitations of the PSAT data, we also investigated anomalous dive behaviors to infer the potential for mortality. Of the data from 21 PSATs, 2 profiles suggested a final relatively deep descent just prior to the release of the tag. These descents suggest a deviation from normal dive behavior. Based on these assumptions and criteria, our PSAT data indicate a mortality rate of 10%. Including tracking duration, level of injury and accounting for potential for tag failure, we estimate the mortality range to be between 0 - 28%. However, such estimates are based on assumptions that have not been verified and rely on telemetry technology that have inherent flaws, given the inability to differentiate tag failure from a turtle that may have died.

3.4. Updates on Unpublished Data

Chris Sasso and Mike James

Pop-up archival transmitting (PAT) tags were deployed on 15 loggerhead turtles that were lightly hooked in the U.S. pelagic longline fishery and 10 loggerheads that we dip-netted off the surface to serve as controls in the North Atlantic Ocean. We received data from tags of 10 lightly hooked turtles and 7 control turtles. We used data transmitted by the tags in a known fate model to estimate annual survival rates and determine if there were differences in survival between the 2 groups (Sasso and Epperly, 2007). The best model indicates there is no difference in survival between the lightly hooked and control turtles, and the estimated annual survival rate was 0.814 (95% CI 0.557 – 0.939). Our results suggest that when all fishing gear is removed, lightly hooked turtles may not suffer any additional mortality relative to control turtles. Post hooking mortality studies have continued with the following tag deployment: 4 PAT tags were deployed on deeply hooked turtles in Bermuda in 2007, 6 PAT tags were deployed on control turtles in the Azores in 2009, and 24 PAT tags were deployed on control turtles in the NED in 2011. In addition, we deployed 14 Mini-PATS on turtles between 30 and 45 cm in 2011. One lightly hooked turtle was also tagged with a PAT by the Canadian fleet in 2011.

3.5. Methods to Estimate Sea Turtle Post-release Mortality

Eric Gilman

Post-release mortality represents one component of unobserved fishing mortality. There are several methods that could be employed to estimate post-release mortality rates of sea turtles following capture in pelagic longline fisheries. These include the following experimental methods: observing turtles caught in pelagic longline fisheries that are subsequently placed into captivity, satellite tracking, and estimating post-release mortality rates by extrapolating from gear haul-back mortality rates. Capture-mark-recapture/dead recovery and information from stranded moribund and dead sea turtles are experimental methods that are unsuitable for estimating sea turtle post-release mortality following capture in pelagic longline fisheries. Similar to all post-release survival studies, sample size limitations and sample biases require consideration. Meta-analyses pool data from multiple studies, and due to the larger pooled sample size plus the number of pooled studies, may provide survival estimates with increased power and precision over the estimates from individual studies. Possible explanatory variables that could be used to predict the probability of post-release mortality include: type and severity of injury; indicators of the severity of stress and injury (e.g., manner of capture, biochemical indicators, degree of impairment of reflexes, and measuring resistance and reactance of tissue to applied electrical current); handling and release practices; and body size, species and sex of the released turtle.

3.6. Veterinary Perspectives

Brian Stacy

Interaction with longline fisheries can result in injuries from physical trauma and physiological derangement. The chronology of effects can be generally categorized and are relevant to inferring injuries using indirect methods, such as satellite telemetry. Factors that may influence the survivability of an injury include environmental conditions, risk of predation, and general health prior to interaction. Fatal, acute injuries from incidental capture occur within minutes to hours of interaction and include forced submergence and trauma resulting in blood loss and loss of vital organ function. Mortality may occur hours to days following interaction (subacute mortality) from severe injuries that are not immediately fatal and continued blood loss, or failure to recover from hypoxic or exertional insults. Some injuries can result in delayed mortality days, weeks, or months after an interaction. Plication and intussusception of the gastrointestinal tract from ingestion of line and secondary infections from perforating injuries are examples of delayed effects. There is very limited ability to assess the degree of internal injuries of turtles aboard vessels in most situations. This limitation is a concern in some telemetry studies because animals with varying degrees of injury may be inappropriately grouped together for analysis. Handling of sea turtles by or in the presence of observers likely is not directly comparable to practices on vessels without observers present. Lastly, comparing the outcomes under rehabilitation conditions with unattended animals under natural conditions requires caution.

3.7. Veterinary Perspectives

Mariluz Parga

In this presentation, the author provides a veterinary perspective based on her extensive at-sea experiences, time working at sea turtle rescue centers, as well as extensive literature review. She discusses the harm caused by various components of longline gear, the importance of exact hook location, turtle anatomical structures that are particularly sensitive, and how all these relate to predicting turtles' mortality after release from longline gear. As a note, her at-sea experiences involve fisheries in the Mid- and Southeastern Pacific where the hooks used are smaller than in most fisheries in the U.S.

Trailing line, especially while still attached to a lodged hook, is considered particularly dangerous for a turtle because it can either 1) affect a flipper, possibly leading to gangrene, amputation, or causing a generalized infection that can lead to delayed (weeks to months) mortality, or 2) can be ingested and affect the GI tract (e.g., causing plication and intussusception, leading to death).

Regarding hooks in the mouth, although they are easier to remove, there are some structures that can be very sensitive, and given the potential for infection, may lead to the animal's death. These include the glottis, tongue, jaw joint (temporomandibular) or the palate. These should be considered separate from hooks in the beak or other areas of the mouth.

In general, proper handling of hooks in the esophagus can lead to a good prognosis. In the Mediterranean, it is common to see animals with 2-3 (medium-small) hooks inside that do not cause any problems. The hook can enter the esophageal wall and can become surrounded by fibrous or necrotic tissue. The esophageal wall, however, is very muscular and resistant and thus usually does not develop related infections. Captive studies even suggest that some of these hooks eventually pass through the animal without any treatment. If improper handling methods are used (for example, lifting the animal by pulling the line or trying to remove the hook by pushing improperly with the de-hooker) very severe lesions can develop, increasing the probability of death after days or weeks.

Hooks lodged in the stomach can pose a high risk of mortality because the hook may perforate the stomach wall and cause infection. This could even happen when the turtle is trying to release itself from the gear or when the turtle is slightly pulled by the line to get it closer to the vessel. There are very important structures in the area where the esophagus leads into the stomach, such as the heart, large blood vessels, trachea and bronchi. Damage to any of these structures can result in a quick death (minutes to hours). The problem with assigning risk is that hooks can be swallowed that do not become lodged, in which case they just transit along the GI tract and are expelled without causing any problems. On board a fishing vessel, if you can only see the line going inside the esophagus, there is no way to tell if the hook is lodged in the stomach or if it is just transiting.

The conclusions from this presentation are as follows:

- Fishing line attached to a lodged hook and hooks lodged in the stomach have the worst prognosis. There are some particularly sensitive areas in the mouth (e.g., glottis, jaw joint, tongue, and palate).
- In order to evaluate the post-release mortality, it is very important to know how and where exactly hooks are lodged, how they were removed (i.e., removing a hook from mid-esophagus can be much worse than leaving it there), if the hook is removed at all, and how the animals were handled. Therefore, knowing the attitude of fishermen and how they react to a captured turtle is very important for accurate estimates of a turtle's fate.
- The proper handling of the hook and the animal are essential to decreasing post-release mortality. Both observers and fishermen need to be well trained.

3.8. Discussion and Critiques of Assumptions and Uncertainties in Ryder et al., 2006

Jeanette Wyneken

The group discussed the following questions:

- Are the mortality criteria scientifically defensible?
  - If not, what must be changed and why?
  - If not, what older data or assumptions should be discarded?
- What new data need to be included and why?
- What key data are missing, but obtainable?
- The Southeast Fisheries Science Center (SEFSC) modified the criteria and Pacific Islands Regional Office (PIRO) uses them as is. Do assumptions made in the SEFSC modifications improve the assessment value of the criteria?
  - Might they apply in other areas?

3.9. What Do We Know Now that We Didn't Know in 2004 that Might Influence Changes in Estimates in Ryder et al., 2006?

Molly Lutcavage

The following topics were discussed:

- Evidence-based confirmation and uncertainties of assumptions
- Animal welfare – conditions after release from gear
  a) Evidence from fishermen and observers: general, superficial, helpful first level information; and
  b) Expert evaluations: Clinical and physiological evaluations using diagnostics, such as ultrasound, x-ray, clinical profiling, and recovery profiles.
- Evaluation of post-release behavior from tag or data loggers
  a) Review/discuss limitations of tags, including hardware and software

b) The appropriate amount of data necessary in order to be meaningful. Is the data being appropriately evaluated with regard to statistical evaluations, auto-correlation, etc.?

- What technology and/or tags/sensors do we need? How soon are they likely to be evaluated if the R&D is funded?

4. SUMMARY OF DISCUSSIONS

This section captures the main points and questions raised during and immediately following the workshop. Bullet points show comments/ideas by one more participants and do not necessarily reflect group consensus. Comments are separated into eight broad themes.

4.1. Injury Categories and Anatomical Hook Locations

- Small sample sizes from narrowly-defined categories of injury level may preclude robust findings. A meta-analyses of appropriately pooled studies would help to augment statistical power by increasing sample sizes.
- A detailed categorization of injury level would enable more accurate estimates of the potential for mortality. Methods for grouping lesions may require further consideration, especially regarding injuries to the rhamphotheca/beak.
- Recent research included only two categories of injury, light and deep -hooked, as a way to increase sample sizes and enable larger statistical power. (i.e., all deep hooked were esophageal and unable to be removed).
- "Deep hooked" may be too broad a category given the high variation in injury type and subsequent mortality from different forms of deep hooking, as determined from captive studies where sea turtles were monitored over time. For example, a hook that lodges in the distal esophagus, stomach or intestines can have a more serious outcome in comparison to hooks in the cervical esophagus or hooks that lodge deeper in the body that don't puncture vital organs. In the latter case, sea turtles have been shown to survive with apparent minimal injury from one or multiple hooks lodged for years. (Note: It's impossible to determine anatomical hook location over time, other than via x-ray or other medical imaging.)
- The potential for mortality is greatly influenced by how much line remains attached upon release. Increased line length correlates to increased probability of mortality.
- Hook sizes and widths may result in specific types of injuries. As such, identifying gear specifics (e.g., hook size, form, material) and related injury types would be useful in estimating turtles' level of injury and risk for mortality.
- A few attendees at the 2004 meeting reported that the tables in Ryder et al. (2006) do not accurately reflect what was discussed at that meeting.
- Recent research has provided insights into the time frames involved in recovery or illness and death. For example, death from acute trauma may result within days, whereas death due to secondary infection may occur months after a hooking event. As such, consideration of these insights should be included in modifications to methods for estimating mortality.

4.2. Satellite Telemetry Studies: Data Interpretation and Evidence for Survival/Mortality

- In general, there is a need to improve our understanding of telemetry data to definitely indicate whether a sea turtle is dead or alive.
- It was noted that animals' responses to oceanographic conditions confound the ability to interpret behavior as a result of fishery interaction. For example, changes in water temperature or the presence of certain oceanographic features (such as gyres, fronts, and currents) may affect sea turtle dive and respiratory behaviors. As such, tag data showing anomalous dive patterns may reflect oceanographic changes and not deterioration in health or a mortality event.
- We need to further consider how the available scientific information supports interpreting the time interval between release to PTT transmission or PSAT pop-up specifics to infer sea turtle mortality. For example, can information on anatomical hook location and whether a sea turtle was released with the hook or line attached, in combination with duration of satellite tag (PTT or PSAT) transmission, be used to accurately estimate probability of mortality/survival? Further consideration is needed, and resolving this issue remains a research priority.
- Under general agreement, if a tag fails within a week, it is reasonable to infer that mortality had occurred as a direct result of the injury(ies) associated with the fishery interaction. If the tag is still transmitting after 2 months, this provides a strong basis to infer that the animal remains alive. However, a sea turtle with an injury to a flipper may take up to 6 months to die if infection occurs.
- More research is needed to interpret duration of PTT transmissions in relation to sea turtle survival. Also, PATs should continue to be used despite concerns regarding data interpretation and other limitations (e.g., tag failure, attachment failure, etc.). PAT data can improve use of survival analysis (the FATE model) as demonstrated by the NMFS Southeast Fisheries Science Center (SEFSC),
- The group discussed the potential to modify PTTs such that data can be used to differentiate sea turtle 'normal' behavior from 'sub-optimal' behavior. For example, tags could be designed to show whether a sea turtle is swimming passively (drifting) or actively against the current. Also, monitoring sea turtles heart rates via satellite transmission is another potential tool to recommend for development.

4.2.1. Satellite Tagging Studies: Statistical Concerns and Biases

- Small sample sizes limit statistical robustness and data interpretation.
- It is necessary to follow best practices in statistical designs and to maintain consistency for comparative purposes.
- Studies that selectively place tags on sea turtles that are believed to have a higher likelihood of surviving the fishery interaction must, at a minimum, acknowledge this selection bias *a priori.*
- Cross-study comparisons are limited by inconsistencies among data collection. For example, some studies omit data from tags that fail prematurely while other studies may interpret this "failure" as mortality.

- Duration of tracking is critical to data interpretation. Based on too short of a duration (e.g., transmissions cease soon after release), data may fail to show mortality. Moreover, based on a relatively long tag duration (e.g. beyond 3 months), additional confounding factors (e.g., natural mortality) can affect fisheries-induced mortality interpretation.
- To account for these biases and statistical concerns, some participants emphasized the use of controls as being critical to the study design and data interpretation.

4.2.2. Tag Modifications Are Needed to Improve Evidence for Mortality

- Some participants expressed that using tags to determine mortality is currently more of an art than a science. Activity sensors don't address what is needed. Ideally, future tags will be able to differentiate tag failure, tag loss, and a mortality event.
- We must think beyond current capabilities of tags and ask for what we need. Questions for tag
  manufacturers include the following:
  a) Are there tags that can detect a live or dead sea turtle floating at surface?
  b) Can a tag determine how long a sea turtle survived?
  c) Can we develop and utilize a sea turtle 'mortality tag' similar to tags designed for marine mammals?
  d) Can tags detect possible differences in an animal's status based on water temperatures (i.e., are rates of decomposition temperature-dependent)?
  e) Can information from mouth/beak sensors be used to determine if a sea turtle is alive?

4.3. Value of Captive Studies in Determining Post-release Mortality

- Estimates of sea turtle mortality derived from captive studies are of limited value, given that conditions drastically differ from life in the wild. Captive conditions introduce a sampling bias, such as changes in stress levels (either positive or negative), that limits utility of information gained.
- To date, there has been limited useful information gleaned from reports of captive studies of hooked or entangled sea turtles for the purpose of estimating post-release mortality. Reasons for limited inference include the following: 1) sea turtles were often grouped with various degrees of injury that were not described; 2) reports showed limited or no information regarding turtle sea handling and source of injury (e.g., type of fishery interaction vs. floating turtle with fishing scars); and 3) reports lacked information on husbandry conditions (e.g., diets, tank sizes) and/or veterinary care.
- The lack of specifics on the type of fishery interaction or anatomical hook location severely restricts interpreting outcomes of captive studies with regard to post-release mortality.
- The discussion highlighted a need to develop guidelines for rescue centers regarding best practices for sea turtle husbandry to maximize likelihood of turtles' survival.
- Findings from captive studies alone do not provide a solution to the problems of assessing post-release mortality. Ideally, future estimates would combine this information with other specifics such as entanglement or hooking location, health condition

(including photos), as well as tracking at sea. A comprehensive reporting of the level of injury with follow-up captive care tracking data would greatly improve the ability to predict the survival outcome of the released turtle.

4.4. Observer Data Collection and Handling and the Use of Safe Release Protocols to Maximize Probability of Survival

- The group generally agreed on the critical importance of capturing as much information as possible on sea turtles' condition at time of retrieval in fishing gear. Details to record include evidence of previous injury from fishery interaction or other injury (e.g., shark bite), deformity, level of emaciation, etc. This information will be helpful to determine the degree of turtles' resilience to all injury types that may affect probability of post-release survival.
- The amount of line remaining on sea turtles (either via entanglement or hooking) is key in assessing survivorship prognosis. As such, it is critical to document the remaining approximate line length that is either hooked or entangled on the sea turtle at time of release, and line cutters should be used at all times to cut line as close to hook as possible. (In the United States, turtles are rarely released with line > ½ carapace length).
- It is imperative to teach and encourage safe-handling best practices as proper handling and hook removal largely influence the post-release survival probability. In Hawaii, sea turtle handling procedures are codified at 50 CFR 665.812 and are also discussed at annual protected-species workshops attended by fishermen.
- A recommendation was made to add a specific field to the observer databases to indicate evidence of a previous fishery or non-fishery injury. This data field, as opposed to recording the information as comments, could facilitate database querying. (Note: U.S. observers on longline vessels in the Atlantic and Pacific write such notes in a comments field that prohibits automated analysis).
- In the Atlantic, the captain/crew on board longline vessels are responsible for bringing the turtle onboard the vessel, and once on board, the observers handle the turtle to collect biological info such as collecting DNA samples, recording flipper tags, etc. In Hawaii, the observers (and not fishermen) do all the turtle handling and release.
- While not proven definitively, it was generally concluded that hook size, length of remaining line, persistent entanglement in line, and location of hook influence the prognosis of sea turtle survivorship.
- Participants questioned practices of non-U.S. longline vessels regarding the amount of line likely remaining on sea turtles. Obtaining this information is needed to derive global or ocean basin mortality estimates. A question was posed if there was a mechanism to quantify how many countries/vessels cut line or remove hooks as this could enable slightly more accurate estimates of post-release survival for unobserved sea turtles.
- Participants discussed safe (best) sea turtle handling and international guidelines for handling sea turtles captured at sea. This may be something to consider in Regional Fisheries Management Organizations (RFMOs). To date, guidelines exist in a few RFMOs, but with limited compliance and no enforcement.

- It was generally agreed that an important component to survival risk assessment is fishermen's behavior—their attitudes and handling techniques of turtles are critical determinants of survival.
- Several key questions remain unanswered. For example, in some longline fisheries, terminal tackle design includes components in addition to hook and line. What are the relative risks from handling practices with a weighted swivel and leader? How does the potential for injury differ between a wire leader and monofilament when left inside a sea turtle? Is it better to leave a lead weight in place or remove it when internally lodged?

4.5. Veterinary Perspectives

- Two categories of post-release mortality were suggested: 1) acute mortality, which occurs between hours to weeks post-interaction. This could result from hooks perforating the stomach, lesions to the glottis, perforations of major vessels, acute infections, severe lesions caused by bad handling (e.g., complicated removal of hooks), etc; and 2) chronic mortality which can occur from months to more than a year post-interaction. This mortality is a result of secondary infections such as osteomyelitis, or development of chronic fibrotic or necrotic lesions. The frequency of developing secondary infections remains uncertain, precluding accurate predictions of post-release mortality.
- A consensus was not reached, but most participants agreed that it was reasonable to assume that the majority of deaths associated with a fishery interaction occurs during the first 90 days (from weeks to months). However a certain proportion would have a delayed mortality (> 90 days), after which time there would be no definitive way to determine if, how or why the animal dies. The current satellite tracking capabilities do not allow for this type of mortality assessment. Predictions can be improved, however, by using a relatively large sample size that includes comparisons with control turtles.
- Death is the likely outcome when a sea turtle swallows monofilament line, unless surgery is performed to remove the line. Lesions in the gastrointestinal tract caused by a line could take anywhere from weeks to months to cause mortality.
- Necropsies conducted on sea turtles retrieved from longline fisheries in Hawaii indicate that most sea turtles die from submergence and not from an obvious physical injury.
- Circle hooks get lodged in the stomach less frequently than J hooks likely due to the shape (the point is bent inwards towards the shank on circle hook).
- Some participants suggest that current estimates (Ryder et al., 2006) likely overestimate the mortality of deep hooked animals and perhaps underestimate that of lightly-hooked or entangled animals.
- Branchline terminal tackle likely has an effect on sea turtle survivability, although there is no clear guidance regarding best handling-release methods specific to different terminal gear.
- Simple protocols from veterinarians are necessary to score the pre-release condition of each released sea turtle and to use as a risk factor in any analysis.
- From a veterinary and rehabilitation perspective, the following information could help in estimating survival:

  a) An intensive evaluation of deep-hooking cases via x-ray, ultrasound or blood work. Some assessments could be conducted on fishing vessels, although preferably in a more

controlled setting. Ideally, portable medical technology, such as ultrasound, blood analyzer or radiograph, could be used to further evaluate cases.
b) Development of protocols to evaluate and report hook-and-line injury cases for sea turtles that enter a rescue center. Case documentation could lead to improved estimates of altered behavior and infection rates over time and by injury type.

- The current NMFS post-interaction mortality criteria include slightly higher mortality rates for leatherbacks than for hard-shelled sea turtles, based on an assumed higher vulnerability to injury from more friable skin, softer tissue, weaker bone structure, and increased susceptibility to entanglement. Leatherback sea turtles are most often too large to land on board, resulting in limited information on the condition and manner of their capture and injury. Relying primarily on comparative physiological studies, participants confirmed that differences in cardiovascular function between leatherbacks and hard-shelled sea turtles would also show differences in their physiological responses and subsequent potential for mortality after a fisheries interaction. As such, the mortality estimate correction factor specified for leatherback turtles in the Ryder et al. (2006) document seems reasonable.
- Currently, it is impossible to distinguish between predation and natural mortality/injury/sickness. The standard mortality parameter is an annual mortality rate to be used in population models/jeopardy analysis. A real issue is whether tags are capable of collecting the data (functioning) over a full year.
- It was recommended that veterinarians devise a list of measurements that an observer could realistically make in addition to his/her other duties that could improve predictions for post-release survival. Several questions were posed: Is there already a list that we could adapt or propose be implemented? If not, what is fair and reasonable to ask that might yield useful information? Would variation be too high to yield meaningful data?
- Despite the value of an ultrasound on board to determine location of hook, this is deemed impractical because of limits in crew time, technical expertise, and cost.
- Given the many demands on the observers while they are at sea, additional requirements are unlikely to be added. Measures should be established to promote consistency in documentation of injuries and behavior. Clear photographs are critical! More complicated assessments would be feasible only in combination with a researcher present onboard vessels.

4.6. Other Methods Not Yet Applied to Sea Turtles' Post-release Mortality from Longline Gear

- Analysis of combined data sets (meta-analysis) could identify potential correlations between sea turtle mortality rates and effects of sea turtle size, sex, and species.
- Biochemical indicators of stress and health status that are used for marine fish have been employed with sea turtles in a gillnet fishery (Snoddy et al., 2009) and in an in progress study in a Mediterranean longline fishery (Swimmer et al., pers. comm.). The group expressed interest in future attempts to link sea turtles' blood work with telemetry data in an effort to generate a comprehensive view of the sea turtles' well-being both at the time of release and once released to sea.

4.7. Ideas for Future Meetings

- The webinar format was satisfactory for the purpose of this meeting. However, there were suggestions for working groups to advance specific discussion topics. The following subjects were deemed worthy of future meetings:
  - Potential to pool data for meta-analysis by data owners/custodians using both telemetry and veterinary data.
  - Understanding physiological and biochemical profiles of various stressors, and their potential use in refining estimates of post release mortality. Discussion of tag improvements, such as additional sensors to indicate mortality, and behavior, and to further develop next generation tags.

4.8. Action Items

- For those working with observers, ensure that observer data collection protocols capture all potentially significant explanatory variables, including sea turtle handling and release practices and fishing gear design and materials (e.g., hook type, hook size, leader material and length, hook location between floats, gear soak time, gear weighting). Accumulation of such information will enhance our understanding of the extent of the injury and potential post-release complications and survivability.
- Researchers conducting telemetry studies should meet with tag manufacturers to identify priority R&D activities to improve the utility of the devices for accurately documenting sea turtle post-release mortality.
- As a group or subgroup of this webinar, confirm the potential value to conduct a meta-analysis to augment statistical power of individual studies and data sets.
- Per veterinarians' request, work to improve assessments of sea turtles' injury level prior to release at sea, such as via video and photo documentation.
- Consider how the table in Ryder et al. (2006) could be restructured to better reflect expert opinion on logical groupings, such as assigning different mortality rates for hooking in the jaw joint, tongue and glottis, and for different hook sizes and gear designs.

5. TABLE SUMMARIZING METHODS AND FINDING OF PUBLICATIONS ESTIMATING SEA TURTLE POST-RELEASE SURVIVAL PROBABILITY

(Prepared by Y. Swimmer, M. Parga and E. Gilman as background material)

Authors	Title	Year	Journal	Comparisons (e.g., control vs. longline caught; deep vs. shallow hook)	Method to determine mortality (e.g., changes in swimming or diving, deep descent)	Mortality estimated	Comments directed from paper
Aguilar et al.	Impact of Spanish swordfish longline fisheries on the loggerhead sea turtle *Caretta caretta* population in the W. Med	1995	NOAA Tech Memo NMFS-SEFSC-361	38 *C. caretta* brought from longliners with hook still in (probably esophagus). Kept in captivity until hook out or animal dead.	Of the 38 turtles, 11 animals died, 6 passed the hook, and 21 were released with hook still in.	20–30%	
Chaloupka et al.	Modelling post-release mortality of loggerhead sea turtles exposed to the Hawaii-based pelagic longline fishery	2004	Mar Ecol Prog Ser, 280	All *C. caretta;* 40-83cm CCL Shallow hook - always removed: (n = 13) Deep hook (anything behind glottis) —always left in place:(n = 27)	PTT tags on 40 sea turtles. 10 transmitters failed from beginning (Day 0—first scheduled transmission) Median tag failure time: deep hook group = ~ 50 d vs. light hook group = ~ 100 d. Estimates of mortality/tag failure on the 1st week are 0.34 for deep hooked and 0.08 for light hooked. Also higher mortality (or transmission failure) rates during the first 50-60 days. No difference at all between the 2 groups after 90 days. However, cannot distinguish between mortality and failure, so not sure. "It is not clear whether it is possible to infer loggerhead post-release survival from the transmitter failure times used to derive the	34% for deep hooked within 1 week 8% for light hooked within 1 week	LH hooked sea turtles had longer tracks, & survival function higher compared to DH turtles, but no difference after 90 days. ”These KMT hazard or time-specific failure rates confound transmitter failure rates and loggerhead mortality if in fact any mortality did occur. Hence these estimates reflect at best the upper bounds on the apparent level of loggerhead mortality for the 2 groups shortly after release. These estimates must be viewed with extreme caution as they clearly reflect overestimated failure and, hence, mortality probabilities attributable to capture in the longline gear. If all the transmitter failures during this period were based solely on equipment failures or tag loss then these estimates would not

Authors	Title	Year	Journal	Comparisons (e.g., control vs. longline caught; deep vs. shallow hook)	Method to determine mortality (e.g., changes in swimming or diving, deep descent)	Mortality estimated	Comments directed from paper
					survival functions".		reflect loggerhead mortality in any way whatsoever."
Casale P et al.	Mortality induced by drifting longline hooks and branchlines in loggerhead sea turtles, estimated through observation in captivity.	2008	Aquatic Conserv: Mar Freshw Ecosyst 18	All *C. caretta*; 25-79 cm CCL 409 animals taken to rescue center, 330 from longline fisheries. Of these, 36% hooks in mouth (M), 29% hooks in upper esoph (HO), 31% in lower esoph (LO), 3% external, 0.3% entangled.	Hooks in LO: caused death by perforation stomach, blood vessel or heart in a short period of time. Out of 34 sea turtles, 24 with hooks in LO died. Of these, 21 (probably 22) died because of the hook and 2 because of the line. A turtle with a hook in the LO has very little chance of surviving, summing up the probabilities of dying because of the hook and because of the line. Lines affected digestive functions, starvation and death in the long term. These hooks may compromise feeding, and cause secondary infections. Of 32 sea turtles found floating with evidence of longline interaction, 23 were killed by the line, 7 by the hook, and in 2 the cause was unknown. Of 42 sea turtles brought by fishermen, 20 animals survived for at least 5-45 days before dying (because of line = 2) being operated or being released. Another 22 died on the first 10 days (because of hooks). They calculate that 84% of turtles killed by hooks	They do not look into mortality induced by hooks in M, but they believe (by experience at rescue center) hooks may compromise feeding and cause secondary infections. They mention that it is possible that a second (and lower) mortality peak occurs after longer periods. A branchline can kill a sea turtle if it is long enough and it is anchored anteriorly (by the hook). A sea turtle with a hook in the LO has very little chance of surviving, summing up the probabilities of dying because of the hook and because of the line. Assumes a mortality rate of 65% in turtles with hooks on LO; and of 82% (% of well anchored hooks)	

Authors	Title	Year	Journal	Comparisons (e.g., control vs. longline caught; deep vs. shallow hook)	Method to determine mortality (e.g., changes in swimming or diving, deep descent)	Mortality estimated	Comments directed from paper
					died within the first day. Forty-four sea turtles found floating with evidence of longline interaction and followed till death or release: 5 killed by hooks quickly (in 1-31 days), 18 killed by lines (in 0-44 days), and 21 survived with the hook.	if swallowed long piece of line.	
Hays et al.	Satellite telemetry suggests high levels of fishing-induced mortality in marine turtles	2003	Mar Ecol Prog Ser 262	No comparisons, not specific to any type of fishing gear type. All species involved.	Undefined satellite tags on 50 turtles, different parts of the world: 3 animals were observed dead on land. Mortality was inferred (not confirmed) by cessation of transmission of 3 sea turtles. Assume 6 of 5 sea turtles died.	Annual mortality estimated at 24% (95% confidence). (Not necessary only from fisheries.)	
Mangel J et al.	Post-capture movements of loggerhead turtles in the southeastern Pacific Ocean	2011	Mar Ecol Progress Series 433	All Caretta; 40–70 cm CCL 14 sea turtles Level 1: external hook or entangled—7 sea turtles Level 2: hook in mouth—4 sea turtles Level 3: deep hook—3 sea turtles All visible lines and hooks were removed before release.	PTT tags; 1 track = 8 days (injury level 3), 2 tracks = 50 days (injury level 2), remainder: 95–290 days. No effect of injury level on track duration, swim speed or time at surface. There was an effect of injury level on displacement rate: levels 2 and 3 had greater displacement rates than level 1. (Mouth- and deep-hooked traveled greater distance than light hooking or entanglement).		"While acknowledging the small sample size of the present study, these results suggest that loggerhead turtles are able to survive for extended periods with injuries, including severe injuries. Or they might indicate that our understanding of what entails a minor or severe injury to a sea turtle is incomplete."

Authors	Title	Year	Journal	Comparisons (e.g., control vs. longline caught; deep vs. shallow hook)	Method to determine mortality (e.g., changes in swimming or diving, deep descent)	Mortality estimated	Comments directed from paper
Parker et al.	Post-hooking survival of sea turtles taken by pelagic longline fishing in the North Pacific	2005	21st Annual ISTS	35 *C. caretta*, 12 *L. olivacea*, 3 *C. mydas* LH: Lightly hooked (entangled, hook external or in beak)—all removed DH: Deep ingested hooks (deep in mouth or throat)—line cut, hooks not removed	54 PTT tags; 4 were still transmitting and not included (50 analyzed) 15 tags did not transmit: 11 in DH and 4 in LH; 13 in Cc and 2 in Lo Remaining 35 tags: 20 DH and 15 LH; 22 Cc, 10 Lo and 3 Cm There was no significant difference in duration of tracking or distance travelled between DH and LH. Comparison of surface time in a sub-sample of 18 sea turtles: no difference between DH and LH.	"Our data suggest a 20-40% mortality rate depending on hook status"	Hawaii-based pelagic longline fishery
Polovina et al.	Forage and migration habitat of loggerhead (*Caretta caretta*) and olive ridley (*Lepidochelys olivacea*) sea turtles in the central North Pacific Ocean.	2004	Fish Oceanogr.	36 turtles: 26 *C. caretta* and 10 *L. olivacea* Animals captured by longlines; but study aimed at use of space, not post-release mortality. Most had hook in mouth or jaw, which was removed. Some had swallowed hooks, which were not removed.	PTT tags; Tags last between 30 and 458 days. The two longest tracks were from animals with swallowed hooks (1 Cc and 1 Lo).		Hawaii-based longline fishery

Authors	Title	Year	Journal	Comparisons (e.g., control vs. longline caught; deep vs. shallow hook)	Method to determine mortality (e.g., changes in swimming or diving, deep descent)	Mortality estimated	Comments directed from paper
Ryder et al.	Report of the Workshop on Marine Turtle Longline Post-Interaction Mortality	2006	NOAA Tech Mem NMFS-OPR-29	Vets and biologists discussing higher and lower risk structures, and probability of mortality.	High risk groups: comatose or resuscitated sea turtles, hooks at or below heart, hooks in cervical esophagus, glottis or jaw joint (this last one even if hook is removed), hooks in soft palate, external entanglement and line trailing greater than 1/2 the carapace length. In general proximity of hook to certain anatomical structures is considered very important. Leatherbacks seem to be more sensitive(+10% mortality estimates in all cases)	Table 1	
Sasso & Epperly	Survival of pelagic juvenile loggerhead turtles in the open ocean	2007	J. Wildlife Manageme nt 71(6)	All *Caretta;* 40–60 cm CCL 15 light hooked (LH) vs. 10 controls	Pop-off sat tag (PSATs) used to determine potential differences in annual survivorship based on 2 groups. Of 15 LH—2 tags failed, 3 released prematurely, 2 turtles died Of 10 C—2 tags failed, 1 released prematurely, 1 turtle died Data only received from 10 LH (10/15 = 67% report rate) and 7 C (7/10 = 70% report rate). No difference in time spent at surface for LH and C group. "no difference in survival between the lightly hooked and	Mortality estimate of 19% in both groups in 1 year	US pelagic longline in North Atlantic; Grand Banks

Authors	Title	Year	Journal	Comparisons (e.g., control vs. longline caught; deep vs. shallow hook)	Method to determine mortality (e.g., changes in swimming or diving, deep descent)	Mortality estimated	Comments directed from paper
					control turtles," Annual survival estimate of 0.81 for both groups in the study. Can't differentiate between fishing-induced or natural mortality.		
Swimmer et al.	Diving behavior and delayed mortality of olive ridley sea turtles *L. olivacea* after their release from longline fishing gear.	2006	Mar Ecol Prog Ser, 323	14 *L. olivacea* (9 longline bycatch, 5 free swimming), 1 *C. mydas* (longline bycatch) 8 *L.o.* caught in jaw or mouth - hook removed 1 hooked in upper esophagus (eye visible in throat) - not removed	Pop-up tags (PSATs). 3 tags did not report: 2 in longline caught and 1 in a free swimming turtle No difference in tags reporting or in distance travelled in all *L.o*; tags transmitted 26 d in *C.m*, and 54-60 in longline caught-control *L.o*. Only 1 instance of mortality: control animal.	No observed mortality within < 2 months after fisheries interaction.	Eastern Tropical Pacific. Conclusions are that *L.o* lightly hooked survive the interaction for at least 2 months. Hooks used are 13 and 14 C hooks, with and without 10^0 offset.

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7. REVIEW OF METHODS FOR ESTIMATING SEA TURTLE POST-RELEASE MORTALITY IN PELAGIC LONGLINE FISHERIES

Background paper prepared for agenda item 4.

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There are several methods that could be employed to estimate post-release mortality rates of sea turtles following capture in pelagic longline fisheries. These include experimental methods: observing turtles caught in pelagic longline fisheries that are subsequently placed into captivity, satellite tracking, and estimating post-release mortality rates by extrapolating from gear haul-back mortality rates. Capture-mark-recapture/dead recovery and information from stranded moribund and dead sea turtles are experimental methods that are unsuitable for estimating sea turtle post-release mortality. Possible explanatory variables that could be used to predict the probability of post-release mortality include: type and severity of injury; indicators of the severity of stress and injury (manner of capture, biochemical indicators, degree of impairment of reflexes, and measuring resistance and reactance of tissue to applied electrical current); handling and release practices; and body size, species and sex of the released turtle.

7.1. Experimental Methods

7.1.1. Observing captive turtles caught in longline fisheries

Sea turtle post-release mortality rates have been estimated by observing turtles caught in pelagic longline fisheries that were subsequently placed into captivity (Aguilar et al., 1995; Casale et al., 2008). Inclusion of a control animal would provide a basis for separating fishery-induced mortality from mortality caused by stressors associated with being held in captivity and other possible contributing sources, including natural mortality. Stressors from being in captivity may artificially reduce survival probability, while the elimination of predation risk, provision of food, and other aspects of captivity artificially increase survival probability relative to survival probability in the wild, confounding observations of mortality rates of captive turtles following capture in fisheries. Furthermore, the collection and modeling of information on the condition of individual turtles upon capture, including the manner of capture and injuries incurred, and information on methods employed to manage turtles while in captivity is necessary to enable explicitly accounting for these potentially significant factors. An issue with all post-release survival studies, sample size limitations and sample bias require consideration.

7.1.2. Satellite telemetry

Satellite data collected from tags attached to sea turtles caught and released from pelagic longline gear, or "control" turtles that had been free-swimming upon capture, have been analyzed to estimate turtles' post release mortality rates (Chaloupka et al., 2004a; Parker et al., 2005; Ryder et al., 2006; Swimmer et al., 2002, 2006; Sasso and Epperly, 2007; Godley et al., 2008). The two main types of tags used are platform terminal transmitters (PTTs) and pop-up satellite archival tags (PSATs). Both devices can provide data on geo-spatial location (PTTs use GPS or Doppler shift and PSATs use changes in ambient light intensity), temperature, and depth (pressure), via transmission to the Argos satellite system (Eckert, 2006; Musyl et al., 2011a). PSATs are programmed to release from the turtle and float to the sea surface when they commence data transmission under three researcher-prescribed, pre-set conditions: (i) on a specified date, (ii) if they remain below the sea surface at a constant depth (pressure) for a designated time period (e.g., four days), and (iii) if they reach a threshold depth (Musly et al., 2011a). PTTs transmit a satellite signal at a programmed rate when they are at the sea surface. PTTs continue to transmit until the device fails (e.g., battery or antenna failure), or if the device remains submerged, such as when a turtle dies and sinks, or if the tag has shed and sinks (Eckert, 2006; Godley et al.,2008; Swimmer et al., 2009).

Dated transmissions from a telemetry device can be used to infer turtle survival: With both PTTs and PSATs, most studies to date have inferred turtle survival based on observation of: (i) signal transmission for a threshold duration (months); (ii) normal/expected diving patterns, consistent with published observations, up until PTT cessation of signal transmission/PSAT pop-up; (iii) normal/expected distance travelled PTT up until cessation of signal transmission/PSAT pop-up; and/or (iv) normal/expected velocity up until PTT cessation of signal transmission/PSAT pop-up. Mortality in most studies to date have been inferred as a result of injuries incurred from a fishery interaction based on observation of: (i) post-release behavior indicative of injury and lack of vigor (e.g., remain at a constant depth for several days, short distance travelled, slow movements) prior to cessation of PTT signal transmission or PSAT pop-up; and (ii) the turtle died and sank beyond the species' depth capacity causing the PSAT to engage the pop-up mechanism (PSATs but not PTTs are able to document this event) (Chaloupka et al., 2004a; Parker et al., 2005; Ryder et al., 2006; Swimmer et al., 2002, 2006; Sasso and Epperly, 2007; Godley et al., 2008).

Unless a PTT is recovered, it is not possible to determine the cause of termination of signals. Causes include death due to injuries incurred from the fishery interaction, other anthropgenic mortality sources (e.g., subsequent fisheries capture, marine debris entanglement), natural mortality factors (e.g., predation), or tag failure (e.g. battery failure, biofouling, antenna damage, and attachment failure including from fishing gear entanglement with the tag) (Chaloupka et al., 2004a; Ryder et al., 2006; Swimmer et al., 2002, 2006; Hays et al., 2007; Sasso and Epperly, 2007; Musly et al., 2011a). For example, because PTTs do not transmit data when a turtle dies and sinks, there is uncertainty in differentiating mortality from other causes of cessation of PTT data transmission. Similarly, the cause of PSAT failure to transmit data also results in uncertainty in determining if the cause was turtle mortality or tag failure (Chaloupka et al., 2004a; Musyl et al., 2011a).

The duration of satellite tagging studies has implications for correctly interpreting observations. Short time series might fail to observe post-release mortalities occurring beyond the study period. Sea turtles may require >9 months to expel an ingested hook and recover from forced submergence and other injuries incurred from capture in pelagic longline fisheries (Aguilar et al., 1995; Ryder et al., 2006), suggesting that studies <9 months might fail to observe mortalities caused or influenced by injuries incurred during the fishery interaction. Relatively long time series require employment of control treatments in order to differentiate natural mortality from fishing mortality (Chaloupka et al., 2004; Ryder et al., 2006).

7.1.3. Correlation between gear haul-back and post-release mortality rates

For some pelagic species, it may be possible to accurately predict post-release mortality rates by extrapolating from the observed proportion of caught turtles that are dead at gear haul-back. Based on the assumption that injuries and stress incurred during capture are the most significant factors determining survival, it has been hypothesized that, for some pelagic species, at-vessel and post-release mortality rates may be correlated (Moyes et al., 2006; Campana et al., 2009a; Musyl et al., 2011b). This has been observed for blue sharks in a small number of studies (Moyes et al., 2006; Campana et al., 2009; Musyl et al., 2011b). The occurrence of this correlation for sea turtle species in pelagic longline fisheries has not been assessed; a meta-analysis of pooled datasets from individual studies would be instructive.

7.2. Explanatory Variables

7.2.1. Type and severity of injury

Type and severity of injury have been used to predict sea turtle post-release survival. For instance, the National Marine Fisheries Service (the U.S. fishery management authority) considers whether or not turtles were resuscitated from a comatose condition prior to release as a part of the model for predicting probably survival (Ryder et al., 2006). In addition, the location of hooking has been used as an indicator of severity of injury and concomitant relative probability of survival (Chaloupka et al., 2004; Ryder et al., 2006; Gilman et al., 2006b, 2007b; Carruthers et al., 2009).

7.2.2. Indicators of severity of stress/injury

The manner of turtle capture provides an indication of stress and injury. Hook design (i.e., circle vs. j-shaped and degree of offset of the point of the hook from the plane in which the shaft is situated), and minimum hook width have been shown to affect hooking location, and hence severity of injury, and thus have significant effects on post-release survival probability (Watson et al., 2005; Gilman et al., 2006b, 2007b; FAO, 2010b; Sales et al., 2010; Swimmer et al., 2010; Gilman, 2011; Musyl et al., 2011b). Gear soak time (how long a turtle was captured – the longer the period, the more stress, including risk of injury and mortality from predation), depth of terminal tackle when soaking, and weight of the gear (how much energy a turtle would expend to reach the surface to breath during the gear soak) are additional factors that may have significant effects on post-release survival probability.
NMFS assumes that: (i) deep-hooked turtles that are hooked in the esophagus at or below the level of the heart are understood to be more seriously injured, and hence have a higher probability of mortality than (ii) turtles deep-hooked in the cervical esophagus (above the level of the heart), glottis, jaw joint, soft palate, tongue or other jaw and mouth tissue parts, which are understood to be more seriously injured than (iii) those hooked in the upper or lower

jaw of the mouth but without penetrating other jaw and mouth tissue parts, which are more seriously injured than (iv) light-hooked turtles, hooked in the body, which are more seriously injured than (v) those captured via entanglement only and not hooked (Ryder et al., 2006).

Biochemical indicators of mortality and morbidity (e.g., blue shark plasma constituents to ascertain degree of blood loss, muscle and other tissue damage, and physical stress, Moyes et al., 2006), reflex action mortality predictors (degree of impairment of five reflexes following simulated gear interaction as an indicator of post-release survival probability for walleye pollock, coho salmon and rock sole, Davis, 2007), and bio-electrical impedance analysis (estimate various physiological parameters, including health as indicated by water distribution within fish, by measuring resistance and reactance of tissue to applied electrical current, Cox and Heintz, 2009; Cox et al., 2011) have been used to provide an indication of severity of injury and stress incurred during the interaction, and to predict post-release mortality probability (Musyl et al., 2009, 2011b). Biochemistry indicators have been used for sea turtles caught in U.S. Atlantic gillnet fisheries (Snoddy et al., 2009), and are being tested with turtles caught in a longline Mediterranean fishery (personal communication, Yonat Swimmer, NMFS, 10 Nov. 2011).

7.2.3. Handling and release practices

NMFS considers whether best handling and release practices (whether and how much gear has been removed) have been employed in estimating the probability of sea turtle post-release survival (NMFS, 2004; Ryder et al., 2006): the NMFS' method for estimating sea turtle mortality in longline fisheries includes consideration of whether or not gear is removed from a turtle prior to release, whether or not the turtle is released entangled in line, and the length of terminal tackle that remains attached upon live release (NMFS, 2004; Ryder et al., 2006). Removal of hooks from lightly hooked turtles, and removal of fishing line, is hypothesized to improve the probability of sea turtle survivability, but leaving hooks that are in the esophagus at or below the level of the heart in place is hypothesized to result in lower severity of injury than results from their removal (Ryder et al., 2006). Trailing line exceeding half the length of the turtle's carapace length is hypothesized to cause higher post-release mortality probability relative to line being less than half the carapace length, while turtles that are released entangled in line have a relatively lower probability of survival than if not entangled but with line trailing (Ryder et al., 2006). Ingestion of branchline, the length of line swallowed relative to the turtle size, and whether or not the line was attached to a hook are additional factors hypothesized to have significant effects on the probability of post-release survival of sea turtles from longline gear (Bjorndal et al., 1994; Oros et al., 2004, 2005; Casale et al., 2008).

7.2.4. Size, species and sex of released organism

The species, size and sex of the released sea turtle may have a significant effect on the probability of post-release mortality. For example, leatherback sea turtles are hypothesized to have lower rates of post-release survival relative to hard-shelled turtles because leatherbacks are believed to have more delicate external and internal hard and soft tissue structure relative to hard-shelled turtles, and as a result leatherbacks might be relatively more susceptible to injury (lower resistance) from interactions with pelagic longline gear (Ryder et al., 2006). Furthermore, leatherbacks are hypothesized to be relatively less resilient to the stresses incurred during fishery interactions. For instance, leatherbacks require a longer time period to recover from acidosis and to resume normal dive behavior (Ryder et al., 2006). The effect of size and sex of released turtles on survival probability has not been explored.

7.3. Methods Unsuitable to Estimating Sea Turtle Post-Release Mortality

7.3.1. Capture-mark-recapture/dead recovery

Long-term (years) capture-mark-recapture and capture-mark-dead recovery studies have been employed to estimate sex and age-class-specific survival probabilities of turtle populations (Chaloupka and Limpus, 2002; Bjorndal et al., 2003). This method has low potential to be effectively applied to estimate post-release mortality caused by the gear interaction given that there would be very low recapture rates of longline-released turtles due to both the short time period (months) required for post-release studies, and the low probability of recapture on the high seas (Godley et al., 2003). Samples sizes would be too low and thus such studies would lack sufficient power.

7.3.2. Information on stranded moribund and dead sea turtles

Information on stranded moribund and dead sea turtles, including information from necropsies of dead turtles, has been used to estimate what proportion of observed strandings were the result of interactions with longline and other hook-and-line fisheries. In turn, this information can be used to estimate a conditional probability for stranded turtles based on specific stressors (Bjorndal et al., 1994; Oros et al., 2004, 2005; Chaloupka et al., 2008).

Information on strandings will not reflect sources of mortality that occur far from land, such as bycatch in high seas fisheries. This method provides information on the relative risk of different mortality sources, and does not contribute directly to estimating post-release mortality rates.

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9. LIST of ACRONYMS

JIMAR-Joint Institute for Marine and Atmospheric Research
NMFS-National Marine Fisheries Service
NOAA-National Oceanic and Atmospheric Administration
PIFSC-NMFS Pacific Islands Fisheries Science Center
PIRO- NMFS Pacific Islands Regional Office
PAT or PSAT- Pop up Archival (Satellite) Tag
PTT-Platform Terminal Transmitter
SEFSC- NMFS Southeast Fisheries Science Center
SERO- NMFS Southeast Regional Office

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