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: observing turtles
caught in pelagic longline fisheries that are subsequently placed into captivity, satellite tracking,
capture-mark-recapture/dead recovery, information from stranded moribund and dead sea
turtles, and estimating post-release mortality rates by extrapolating from gear haul-back
mortality rates. 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.

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. 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 account for these potentially significant factors.

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 pre-set conditions: (i) on a specified date, (ii) if
they remain at a constant depth (pressure) for a designated time period, and (iii) if they reach a
threshold depth, at which time data are transmitted (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). Unlike PSATs, PTTs lack a fail-safe measures to
indicate a shed tag or a mortality. In these situations, the PTT would fail. It is therefore not
possible to differentiate between a turtle mortality vs. other causes of PTTs to cease
transmitting.
Dated transmissions from a telemetry device can be used to infer turtle survival: With both PTTs and PSATs, a tagged turtle is inferred to have survived 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 (iv) normal/expected velocity up until PTT cessation of signal transmission/PSAT pop-up. Mortality can be 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, marine debris/fishing gear entanglement with the tag, subsequent fisheries capture, drainage or failure of the battery, or failure of the instrument, for instance, from biofouling, antenna damage, and attachment failure (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 delayed 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).

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.

1.4. 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).

1.5. Indicators of severity of stress/injury

The manner of turtle capture provides an indication of stress and injury. Hook design (shape) and minimum hook width effect hooking location (Gilman, 2011), and hence severity of injury, and thus indirectly significantly affect post-release survival probability. Gear soak time (how long a turtle was captured), 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.

The National Marine Fisheries Service 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).

1.6. Handling and release practices

The National Marine Fisheries Service considers whether best practice handling and release practices have been employed in estimating the probability of sea turtle post-release survival (National Marine Fisheries Service, 2004; Ryder et al., 2006): the National Marine Fisheries Service’s 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 (National Marine Fisheries Service, 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).
1.7. 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.

1.8. 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.

1.9. 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). This method provides information on the relative risk of different mortality sources, and does not contribute directly to estimating post-release mortality rates.