Factors affecting post-release survival in large pelagic fish and sharks

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Post-release survival
Marlin, sharks and other pelagic bycatch species are released from fishing gear and it is unknown whether animals survive long term and what population-level effects might encompass (e.g. disruption of spawning).

Many discards represent a significant portion of parental (i.e. spawning) biomass and thus determining their mortality is a management priority.

To this point, National Standard 9 of the Magnuson Fishery Conservation and Management Act (MSFCMA) requires that: “to the extent bycatch cannot be avoided, minimize the mortality of such bycatch” (16 U.S.C. § 1851(9)) and Sec. 303 extends this requirement; “minimize the mortality of bycatch which cannot be avoided (16 U.S.C. § 1853(11))

For catch-and-release to be a viable management strategy, there must be a high likelihood of post-release survival (Kitchell et al. 2004, Kaplan et al. 2007, Pine et al. 2008).
However, to appraise the efficacy of the MSFCMA, and possible management options, the post-release fate of animals must first be determined.

**Methods to estimate delayed mortality in pelagic fishes and sharks**

1. Conventional plastic tags
2. Ultrasonic telemetry (active)
3. Fixed listening stations (passive telemetry)
4. Observation studies in tanks
5. PSATs
6. Biochemical
Methods to estimate delayed mortality in pelagic fishes and sharks

(1) Conventional plastic tags

Historically, long-term post-release survival of pelagic species estimated by large-scale tagging programs.

However...
tag return rates for species such as blue marlin (~1%) and blue shark (dominant bycatch species in global marine longline fisheries; <5%) are extremely low (Kohler et al. 1998, Ortiz et al. 2003).

Such results are consistent with a high post-release mortality, but could also be attributed to large population sizes, dispersal, tag loss, or uncooperative fishers.
(2) Short duration (active) ultrasonic telemetry studies

Marlin and sharks survive for at least 24-72 h following release from sports fishing and longline gear (Holland et al. 1990, Block et al. 1992, Brill et al. 1993, Pepperell and Davis 1998).

However...

time periods could be too short.

Mortality estimates in large pelagic species such as blue shark and blue marlin using PSATs suggest delayed mortality occurs up to ~ 14 d (Musyl et al. in prep) [delayed mortality for halibut reported at 30 d, Davis 2007]
(3) Passive telemetry

Fixed listening stations that require tagged fish to come within a certain radius of the instrument (e.g. “CHAT” tags, Kim’s “Business Card”)

However… probably not likely to be very informative for most pelagic species (i.e. what if they don’t swim by the listening station or exchange information with instrumented species who swim by…?)
(4) Tanks or pens

Discards can be placed in pens or tanks (e.g. Mandelman and Farrington 2007, Enevar et al. 2009, Davis and Olla 2001) and observed for short periods.

Ancillary diagnostic tests, reflex action mortality predictors (RAMP, Davis 2007), have been successfully used on salmon.

However…

but these techniques are not well suited to pelagic fishes (i.e. too large!). Moreover, scientific handling of large species could introduce additional stress.
(5) Pop-up satellite archival tags (PSATs)

The “right-tool” for the job – fishery independent
Fail-safe options can discriminate mortality from shed tags

However…

The cost of PSATs (~$3700 - $4000, + ARGOS) and deployment costs (NOAA RV ships ~ $10K/d) precludes their wide application in survival studies (translates into small sample sizes)
(6) Biochemical correlates of morbidity and mortality

*reduces experimental bias, increases sample size: more animals could be sampled, regardless of condition

*optimize experimental design (increase statistical power) and cost:benefit:

once the method is operational, about 40 samples can be assayed for the cost of one PSAT

Sample size/cost:benefit calculation:

assuming ~5% delayed mortality with $\alpha = 5$
90% power $n = 400$ (Type II error 10%) $\$1.6M$ PSATs v. $\$16K$ blood
50% power $n = 146$ (Type II error 50%) $\$0.6M$ PSATs v. $\$6K$ blood

assumes fish have equal chance of survival but this is probably not true [e.g. factors like hook type, handling, etc. can influence survival rates]

However… Sampling blood and tissues can be difficult
Developing biochemical predictors

Stress during capture → Cell & Tissue Damage → Death → Delayed Death

Assessing death: vital importance of good tagging data
False +ves: changes that don’t cause death
False -ves: undetectable changes that kill later
Pleiotropy: many different things can kill
Tissue sampling: where do you look?
Parameters measured in Blue Shark

1. Gender and size
2. Blood loss
3. Metabolic distress
   - glucose, lactate
4. Physical tissue damage
   - liver
   - kidney
   - heart and muscle
   - AST, ALT, AlkP
   - AlkP, creatinine
   - CK, LDH,
5. Systems failure
   - ionic regulation
   - osmotic regulation
   - plasma ions (Mg)
   - urea, osmolarity
6. Stress response
   - heat shock protein
The best logistic model incorporated a combination of plasma concentrations of Mg2+ and lactate. It successfully categorized 95% fish of known outcome (19 of 20) and predicted that 95% of apparently healthy sharks would have a high probability of long-term survival upon release.
Factors influencing post-release mortality estimates

comparison of blue shark survival studies
Factors influencing post-release mortality estimates

Comparative studies on blue shark post-release survival from pelagic longline gear targeting swordfish

North Atlantic: Campana et al. (2009) commercial longlines, used observer studies and PSATs (40) ~35% mortality, ~16% acute + ~19% delayed

Hawaii: Moyes et al. (2006) NOAA Research longline cruises, used biochemical, PSATs (32), catch data ~10% mortality, ~5% acute + ~5% delayed
Factors influencing post-release mortality estimates

(1) Bias in tagging (i.e. ‘triage samples’)

choice of which individuals to tag inevitably introduces bias that must be considered when extrapolating experimental results to the commercial fishery

North Atlantic: ~35% mortality, ~16% acute + ~19% delayed randomly tagged a sample of injured and healthy sharks

Hawaii: ~10% mortality, ~5% acute + ~5% delayed did not tag sharks that were dead or apparently moribund (i.e. lethargic and unresponsive to handling). Still, one PSAT-tagged blue shark ultimately died post-release.

choice would appear to introduce some bias? 5% of the captured sharks were categorized as dead or moribund in Hawaii study.

This estimate has recently been confirmed in a larger scale study by Walsh et al. (2009), who estimated a minimum mortality of 4.0% to 8.5% on observed longline trips in the Hawaii-based commercial fishery.
Bias in tagging

(a) Fish size

North Atlantic: ~35% mortality, ~16% acute + ~19% delayed
Used different type and sized hooks and reported that smaller sharks were 'more likely to be retrieved dead from the hook'.

Diaz and Serafy (2005) found significantly higher survival of larger blue sharks captured in longline fisheries but this trend was not found by Carruthers et al. (2009) in similar North Atlantic longline fisheries.

Hawaii: ~10% mortality, ~5% acute + ~5% delayed
used similar gear and fished at the same time and locations as the commercial longline fleet. Blue sharks had a mean fork length (FL) of ~170 cm which was similar to the mean size in the fishery (Walsh et al. 2009).

No significant differences could be demonstrated between biochemical correlates of stress and morbidity and shark size.
(2) Capture and tagging stress

(a) hook type

North Atlantic: ~35% mortality, ~16% acute + ~19% delayed
Used circle and J hooks and concluded J hooks caused a much greater degree of mortality, as result of ingestion of the hook. Confirmed by many other studies comparing hook types (e.g. circle v. J, Serafy et al. 2008)

Hawaii: ~10% mortality, ~5% acute + ~5% delayed
The Hawaii-based fishery and study (all circle) use circle hooks, or Japanese ringed hooks, which cause much less injury (J hooks have been banned since 2004).

In addition to fishing gear, the Hawaii study used soak times (time during which the gear is in the water; 10 to 18 h), nighttime sets (gear deployed at dusk and retrieved at dawn), number of hooks between floats (4 to 5), and bait (squid *Illex* spp.) (now banned) that accurately reflect those of the Hawaii-based fishery. Conditions on research cruise emulates conditions in the commercial fishery.
(2) Capture and tagging stress

(b) Release and ‘handling’ techniques

North Atlantic: ~35% mortality, ~16% acute + ~19% delayed in addition to body gaffing, hooks were removed forcefully from the shark, occasionally leading to detachment of the jaw.

Hawaii: ~10% mortality, ~5% acute + ~5% delayed. In the Hawaii-based fishery, unwanted sharks are quickly released by cutting lines, leaders or hooks — sharks are not gaffed and hoisted aboard, to avoid wasting time while the crew processes the target species.

It is therefore logical that the mortality of sharks should be greater in the North Atlantic fishery.
(2) Capture and tagging stress

c) Tagging

North Atlantic: ~35% mortality, ~16% acute + ~19% delayed completed tagging within 3 min of handling

Hawaii: ~10% mortality, ~5% acute + ~5% delayed required additional time to hoist the shark aboard the vessel to collect blood samples and affix PSATs. Thus, handling stress in our study was probably much greater than in the Hawaii-based commercial fishery (e.g. one PSAT tagged shark probably died as the direct result of scientific handling).

Mortality of a Blue Shark (*Prionace glauca*)

Fail safe mechanism jetizons PSAT after reaching 1200 m

Depth (m) — Temperature (°C)
Sharks are tagged, sampled on deck
Conclusions – Blue shark post-release survival

Comparisons between different survival studies require standardization of methods, both in the fisheries and in the sampling programs.

In Hawaii (Moyes et al. 2006) and North Atlantic (Campana et al. 2009) survival studies:

Fishing techniques (hook type, fish size, soak time, handling during release) appear to be the main factors affecting post-release mortality of blue sharks, and their post-release fate appears to be much more favorable in the Hawaii-based fishery (~5%) than in the North Atlantic fishery (~19%)
Post-release Survival of Blue Marlin
What do we know about marlin mortality?

Kitchell et al. (2004) estimated that >90% mortality in marlin caused by commercial longlines targeting yellowfin and bigeye tuna.

Concerns about stock status due to significant removal of parental biomass

Survival of blue marlin captured from commercial longline gear appears to be variable. Atlantic studies from observer data (ICCAT reports)

Jackson and Farber (1998) - 51% blue marlin alive at haulback
Lee and Brown (1998) - 66% survival
Cramer (1998, 2000) ~60 to 75%
Semba and Yokawa (2007) 50 to 70% (although the data suggest ~45%).

Other factors (e.g. soak time, leader material, handling procedures, hook type, water temperature) and fish size may influence the survival of blue marlin released from longline gear (Ward et al. 2004, 2008, Diaz and Serafy 2005, Serafy et al. 2008, Carruthers et al. 2009, Musyl et al. 2009).
Post-release mortality of marlin in fisheries

*Pop-up satellite archival tag (PSAT) studies (>200 tags):

post-release mortality was ~9.5% (CI*, 7 – 19%) for longline caught billfish (not swordfish) in the Atlantic

~12.5% (CI*, 2 – 19%) for sports caught billfish and the majority of fishing related fatalities were probably attributable to the use of J hooks
Examine whether prolonged fight times correlated with mortality in Blue marlin released from sports fishing gear in Kona, Hawaii.
Estimated sizes of 47 tagged marlin (1 black, 3 striped, 43 blue marlin in the study)

Black Marlin ~ “Grander” (i.e. 1000 lbs.)
Striped Marlin ~ 120 lbs.
Blue Marlin, range ~ 100-500 (avg. 200 lbs.)
(fight times from 5 – 120 min, avg. 15 min)
16% caught on bait, 84% on lures

Only 1 confirmed mortality (2.6%, CI*, 0 – 8.5%) in 38 blue marlin PSATs but this was clearly 82 days after catch-tag-release insult

Obviously other factors may have caused mortality other than stress from initial capture period

But what is a “post-release mortality”? (blue marlin mortality after 82 days)

Fail safe mechanism jettisons PSAT after reaching 1200m
Conclusions – Blue marlin post-release survival

Sports fishing tournaments favour post-release survival in marlin where incentive for receiving tag points promotes the use of heavier lines which consequently shortens fight time and overall stress levels.

Tag points from catch-release can win tournaments! 1256# (1256 points) lost out to boat that conventionally tagged and released 8 marlin (1600 points). However, marlin mortality from sports fishing represents a fraction of parental biomass
Overall Conclusions

Data suggest that incidental and bycatch species can have a relatively high level of post-release survival in commercial longline and sports fisheries which probably represent a significant fraction of parental biomass.

Possible Mitigation strategy – “avoidance” Create “mismatches” between depth/habitat of fishing hooks and vertical distribution of pelagic species... remove shallow hooks (Boggs 1992, Kitchell et al. 1999, Beverly et al. 2009)...

for those pelagic species incidentally caught....

circle hooks, shorter soak times, nylon leaders, humane release of animals can influence survival rates
Vertical niche partitioning:

**DAYTIME**
Vertical niche partitioning: NIGHTTIME

0 - 50m
- Striped Marlin
  0 - 50m
  24 – 25.6 °C
- Green Sea Turtle
  0 - 50m
  20.5 – 28.7 °C
- Loggerhead
  0 - 48m
  15.2 – 19.6 °C
- Olive ridley
  0 - 115m
  16.2 – 29.3 °C
- Black Marlin
  5.4 - 194m
  24.6 – 28.9 °C
- Yellowfin Tuna
  0 - 116m
  17.8 – 24.6 °C
- Blue Marlin
  0 - 59.2m
  21.9 – 28.4 °C
- Oceanic White-tip
  0 - 108m
  22.6 – 29.3 °C
- Bigeye Tuna
  15 - 123m
  24.2 – 26.3 °C
- Silky Shark
  0 - 118m
  23.8 – 26.4 °C
- Leatherback
  0 - 158m
  21.5 – 30.3 °C
- Shortfin Mako
  5.4 - 194m
  13.4 – 24.4 °C
- Blue Shark
  0 - 194m
  12.9 – 27.4 °C
- Yellowfin Tuna
  0 - 116m
  17.8 – 24.6 °C
- Blue Marlin
  0 – 59.2m
  21.9 – 28.4 °C
- Green Sea Turtle
  0 - 50m
  20.5 – 28.7 °C
- Loggerhead
  0 - 48m
  15.2 – 19.6 °C
- Olive ridley
  0 - 115m
  16.2 – 29.3 °C

100m
- Lemon Shark
  0 - 115m
  23.8 – 26.4 °C

200m
- Shortfin Mako
  5.4 - 194m
  13.4 – 24.4 °C

300m
- Bigeye Thresher
  21.5 - 328m
  9.9 – 26.2 °C

> 400m
- Swordfish
  0 - 495m
  7.1 – 24.5 °C

Thermocline
Animals located at depth range midpoints, with values giving 95% depth & temperature ranges, as indicated by electronic tagging studies funded by the University of Hawaii/PFRP & NOAA/NMFS.

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Modified longline with shallowest hooks removed and weights attached to reduce epipelagic bycatch while retaining or increasing the target catch of bigeye tuna.
No-shallow hook method catches significantly fewer epipelagic species

Beverly et al. (2009)
Show marlin tagging video if enough time...