HOOK, BAIT AND LEADER TYPE EFFECTS ON SURFACE PELAGIC LONGLINE RETENTION AND MORTALITY RATES: A META-ANALYSIS WITH COMPARISONS FOR TARGET, BYCATCH AND VULNERABLE FAUNA INTERACTIONS

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SUMMARY

A meta-analysis of 24 publications was conducted to assess effects of hook, bait and leader type on retention and at-haulback mortality rates of target, bycatch and vulnerable species of the pelagic longline fishery. Turtles and swordfish had lower retention rates with circle hooks. In contrast, retention rates of 3 sharks and 2 tuna species were greater with circle hooks. Bait type did not seem to significantly influence the retention rates of most of the species examined. Wire leader lead to a decrease in retention rates of bony fishes and a mix for elasmobranchs. For at-haulback mortality, hook type was the most influential, with 5 elasmobranch species and 6 bony fishes having a significantly lower at-haulback mortality rates when using circle hooks. Bait type and leader type did not have a significant effect on at-haulback mortality rates for most species. The results presented here should be considered preliminary. Future work will consider expanded information on fishery characteristics.

KEYWORDS: Meta-analysis, J-hooks, circle hooks, squid, fish, target species, bycatch

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1. Introduction

Marine fisheries have a major anthropogenic influence on marine systems worldwide, affecting both marine populations and ecosystems, and warranting urgent and comprehensive management. Among the different key issues in marine fisheries, bycatch - the unintended capture of non-target organisms during fishing operations, is a major problem. Amongst these species are sea turtles, sharks and rays, seabirds and marine mammals. While some bycaught species are also commercial species, and therefore retained, others are discarded having no economical value. There is an evident need for measures that minimize catches of the bycatch species and/or measures that decrease mortality rates, that together with good handling practices, could decrease the at-haulback and post-release mortality.

Awareness of the impacts of incidental catches on species of concern is increasing, as well as the research on measures that minimize catch of non-target species. Gear modification measures are seen as to have relatively easy implementation and low economical impact. The use of circle hooks instead of J-hooks is one of the measures seen as beneficial in reducing bycatch while maintaining the target species catch, however different results between studies and species have prevented a wider implementation of this measure. Besides hook type, bait species type has also been reported to have an effect on the catches of bycatch species. A species-specific meta-analysis of the changes in retention and at-haulback mortality rates between hook, bait and leader type is presented in this study.

2. Methods

2.1. Data collection

Information from studies and experiments that examined hook type (circle, tuna or J-hook) effects, bait type (squid or fish) effects and leader type (nylon or steel) effects on retention and at-haulback mortality in pelagic longline fisheries was compiled. Published literature, technical reports and unpublished data relevant to our search were identified based on electronic database searches, using relevant keywords (e.g. “circle hook”, “bait type”, “leader type”, “pelagic longline”). Initial references were collected from a recent meta-analysis by Reinhardt et al. (2017). Furthers references in the available literature were also analysed if there was a match with the searching criteria. Following Reinhardt et al. (2017), the term “reference” is used to refer to a document; “experiment” to refer to a unique data set considered in our analysis. An experiment was considered unique if they differed with respect to attributes such as the year of study or season, location, gear, vessel size or fleet. Each unique experiment was assigned an identification number, and a unique reference could have more than one experiment. References used were collected by January 2019.

Data collected from each reference included date and location, set type, species name, hook type, size, offset and manufacturer, bait type, leader type, number of hooks, total catch, and at-haulback mortality. The set type was classified as “Deep-set” or “Shallow-set” depending on the longline depth during the fishing operation. If this information was not available, the target species and number of hooks between floats were used to differentiate between set type. Hook type was classified as “circle”, “J” or “Tuna” hook. When available, information on hook size, offset and manufacturer were also recorded. Bait type was classified as “fish” or “squid” depending on the bait species used. Leader type was classified as “nylon” or “wire”; when available information on leader length was also recorded. Some values that were required, but not directly reported, were derived where possible. For example, the number of fish caught was often derived from retention rates and effort reported in the reference.

Data from the National Marine Fisheries Service (NMFS) Southeast Fisheries Science Center Pelagic Observer Program (POP), Epperly et al. (2012) and Foster et al. (2012) were obtained from Reinhardt et al. (2017). Data from Coelho et al. (2012), Amorim et al. (2015), Fernandez-Carvalho et al. (2015), Santos & Coelho (2016) and Santos et al. (2017) was used directly from the raw data provided by the authors.

2.2. Meta-analysis

Differences in retention and at-haulback mortality rates for bony fishes (tuna and billfish species), both target and bycatch, elasmobranchs and sea turtles retained on different hook, bait and leader type for shallow setting

pelagic longlines were analysed through a meta-analysis. Deep setting and tuna hooks were not considered in the analysis. Our analysis follows the method used by Reinhardt et al. (2017) but is specific to the shallow pelagic longline fishery and expands the analysis to include bait type and the leader type. The difference between the calculated RR and a value of 1.0 represents the mean percent change associated with the experimental treatment, such that an RR < 1.0 indicates lower values for treatment compared with the control (e.g circle vs J-hooks).
The RR is equal to:

$$RR = \frac{ai/n1i}{ci/n2i}$$

where for the ith experiment, a_i is the number of animals retained on experimental hook (circle hook), $n1_i$ is the number of experimental hooks fished, c_i is the number of animals retained on control hooks (J-hooks), and $n2_i$ is the number of control hooks fished for the analysis of retention rate.

For the comparison between bait type, for the ith experiment, a_i is the number of animals retained on experimental bait (squid), $n1_i$ is the number of experimental hooks fished, c_i is the number of animals retained on control hooks (fish), and $n2_i$ is the number of control hooks fished for the analysis of retention rate.

For the comparison between leader type, for the ith experiment, a_i is the number of animals retained on experimental leader (nylon), $n1_i$ is the number of experimental hooks fished, c_i is the number of animals retained on control hooks (steel wire), and $n2_i$ is the number of control hooks fished for the analysis of retention rate.

The same methods apply to at-haulback mortality, where the a_i and c_i is be the number of animals dead at-haulback for the experiment and control, respectively, and $n1_i$ and $n2_i$ is the number of animals retained for the experiment and control, respectively.

Retention and at-haulback mortality rates were estimated using the “metafor” package (Viechtbauer, 2010) in R 3.5.1 (R Core Team, 2018) for each species. The RR value is log-transformed to normalize the distribution of effect sizes around zero and to meet the assumption of normality for the analysis. A summary effect size was computed for all taxa that had at least two experiment IDs. For this preliminary analysis, experiments with low sample size and large confidence intervals on the RR were excluded. A two-sided Wald-type Z test was used to test for differences between effects mean and zero. Effect sizes were estimated using a random effects model. The random effects model computes a global mean effect size based on a weighted mean of the studies’ effect sizes. Weights were computed as the inverse of the sample variance and the between-study variance (τ2). Sample variance, v_i, for ln(RR) of the ith experiment was calculated as:

$$Vi = \frac{1}{ai} - \frac{1}{n1i} + \frac{1}{ci} - \frac{1}{n2i}$$

Heterogeneity factor (I^2) was calculated as a measure of total variation across experiments due to observed variability that is real. Values of I^2 vary from 0% to 100%, with higher values indicating greater heterogeneity between experiments.

3. Results

For data compilation, in total 35 unique references were identified, totalling 52 experiments. For this preliminary analysis, considering only shallow sets, 24 references were available, totalling 28 experiments.

Retention rate analyses between hook type were performed for 23 species (8 bony fishes, 3 sea turtles, 12 elasmobranchs; Table 1), between bait type for 18 species (7 bony fishes, 3 turtles, 8 elasmobranchs; Table 2), and between leader type for 13 species (6 bony fishes and 7 elasmobranchs, Table 3).

At-haulback mortality was analysed for 19 species (8 bony fishes and 11 elasmobranch species) considering hook type (Table 4), 15 species (7 bony fishes and 8 elasmobranch species considering bait type (Table 5) and 8 species (4 bony fishes and 4 elasmobranch species) considering leader type (Table 6). Sea turtles were not considered so far for the at-haulback mortality analysis as in most studies the individuals were alive at-haulback.

3.1. Retention rates

3.1.1. Hook type

Of the 23 analysed species, 12 species had lower retention rates on circle hooks when comparing to J-hooks (Table 1, Figure 1). Tuna species (albacore, bigeye tuna, bluefin tuna and yellowfin tuna) had higher retention rates on circle hooks, however significant differences were found only for albacore and bluefin tuna ($p<0.05$). On the other hand, all billfish species had lower retention with circle hooks, particularly swordfish and blue marlin, for which the difference was statistically significant. For the analysed turtle species, all had significantly lower retention rates when using circle hooks. For elasmobranch species, there was mixed effects, with 7 species having higher retention rates with circle hooks. For porbeagle, shortfin mako, tiger shark and crocodile shark this difference was significant, while the pelagic stingray was the only elasmobranch species to have a significantly lower retention rate with circle hooks comparing to J-hooks.

Overall, increases in retention rate with circle hooks (vs. J-hooks) ranged from 20% greater in the shortfin mako to 45% greater in the porbeagle. For bony fishes, retention rate ranged from 30% greater in bluefin tuna to 41% greater in albacore when circle hooks were used. Among elasmobranchs, increases in retention rate using circle hooks were approximately 40% higher for the porbeagle, crocodile shark, tiger shark. Retention rate with circle hooks (vs. J-hooks) ranged from 17% lower in swordfish to 76% lower in the pelagic stingray. For blue marlin, retention rate was 30% lower when using circle hooks. Retention rates for all turtle species were lower (40-61%) when circle hooks were used rather than J-hooks.

3.1.2 Bait type

Of the 18 analysed species, 9 species had lower retention rates on fish baited hooks in comparison with squid baited hooks (Table 2, Figure 2). For the billfishes, it is noted that blue marlin had a RR higher than 1, meaning that the retention rate is higher with fish baited hooks, while for swordfish the bait type had no effect on the retention rate. For the tunas changing bait to fish decreased the retentions, however differences were only statistically significant for albacore. Among sea turtles, the loggerhead sea turtle and the leatherback sea turtle had significantly lower retention rates when baiting hooks with fish. The olive ridley sea turtle had a slightly higher retention rate, but differences observed were not statistically significant. For elasmobranchs, 6 of the 8 species analysed had a higher retention rate with fish baited hooks, however differences were not statistically significant. Retention rates with fish baited hooks (vs. squid baited hooks) ranged from 49% lower in the leatherback sea turtle to 81% lower in the albacore.

3.1.3 Leader type

Of the 13 analysed species, 5 species had higher retention rates on wire leaders when comparing to nylon leaders (Table 3, Figure 3). All billfishes and tuna species had lower retention rates on wire leader, except for sailfish which showed a non-significant increase, however significant differences were found only for albacore, yellowfin tuna and blue marlin ($p<0.05$). On the other hand, for elasmobranch species, there were mixed effects, with 3 species (blue shark, silky shark and shortfin mako) having higher retention rates with wire leaders, although this was only significant for blue shark. For bigeye thresher, pelagic stingray and crocodile shark, there was a decrease in retention rates when using wire leader, this difference was only significant for crocodile shark. For oceanic whitetip there was no difference in retention rate.

3.2. At-haulback mortality rates

3.2.1. Hook type

Of the 19 analysed species, 11 species had significantly lower (6-27%) at-haulback mortality rates on circle hooks when comparing to J-hooks ($p<0.05$) (Table 4, Figure 4). Blue shark, silky shark, oceanic whitetip, shortfin mako and scalloped hammerhead had significantly lower at-haulback mortality rates on circle hooks, while the porbeagle showed a decrease in at-haulback mortality rate, although it was not significant. Bigeye thresher, longfin mako, crocodile shark, smooth hammerhead shark and tiger shark had higher at-haulback mortality rates when using circle hooks, however this increase was only significant for the bigeye thresher ($p<0.05$). Bony fishes had generally lower at-haulback mortality rates with circle hooks when comparing to J-hooks, with the exception of bluefin tuna. However, differences were not statistically significant for albacore and bluefin tuna. Bony fishes had generally lower at-haulback mortality rates with circle hooks when comparing to J-hooks, except for bluefin tuna. However, differences were not statistically significant for albacore and bluefin tuna.

3.2.2. Bait type

At-haulback mortality rates were lower for 6 of the 15 species analyzed. Of the 8 analysed elasmobranch species, 4 species had lower at-haulback mortality rates on fish baited hooks when comparing to squid baited hooks (Table 55, Figure 5), while the other 4 species showed an increase in at-haulback mortality rate. Only for blue shark there was a significant increase (71%) in at-haulback mortality when fish baited hooks were used ($p<0.05$) when fish baited hooks were used ($p<0.05$). At-haulback mortality rates were higher for swordfish, albacore, yellowfin tuna, Atlantic sailfish and white marlin with fish baited hooks, although the differences were only significant for swordfish.

3.2.3. Leader type

At-haulback mortality rates were lower on wire leaders when comparing to nylon leaders for blue shark, bigeye thresher and silky shark (Table 6, Figure 6). On the contrary, crocodile shark had higher at-haulback mortality rates on wire leaders. However, none of these differences were significant. For bony fishes, at-haulback mortality rates were higher for yellowfin tuna and lower for swordfish, albacore and bigeye tuna when wire leaders were used, although significant differences were not found.

4. Discussion

4.1. Retention rates

The main results of our study show that sea turtles retention rates are reduced when J-hooks are changed to circle hooks. For swordfish, the main target species of shallow pelagic longlines, there were also reductions in retention rates when using circle hooks instead of J-types. For other billfishes that are captured mostly as bycatch, there were also reductions, especially for the blue marlin. In contrast, retention rates of the bluefin tuna and albacore were greater with circle hooks. With regards to elasmobranchs, the retention rates for species such as porbeagle, shortfin mako, tiger shark and crocodile shark were higher when using circle hooks, while the pelagic stingray had lower retention rates with circle hooks.

Bait type did not seem to have a major influence on the retention rates of elasmobranchs and the majority of the bony fishes, both target and bycatch. For the loggerhead sea turtle and the leatherback sea turtle, interactions were lower when the bait used was fish. Albacore tuna retention was higher when fish was used as bait.

Using wire leaders leads to a decrease in retention of all analysed bony fishes, except for sailfish. For sharks there is a mixed effect, but only a significant increase for blue shark. At this time it was not possible to compare the retention rates of sea turtles by leader type as not enough information was available.

4.2. At-haulback mortality rates

With regards to elasmobranchs, changing from J-hooks to circle hooks significantly decreased at-haulback mortality rates of 5 of the 11 analysed species, while a significant increase in at-haulback mortality was only observed for bigeye thresher. Regarding bony fishes, there was a tendency for lower at-haulback mortality rates when circle hooks were used.

Bait type had no significant effect on at-haulback mortality rates, except for blue shark, however this may be related with other factors that are not being analysed here, rather than being a real effect of bait on mortality rates.

Few studies are available comparing at-haulback mortality by leader type, therefore it was only possible to conduct this analysis for 8 species (4 elasmobranchs and 4 bony fishes), and none of these show a significant change in at-haulback mortality rates when changing leader type.

4.3. Final remarks

This study is looking at retention rates, as it is not possible to know the true catch of the gear. It is known that bite-offs occur, especially in monofilament leader, however it is very difficult to ascertain which species has bitten off the leader and escaped.

Also, only at-haulback mortality is being analysed so there is the need to estimate what are the effects of changing hook type on post-release mortality. On one hand, J-hooks tend to deep-hook the specimens more than circle hooks, which could imply that post-release mortality due to internal injuries would be higher. On the other hand, sharks or other species caught on J-hooks that are able to bite-off and escape, spend much less time hooked (lower retention times), which in this case would likely imply a higher survival rate. As such, it is very difficult to estimate what could be the implications on the post-release mortality of using one hooks type versus the other, especially on specimens that can bite-off the line and escape when using J-hooks.

It is important to note that the results presented here are preliminary. For some species, only few studies were available, therefore the data used does not allow for strong conclusions, especially when analysing bait and leader type effects. More experimental studies are needed, especially for the more rare species with low sample sizes. Further work will, if possible, expand on the fishery characteristics considered (e.g. include tuna hooks and deep setting data).

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6. References

Afonso, A.S., Hazin, F.H.V., Carvalho, F., Pacheco, J.C., Hazin, H., Kerstetter, D.W., Murie, D. and Burgess, G.H. 2011. Fishing gear modifications to reduce elasmobranch mortality in pelagic and bottom longline fisheries off Northeast Brazil. *Fisheries Research*, 108:336-343.

Afonso, A.S., Santiago, R., Hazin, H. and Hazin, F.H.V. 2012. Shark bycatch and mortality and hook bite-offs in pelagic longlines: Interactions between hook types and leader materials. *Fisheries Research*, 131– 133:9-14.

Amorim, S., Santos, M. N., Coelho, R. and Fernandez-Carvalho, J. 2015. Effects of 17/0 circle hooks and bait on fish catches in a Southern Atlantic swordfish longline fishery. *Aquatic Conservation: Marine and Freshwater Ecosystems*, 52:518–533.

Andraka, S., Mug, M., Hall, M., Pons, M., Pacheco, L., Parrales, M. and Vogel, N. 2013. Circle hooks: Developing better fishing practices in the artisanal longline fisheries of the Eastern Pacific Ocean. *Biological Conservation*, 160:214–224.

Boggs, C. H. and Swimmer, Y. 2007. Developments (2006-2007) in scientific research on the use of modified fishing gear to reduce longline bycatch of sea turtles. WCPFC document WCPFC-SC3-EB-SWG_WP-7. 9p.

Bolten, A.B. and Bjorndal, K.A. 2005. Experiment to Evaluate Gear Modification on Rates of Sea Turtle Bycatch in the Swordfish Longline Fishery in the Azores-Phase 4. Final project report NOAA Award Number NA03NFM4540204. 21p.

Cambiè, G., Muiño, R., Freire, J. and Mingozzi, T. 2012. Effects of small (13/0) circle hooks on loggerhead sea turtle bycatch in a small-scale, Italian pelagic longline fishery. *Bulletin of Marine Science*, 88:719-730.

Coelho, R., Santos, M. N. and Amorim, S. 2012. Effects of hook and bait on targeted and bycatch fishes in an equatorial and bycatch fishes in an equatorial Atlantic pelagic longline fishery. *Bulletin of Marine Science*, 88:449-467.

Coelho, R., Santos, M. N., Fernandez-Carvalho, J. and Amorim, S. 2015. Effects of hook and bait in a tropical northeast Atlantic pelagic longline fishery: Part I—Incidental sea turtle bycatch. *Fisheries Research*, 164:302-311.

Domingo, A., Pons, M., Jiménez, S., Miller, P., Barceló, C. and Swimmer, Y. 2012. Circle hook performance in the Uruguayan pelagic longline fishery. *Bulletin of Marine Science*, 88:499–511.

Epperly, S. P., Watson, J. W., Foster, D. G. and Shah, A. K. 2012. Anatomical hooking location and condition of animals captured with pelagic longlines: The Grand Banks experiments 2002–2003. *Bulletin of Marine Science*, 88:513–527.

Fernandez-Carvalho, J., Coelho, R., Santos, M. N. and Amorim, S. 2015. Effects of hook and bait in a tropical northeast Atlantic pelagic longline fishery: Part II—Target, bycatch and discard fishes. *Fisheries Research*, 164:312-321.

Foster, D. G., Epperly, S. P., Shah, A. K. and Watson, J. W. 2012. Evaluation of hook and bait type on the catch rates in the western North Atlantic Ocean pelagic longline fishery. *Bulletin of Marine Science*, 88:529–545.

Gilman, E., Kobayashi, D., Swenarton, T., Brothers, N, Dalzell, P. and Kinan-Kelly, I. 2007. Reducing sea turtle interactions in the Hawaii-based longline swordfish fishery. *Biological Conservation*, 139:19-28.

Mejuto, J., Garcia-Cortes, B. and Ramos-Cartelle, A. 2008. Trials using different hook and bait types in the configuration of the surface longline gear used by the Spanish Swordfish (Xiphias gladius) fishery in the Atlantic Ocean. *Collective Volume Scientific Papers of ICCAT*, 62:1793-1830.

NMFS and 2011. Southeast Fisheries Science Center Pelagic Observer Program Data. Miami, FL: Southeast Fisheries Science Center. Unpublished raw data.

Pacheco, J. C., Kerstetter, D. W., Hazin, F. H., Hazin, H., Segundo, R. S., Graves, J. E. and Travassos, P. E. 2011. A comparison of circle hook and J hook performance in a western equatorial Atlantic Ocean pelagic longline fishery. *Fisheries Research*, 107:39-45.

Piovano, S., Basciano, G., Swimmer, Y. and Giacoma, C. 2012. Evaluation of a bycatch reduction technology by fishermen: A case study from Sicily. *Marine Policy*, 36:272–277.

Piovano, S., Swimmer, Y. and Giacoma, C. 2009. Are circle hooks effective in reducing incidental captures of loggerhead sea turtles in a Mediterranean longline fishery? *Aquatic Conservation: Marine and Freshwater Ecosystems*, 19:779–785.

R Core Team. 2018. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/.

Reinhardt, J. F., Weaver, J., Latham, P.J., Dell'Apa, A., Serafy, J.E.,Browder, J.A., Christman, M., Foster, D. G. and Blankinship, D. R. 2018. Catch rate and at-vessel mortality of circle hooks versus J-hooks in pelagic longline fisheries: A global meta-analysis. *Fish and Fisheries*, 19(3): 413–430.

Sales, G., Giffoni, B.B., Fiedler, F.N., Azevedo, V.G., Kotas, J.E., Swimmer, Y. and Bugoni, L. 2010. Circle hook effectiveness for the mitigation of sea turtle bycatch and capture of target species in a Brazilian pelagic longline fishery. *Aquatic Conservation: Marine and Freshwater Ecosystems*, 20:428-436.

Santos, M. N., Coelho, R., Fernandez-Carvalho, J. and Amorim, S. 2012. Effects of hook and bait on sea turtle catches in an equatorial Atlantic pelagic longline fishery. *Bulletin of Marine Science*, 88:683-701.

Santos, M. N., Coelho, R., Fernandez-Carvalho, J. and Amorim, S. 2013. Effects of 17/0 circle hooks and bait on sea turtles bycatch in a Southern Atlantic swordfish longline fishery. *Aquatic Conservation: Marine and Freshwater Ecosystems*, 23:732–744.

Santos, M.N. and Coelho, R. 2016. LL-SHARKS - Mitigação das capturas de tubarões na pescaria de palangre de superfície. Final project report FCT reference 31-03-05-FEP-44. 74p.

Viechtbauer, W. 2010. Conducting meta-analyses in R with the metafor package. *Journal of Statistical Software*, 36(3): 1-48. URL: http://www.jstatsoft.org/v36/i03/

Yokota, K., Kiyota, M. and Okamura, H. 2009. Effect of bait species and color on sea turtle bycatch and fish catch in a pelagic longline fishery. *Fisheries Research*, 97:53–58.

Tables

Table 1. Summary of the results of the meta-analysis on retention rates showing the summary effect size (relative risk, RR) and 95% confidence interval (CI), the number of experiments used (#exp) for each species. RR > 1 indicates a higher retention was calculated on circle hooks vs J-hooks. If the p-value <0.05 the RR is significantly different from 1 (in bold). I^2 describes the percentage of total variation across studies that are due to heterogeneity rather than chance.

Species	#exp	RR	CI	I^2	p-value	References
Elasmobranchs						
BSH – Blue shark	14	1.09	0.94-1.26	99.13%	0.26	Bolten and Bjorndal, 2005; Mejuto et al., 2008; Sales et al., 2010; Afonso et al., 2011; NMFS, 2011; Pacheco et al., 2011; Domingo et al., 2012; Foster et al., 2012; Afonso et al., 2012; Fernandez-Carvalho et al., 2015; Amorim et al., 2015; Coelho et al., 2012
BTH – Bigeye thresher	4	0.84	0.69-1.04	76.85%	0.11	NMFS, 2011; Coelho et al., 2012; Fernandez-Carvalho et al., 2015; Amorim et al., 2015
FAL – Silky shark	6	0.94	0.63-1.40	88.83%	0.75	Afonso et al., 2011; NMFS, 2011; Andraka et al., 2013; Coelho et al., 2012; Afonso et al., 2012; Fernandez-Carvalho et al., 2015
LMA – Longfin mako	3	0.67	0.30-1.52	85.10%	0.34	Coelho et al., 2012; Fernandez-Carvalho et al., 2015; Amorim et al., 2015
OCS – Oceanic whitetip	5	1.05	0.80-1.39	18.63%	0.72	Pacheco et al., 2011; Coelho et al., 2012; Afonso et al., 2012; Fernandez-Carvalho et al., 2015; Amorim et al., 2015
POR – Porbeagle	5	1.45	1.24-1.69	39.44%	**<0.0001**	NMFS, 2011; Domingo et al., 2012; Foster et al., 2012; Amorim et al., 2015
PSK – Crocodile shark	5	1.43	1.06-1.93	80.93%	**0.02**	Pacheco et al., 2011; Coelho et al., 2012; Afonso et al., 2012; Fernandez-Carvalho et al., 2015; Amorim et al., 2015
SMA – Shortfin mako	10	1.20	1.01-1.20	88.04%	**0.04**	Mejuto et al., 2008; Sales et al., 2010; Afonso et al., 2011; NMFS, 2011; Domingo et al., 2012; Foster et al., 2012; Coelho et al., 2012; Fernandez-Carvalho et al., 2015; Amorim et al., 2015
SPL – Scalloped hammerhead	5	0.95	0.46-1.97	53.51%	0.90	Afonso et al., 2011; NMFS, 2011; Pacheco et al., 2011; Coelho et al., 2012; Fernandez-Carvalho et al., 2015
SPZ – Smooth hammerhead	3	1.05	0.69-1.61	69.23%	0.82	Coelho et al., 2012; Fernandez-Carvalho et al., 2015; Amorim et al., 2015
TIG – Tiger shark	4	1.42	1.30-1.54	0%	**<0.0001**	NMFS, 2011; Coelho et al., 2012; Fernandez-Carvalho et al., 2015; Afonso et al., 2012
PLS – Pelagic stingray	9	0.24	0.15-0.38	77.51%	**<0.0001**	Pacheco et al., 2011; Cambie et al., 2012; Domingo et al., 2012; Coelho et al., 2012; Fernandez-Carvalho et al., 2015; Afonso et al., 2012; Amorim et al., 2015; Piovano et al., 2009
Turtles						
TTL – Loggerhead sea turtle	18	0.46	0.33-0.65	91.31%	**<0.0001**	Bolten and Bjorndal, 2005; Boggs and Swimmer, 2007; Gilman et al., 2007; Mejuto et al., 2008; Sales et al., 2010; NMFS, 2011; Cambie et al., 2012; Domingo et al., 2012; Epperly et al., 2012; Foster et al., 2012; Piovano et al., 2012; Santos et al., 2012; Piovano et al., 2009; Coelho et al., 2015; Santos et al., 2013
DKK – Leatherback sea turtle	9	0.39	0.28-0.56	82.62%	**<0.0001**	Gilman et al., 2007; Mejuto et al., 2008; Sales et al., 2010; NMFS, 2011; Pacheco et al., 2011; Foster et al., 2012; Santos et al., 2012; Coelho et al., 2015; Santos et al., 2013
LKV – Olive ridley sea turtle	6	0.60	0.43-0.83	56.73%	**<0.01**	Mejuto et al., 2008; Andraka et al., 2013; Santos et al., 2012; Coelho et al., 2015

Target species						
SWO – Swordfish	18	0.83	0.75-0.91	98.38%	**0.0001**	Bolten and Bjorndal, 2005; Boggs and Swimmer, 2007; Gilman et al., 2007; Mejuto et al., 2008; Sales et al., 2010; NMFS, 2011; Pacheco et al., 2011; Domingo et al., 2012; Foster et al., 2012; Piovano et al., 2012; Coelho et al., 2012; Afonso et al., 2012; Piovano et al., 2009; Fernandez-Carvalho et al., 2015; Amorim et al., 2015
ALB – Albacore	10	1.41	1.02-1.94	95.63%	**0.04**	Sales et al., 2010; NMFS, 2011; Pacheco et al., 2011; Domingo et al., 2012; Foster et al., 2012; Coelho et al., 2012; Afonso et al., 2012; Fernandez-Carvalho et al., 2015; Amorim et al., 2015
BET – Bigeye tuna	5	1.04	0.64-1.67	98.76%	0.89	Sales et al., 2010; NMFS, 2011; Pacheco et al., 2011; Domingo et al., 2012; Foster et al., 2012
BFT – Bluefin tuna	3	1.30	1.04-1.62	56.44%	**0.02**	NMFS, 2011; Cambie et al., 2012; Foster et al., 2012
YFT – Yellowfin tuna	8	1.07	0.89-1.29	85.82%	0.47	Sales et al., 2010; NMFS, 2011; Pacheco et al., 2011; Domingo et al., 2012; Coelho et al., 2012; Afonso et al., 2012; Fernandez-Carvalho et al., 2015; Amorim et al., 2015
BUM – Atlantic blue marlin	6	0.70	0.61-0.80	36.23%	**<0.0001**	NMFS, 2011; Pacheco et al., 2011; Coelho et al., 2012; Afonso et al., 2012; Fernandez-Carvalho et al., 2015; Amorim et al., 2015
SAI – Atlantic sailfish	3	0.60	0.28-1.28	59.38%	0.19	Coelho et al., 2012; Afonso et al., 2012; Fernandez-Carvalho et al., 2015
WHM – White marlin	4	0.75	0.39-1.44	96.77%	0.38	NMFS, 2011; Pacheco et al., 2011; Coelho et al., 2012; Amorim et al., 2015

Table 2. Summary of the results of the meta-analysis on retention rates showing the summary effect size (relative risk, RR) and 95% confidence interval (CI), the number of experiments used (#exp) for each species. RR > 1 indicates a higher retention was calculated on fish baited hooks vs squid baited hooks. If the p-value <0.05 the RR is significantly different from 1 (in bold). I^2 describes the percentage of total variation across studies that are due to heterogeneity rather than chance.

Species	#exp	RR	CI	I^2	p-value	References
Elasmobranchs						
BSH – Blue shark	6	1.07	0.77-1.47	99.69%	0.70	Foster et al., 2012; Coelho et al., 2012; Yokota et al., 2009; Fernandez-Carvalho et al., 2015; Amorim et al., 2015; Santos and Coelho, 2016
BTH – Bigeye thresher	4	1.10	0.86-1.41	61.11%	0.45	Coelho et al., 2012; Fernandez-Carvalho et al., 2015; Amorim et al., 2015; Santos and Coelho, 2016
FAL – Silky shark	4	1.46	0.82-2.61	60.64%	0.20	Coelho et al., 2012; Yokota et al., 2009; Fernandez-Carvalho et al., 2015; Amorim et al., 2015; Santos and Coelho, 2016
OCS – Oceanic whitetip	4	0.82	0.60-1.13	45.10%	0.23	Coelho et al., 2012; Fernandez-Carvalho et al., 2015; Amorim et al., 2015; Santos and Coelho, 2016
PSK – Crocodile shark	4	0.72	0.21-2.49	99.12%	0.60	Coelho et al., 2012; Fernandez-Carvalho et al., 2015; Amorim et al., 2015; Santos and Coelho, 2016
SMA – Shortfin mako	6	1.45	0.96-2.18	94.17%	0.07	Foster et al., 2012; Coelho et al., 2012; Yokota et al., 2009; Fernandez-Carvalho et al., 2015; Amorim et al., 2015; Santos and Coelho, 2016
SPZ – Smooth hammerhead	3	1.11	0.50-2.50	91.40%	0.80	Coelho et al., 2012; Fernandez-Carvalho et al., 2015; Santos and Coelho, 2016
PLS – Pelagic stingray	5	1.07	0.64-1.81	81.98%	0.79	Coelho et al., 2012; Yokota et al., 2009; Fernandez-Carvalho et al., 2015; Amorim et al., 2015; Santos and Coelho, 2016
Turtles						
TTL – Loggerhead sea turtle	8	0.22	0.13-0.36	77.42%	**<0.001**	Boggs and Swimmer 2007; Gilman et al., 2007; Foster et al., 2012; Santos et al., 2012; Yokota et al., 2009; Coelho et al., 2015; Santos et al., 2013; Santos and Coelho, 2016
DKK – Leatherback sea turtle	6	0.51	0.27-0.94	89.27%	**<0.001**	Gilman et al., 2007; Foster et al., 2012; Santos et al., 2012; Coelho et al., 2015; Santos et al., 2013; Santos and Coelho, 2016
LKV – Olive ridley sea turtle	3	1.01	0.22-4.59	94.61%	0.99	Santos et al., 2012; Coelho et al., 2015; Santos and Coelho, 2016
Target species						
SWO – Swordfish	7	1.00	0.83-1.21	99.02%	0.97	Gilman et al., 2007; Foster et al.,2012; Coelho et al., 2012; Yokota et al., 2009; Fernandez-Carvalho et al., 2015; Amorim et al., 2015; Santos and Coelho, 2016
ALB – Albacore	5	0.19	0.09-0.42	87.70%	**<0.0001**	Foster et al.,2012; Coelho et al., 2012; Yokota et al., 2009; Fernandez-Carvalho et al., 2015; Amorim et al., 2015
BET – Bigeye tuna	6	0.61	0.20-1.87	99.22%	0.38	Foster et al.,2012; Coelho et al., 2012; Yokota et al., 2009; Fernandez-Carvalho et al., 2015; Amorim et al., 2015; Santos and Coelho, 2016
YFT – Yellowfin tuna	4	0.60	0.25-1.45	97.11%	0.26	Coelho et al., 2012; Fernandez-Carvalho et al., 2015; Amorim et al., 2015; Santos and

						Coelho, 2016
BUM – Atlantic blue marlin	4	1.48	0.86-2.53	90.31%	0.15	Coelho et al., 2012; Fernandez-Carvalho et al., 2015; Amorim et al., 2015; Santos and Coelho, 2016
SAI – Atlantic sailfish	3	0.67	0.17-2.71	92.41%	0.58	Coelho et al., 2012; Fernandez-Carvalho et al., 2015; Santos and Coelho, 2016
WHM – White marlin	3	0.52	0.13-2.12	97.08%	0.36	Coelho et al., 2012; Fernandez-Carvalho et al., 2015; Santos and Coelho, 2016

Table 3. Summary of the results of the meta-analysis on retention rates showing the summary effect size (relative risk, RR) and 95% confidence interval (CI), the number of experiments used (#exp) for each species. RR > 1 indicates a higher retention was calculated on wire leader vs nylon leader. If the p-value <0.05 the RR is significantly different from 1 (in bold). I² describes the percentage of total variation across studies that are due to heterogeneity rather than chance.

Species	**#exp**	**RR**	**CI**	**I²**	**p-value**	**References**
Elasmobranchs						
BSH – Blue shark	5	1.44	1.27-1.64	44.70%	**<0.0001**	Vega et al., 2009; Afonso et al., 2012; Santos et al., 2017; Santos & Coelho, 2016 44, 45, 51, 52
BTH – Bigeye thresher	2	0.37	0.06-2.25	64.20%	0.28	Santos et al., 2017; Santos & Coelho, 2016
FAL – Silky shark	3	1.22	0.59-2.50	49.67%	0.59	Afonso et al., 2012; Ward et al., 2008; Santos & Coelho, 2016 45,48,52
OCS – Oceanic whitetip	2	0.99	0.19-5.56	82.27%	0.99	Afonso et al., 2012; Santos & Coelho, 2016
PSK – Crocodile shark	2	0.62	0.39-1.00	0.0%	**0.05**	Afonso et al., 2012; Santos & Coelho, 2016
SMA – Shortfin mako	2	2.23	0.67-7.45	84.91%	0.19	Vega et al., 2009; Santos et al., 2017
PLS – Pelagic stingray	4	0.32	0.08-1.30	88.59%	0.11	Vega et al., 2009; Afonso et al., 2012; Santos et al., 2017; Santos & Coelho, 2016
Target species						
SWO – Swordfish	4	0.69	0.46-1.04	96.33%	0.08	Vega et al., 2009; Afonso et al., 2012; Santos et al., 2017; Santos & Coelho, 2016
ALB – Albacore	2	0.36	0.14-0.90	0.0%	**0.03**	Afonso et al., 2012; Santos et al., 2017
BET – Bigeye tuna	3	0.75	0.32-1.76	90.53%	0.51	Afonso et al., 2012; Santos et al., 2017; Santos & Coelho, 2016
YFT – Yellowfin tuna	4	0.23	0.06-0.93	86.47%	**0.04**	Vega et al., 2009; Afonso et al., 2012; Santos et al., 2017; Santos & Coelho, 2016
BUM – Atlantic blue marlin	3	0.63	0.41-0.97	0.0%	**0.04**	Afonso et al., 2012; Santos et al., 2017; Santos & Coelho, 2016
SAI – Atlantic sailfish	3	1.13	0.73-1.74	0.0%	0.58	Afonso et al., 2012; Santos & Coelho, 2016

Table 4. Summary of the results of the meta-analysis on mortality showing the summary effect size (relative risk, RR) and 95% confidence interval (CI), the number of experiments used (#exp) for each species. RR > 1 indicates a higher at-haulback mortality was calculated on circle hooks vs J-hooks. If the p-value <0.05 the RR is significantly different from 1 (in bold). I² describes the percentage of total variation across studies that are due to heterogeneity rather than chance.

Species	#exp	RR	CI	I²	p-value	References
Elasmobranchs						
BSH – Blue shark	8	0.82	0.71 - 0.96	92.15	**0.01**	Afonso et al., 2011; NMFS, 2011; Pacheco et al., 2011; Epperly et al. 2012; Coelho et al., 2012; Afonso et al., 2012; Fernandez-Carvalho et al. 2015; Amorim et al., 2015
BTH – Bigeye thresher	4	1.17	1.07 - 1.28	0.02	**<0.001**	NMFS, 2011; Coelho et al., 2012; Fernandez-Carvalho et al. 2015; Amorim et al., 2015
FAL – Silky shark	7	0.75	0.7 - 0.81	4.58	**<0.001**	Afonso et al., 2011; NMFS, 2011; Pacheco et al., 2011; Coelho et al., 2012; Afonso et al., 2012; Fernandez-Carvalho et al. 2015; Amorim et al., 2015
LMA – Longfin mako	3	1.2	0.7 - 2.08	0.0	0.51	Coelho et al., 2012; Fernandez-Carvalho et al. 2015; Amorim et al., 2015
OCS – Oceanic whitetip	6	0.73	0.57 - 0.95	0.0	**0.02**	Afonso et al., 2011; Pacheco et al., 2011; Coelho et al., 2012; Afonso et al., 2012; Fernandez-Carvalho et al. 2015; Amorim et al., 2015
POR – Porbeagle	3	0.89	0.79 - 1.01	3.32	0.06	NMFS, 2011; Epperly et al. 2012; Amorim et al., 2015
PSK – Crocodile shark	4	1.23	0.85 - 1.78	0.0	0.27	Pacheco et al., 2011; Afonso et al., 2012; Fernandez-Carvalho et al. 2015; Amorim et al., 2015
SMA – Shortfin mako	7	0.9	0.83 - 0.97	0.01	**<0.001**	Afonso et al., 2011; NMFS, 2011; Pacheco et al., 2011; Epperly et al. 2012; Coelho et al., 2012; Fernandez-Carvalho et al. 2015; Amorim et al., 2015
SPL – Scalloped hammerhead	4	0.79	0.73 - 0.86	0.0	**<0.001**	Afonso et al., 2011; NMFS, 2011; Pacheco et al., 2011; Coelho et al., 2012
SPZ – Smooth hammerhead	2	1.04	0.92 - 1.18	0.0	0.54	Coelho et al., 2012; Fernandez-Carvalho et al. 2015
TIG – Tiger shark	5	1.39	0.92 - 2.1	0.0	0.12	Afonso et al., 2011; NMFS, 2011; Coelho et al., 2012; Afonso et al., 2012; Fernandez-Carvalho et al. 2015
Target species						
SWO – Swordfish	6	0.94	0.9 - 0.98	95.02	**0.01**	NMFS, 2011; Pacheco et al., 2011; Epperly et al., 2012; Santos et al., 2012; Coelho et al., 2015; Amorim et al., 2015
ALB – Albacore	6	0.99	0.91 - 1.07	63.1	0.72	NMFS, 2011; Pacheco et al., 2011; Epperly et al., 2012; Santos et al., 2012; Coelho et al., 2015; Amorim et al., 2015
BET – Bigeye tuna	6	0.8	0.75 - 0.85	39.89	**<0.001**	NMFS, 2011; Pacheco et al., 2011; Epperly et al., 2012; Santos et al., 2012; Coelho et al., 2015; Amorim et al., 2015
BFT – Bluefin tuna	2	1.12	0.65 - 1.94	94.62	0.68	NMFS, 2011; Epperly et al., 2012
YFT – Yellowfin tuna	5	0.78	0.71 - 0.86	43.84	**<0.001**	NMFS, 2011; Pacheco et al., 2011; Santos et al., 2012; Coelho et al., 2015; Amorim et al., 2015

BUM – Atlantic blue marlin	5	0.82	0.75 - 0.89	0.0	**<0.001**	NMFS, 2011; Pacheco et al., 2011; Santos et al., 2012; Coelho et al., 2015; Amorim et al., 2015
SAI – Atlantic sailfish	2	0.76	0.59 - 0.98	1.81	**0.03**	Santos et al., 2012; Coelho et al., 2015
WHM – White marlin	4	0.84	0.79 - 0.9	0.0	**<0.001**	NMFS, 2011; Pacheco et al., 2011; Santos et al., 2012; Amorim et al., 2015

Table 5. Summary of the results of the meta-analysis on mortality showing the summary effect size (relative risk, RR) and 95% confidence interval (CI), the number of experiments used (#exp) for each species. RR > 1 indicates a higher at-haulback mortality was calculated on fish baited hooks vs squid baited hooks. If the p-value <0.05 the RR is significantly different from 1 (in bold). I² describes the percentage of total variation across studies that are due to heterogeneity rather than chance.

Species	#exp	RR	CI	I^2	p-value	References
Elasmobranchs						
BSH – Blue shark	4	1.71	1.50 – 1.95	69.59	**<0.001**	Coelho et al., 2012; Fernandez-Carvalho et al. 2015; Amorim et al., 2015; Santos & Coelho, 2016
BTH – Bigeye thresher	4	1.06	0.91 – 1.2	31.63	0.43	Coelho et al., 2012; Fernandez-Carvalho et al. 2015; Amorim et al., 2015; Santos & Coelho,2016
FAL – Silky shark	4	0.91	0.57 – 1.45	70.31	0.7	Coelho et al., 2012; Fernandez-Carvalho et al. 2015; Amorim et al., 2015; Santos & Coelho, 2016
LMA – Longfin mako	2	0.76	0.33 – 1.72	35.34	0.51	Coelho et al., 2012; Amorim et al., 2015
OCS – Oceanic whitetip	4	1.24	0.95 – 1.63	0.0	0.12	Coelho et al., 2012; Fernandez-Carvalho et al. 2015; Amorim et al., 2015; Santos & Coelho, 2016
PSK – Crocodile shark	3	0.9	0.58 – 1.42	14.21	0.66	Fernandez-Carvalho et al. 2015; Amorim et al., 2015; Santos & Coelho, 2016
SMA – Shortfin mako	4	1.11	0.95 – 1.30	0.0	0.18	Coelho et al., 2012; Fernandez-Carvalho et al. 2015; Amorim et al., 2015; Santos & Coelho, 2016
SPZ – Smooth hammerhead	4	0.93	0.82 – 1.05	6.41	0.25	Coelho et al., 2012; Fernandez-Carvalho et al. 2015; Amorim et al., 2015; Santos & Coelho, 2016
Target species						
SWO – Swordfish	4	1.02	1 - 1.04	40.61	**0.05**	Santos et al., 2012; Coelho et al., 2015; Amorim et al., 2015; Santos & Coelho, 2016
ALB – Albacore	3	1.01	0.93 - 1.09	0.0	0.86	Santos et al., 2012; Coelho et al., 2015; Amorim et al., 2015
BET – Bigeye tuna	4	0.99	0.9 - 1.1	0.0	0.91	Santos et al., 2012; Coelho et al., 2015; Amorim et al., 2015; Santos & Coelho, 2016
YFT – Yellowfin tuna	4	1.03	0.72 - 1.47	83.61	0.87	Santos et al., 2012; Coelho et al., 2015; Amorim et al., 2015; Santos & Coelho, 2016
BUM – Atlantic blue marlin	4	0.95	0.84 - 1.07	0.03	0.39	Santos et al., 2012; Coelho et al., 2015; Amorim et al., 2015; Santos & Coelho, 2016
SAI – Atlantic sailfish	3	1.07	0.88 - 1.29	0.0	0.5	Santos et al., 2012; Coelho et al., 2015; Amorim et al., 2015
WHM – White marlin	3	1.1	0.99 - 1.22	0.0	0.07	Santos et al., 2012; Coelho et al., 2015; Amorim et al., 2015

Table 6. Summary of the results of the meta-analysis on at-haulback mortality showing the summary effect size (relative risk, RR) and 95% confidence interval (CI), the number of experiments used (#exp) for each species. RR > 1 indicates a higher at-haulback mortality was calculated on wire vs nylon leader. If the p-value <0.05 the RR is significantly different from 1 (in bold). I² describes the percentage of total variation across studies that are due to heterogeneity rather than chance.

Species	#exp	RR	CI	I²	p-value	References
Elasmobranchs						
BSH – Blue shark	3	0.88	0.76 – 1.00	0.0	0.06	Afonso et al., 2012; Santos et al., 2017; Santos & Coelho, 2016
BTH – Bigeye thresher	2	0.94	0.46 – 1.92	0.0	0.87	Santos et al., 2017; Santos & Coelho, 2016
FAL – Silky shark	2	0.86	0.45 – 1.63	75.62	0.65	Afonso et al., 2012; Santos & Coelho, 2016
PSK – Crocodile shark	3	1.47	0.78 – 2.75	35.52	0.23	Afonso et al., 2012; Santos et al., 2017; Santos & Coelho, 2016
Target species						
SWO – Swordfish	2	0.93	0.81 - 1.07	90.57	0.30	Santos et al., 2017; Santos & Coelho, 2016
ALB – Albacore	2	0.88	0.32 - 2.42	0.0	0.81	Santos & Coelho, 2016
BET – Bigeye tuna	2	0.92	0.75 - 1.14	0.0	0.47	Santos et al., 2017; Santos & Coelho, 2016
YFT – Yellowfin tuna	2	1.15	0.54 - 2.48	35.44	0.72	Santos et al., 2017; Santos & Coelho, 2016

Figures ¶

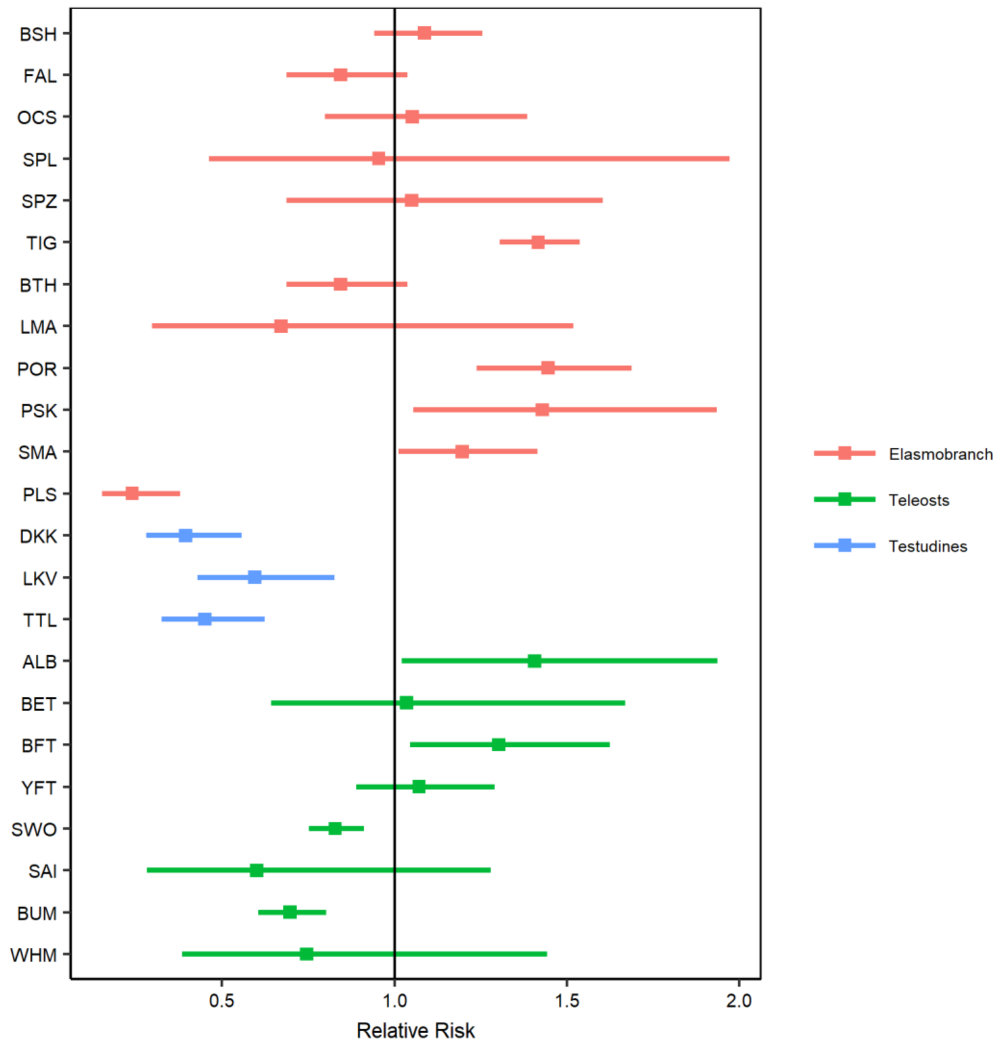

Figure 1. Effect size (relative risk—RR) of hook type (circle or J-hook) on retention rate by species. Squares represent mean values, and lines show the Wald-type 95% confidence intervals estimated by the model. RR > 1 indicates a higher retention was calculated on circle hooks vs J-hooks.

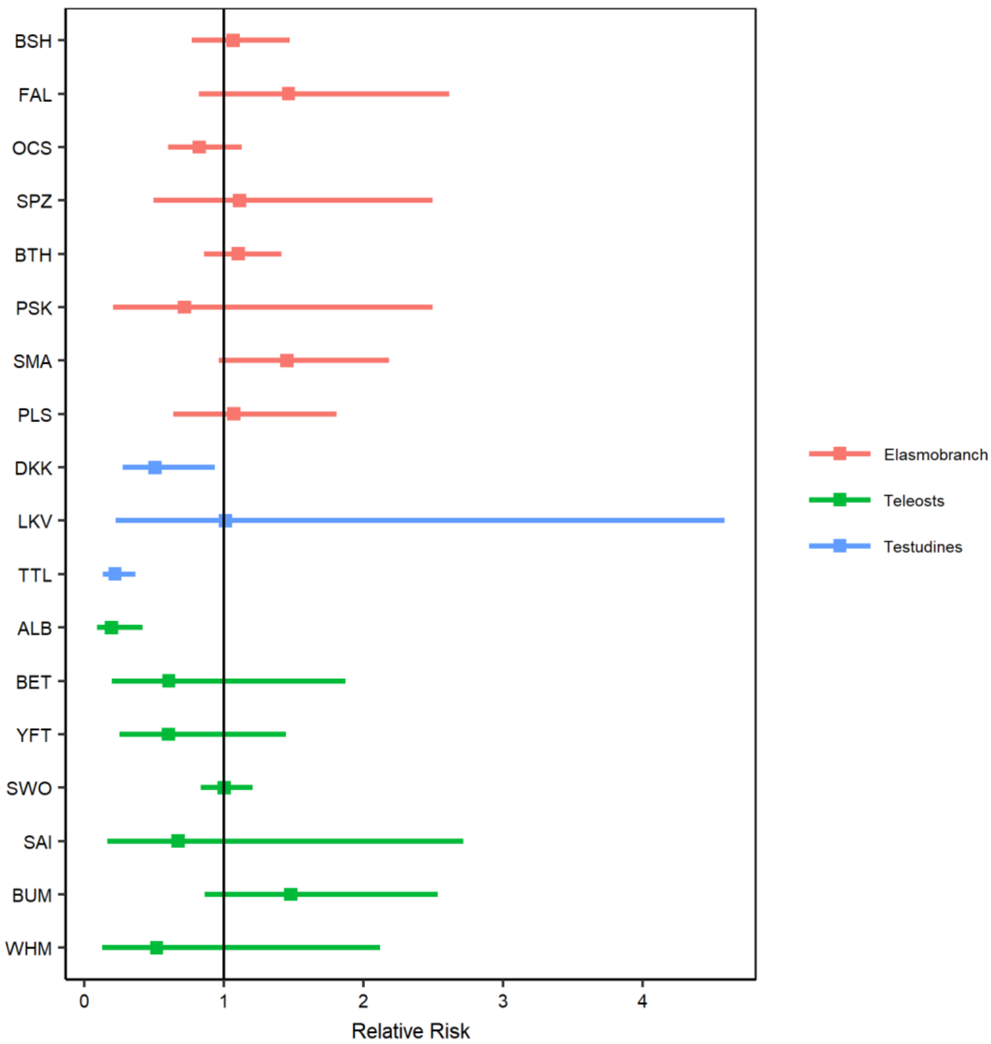

Figure 2. Effect size (relative risk—RR) of bait type (squid or fish) on retention rate by species. Squares represent mean values, and lines show the Wald-type 95% confidence intervals estimated by the model. RR > 1 indicates a higher retention was calculated on fish baited hooks vs squid baited hooks.

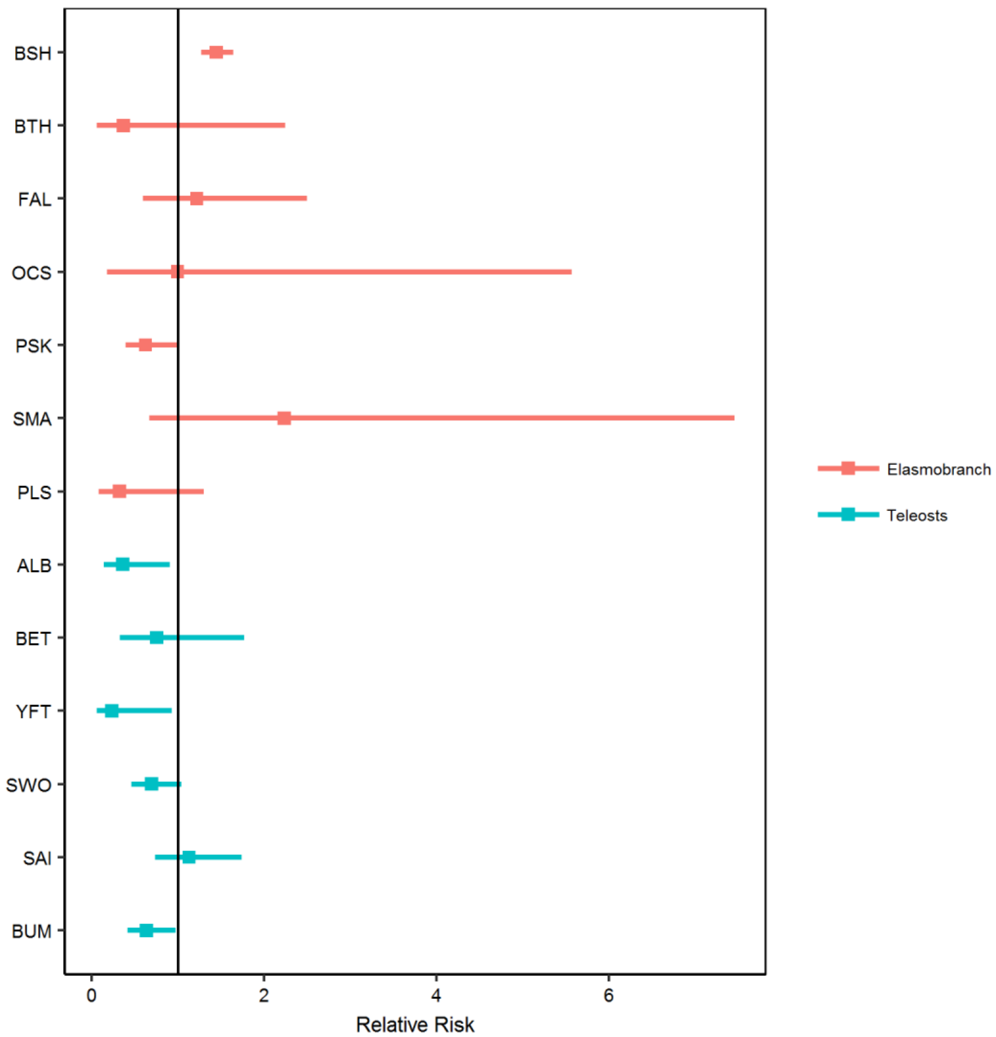

Figure 3. Effect size (relative risk—RR) of wire leaders compared with nylon leaders on retention rate by species. Squares represent mean values, and lines show the Wald-type 95% confidence intervals estimated by the model. RR > 1 indicates a higher retention was calculated on wire leader vs nylon leader.

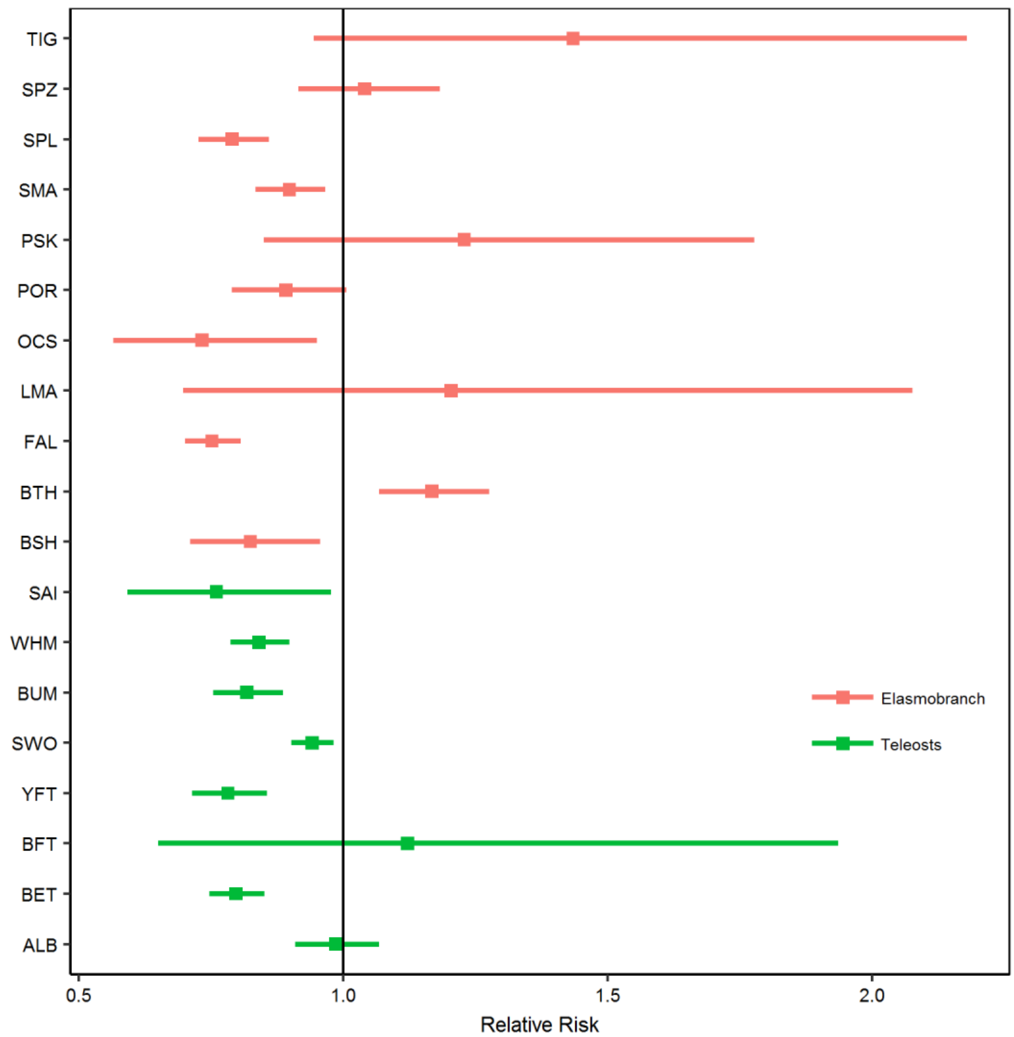

Figure 4. Effect size (relative risk—RR) of hook type (circle or J-hook) on at-haulback mortality rate by species. Squares represent mean values, and lines show the Wald-type 95% confidence intervals estimated by the model. RR > 1 indicates a higher mortality was calculated on circle hooks vs J-hooks.

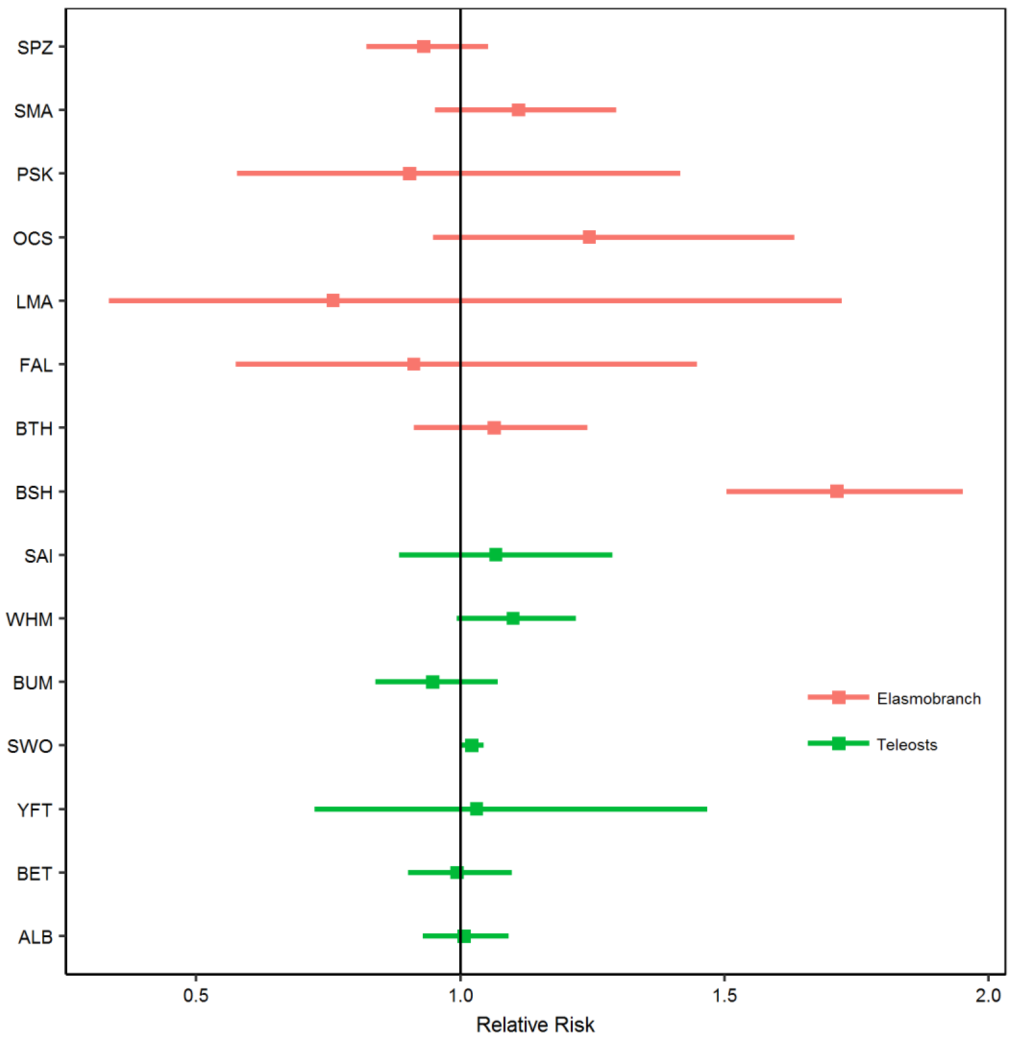

Figure 5. Effect size (relative risk—RR) of bait type (squid or fish) on at-haulback mortality rate by species. Squares represent mean values, and lines show the Wald-type 95% confidence intervals estimated by the model. RR > 1 indicates a higher mortality was calculated on fish baited hooks vs squid baited hooks.

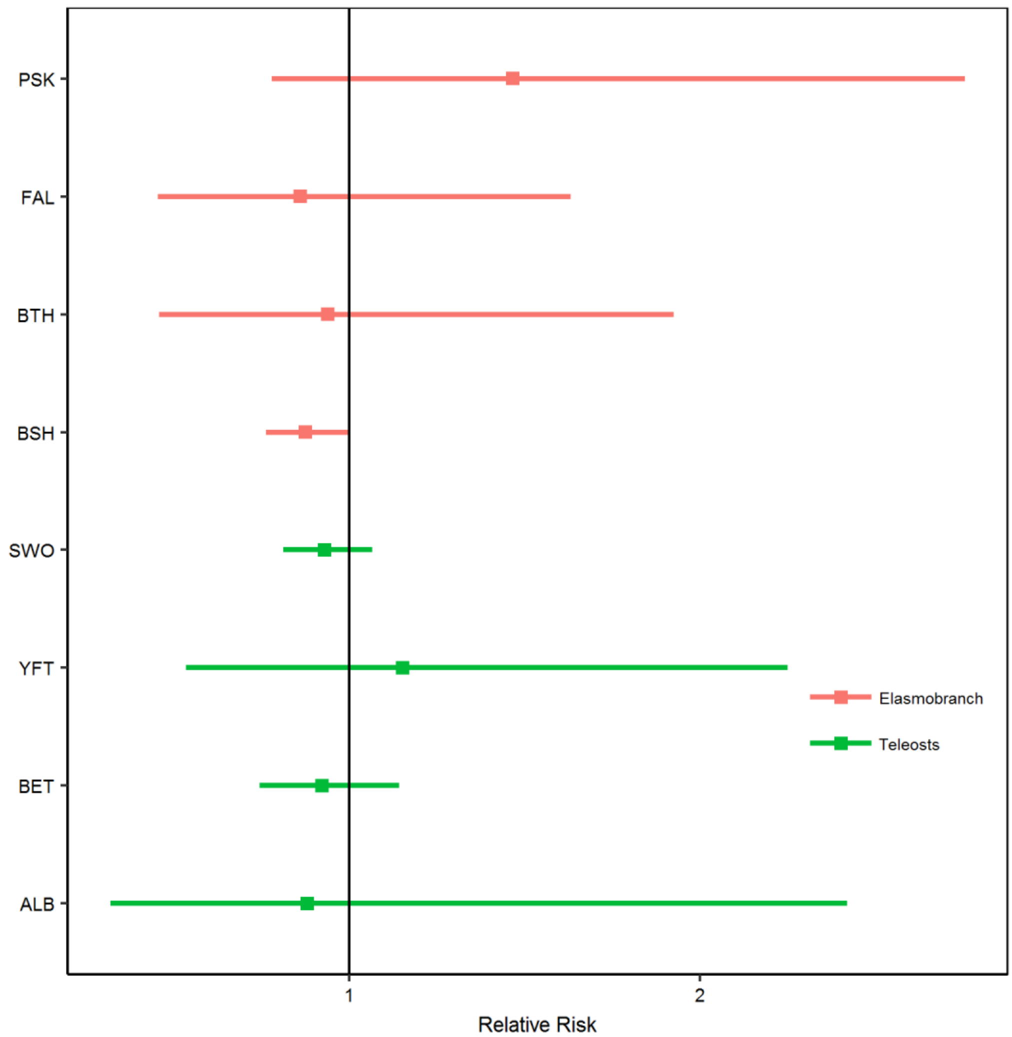

Figure 6. Effect size (relative risk—RR) of wire leaders compared with nylon leaders on at-haulback mortality rate by species. Squares represent mean values, and lines show the Wald-type 95% confidence intervals estimated by the model. RR > 1 indicates a higher mortality was calculated on wire leader vs nylon leader.