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Introduction

Catch and release (CAR) fishing has been used in the United States since the 1950's as a regulation to promote sustainable fisheries and is widely accepted by most anglers to be beneficial in fisheries management. Despite the conservation goals of CAR fishing regulations, for many species, stress of capture can lead to physiological trauma that often results in increased release mortality (Davis 2010, Campbell et al. 2010a). Stresses experienced by fish during CAR fishing can include hook trauma, physical overexertion, barotraumas, rapid thermal change, air exposure, and physical handling (Davis et al. 2001, Rummer and Bennett 2005, Nieland et al. 2007, Jarvis and Lowe 2008). The effects of CAR fishing can be particularly problematic for marine species such as gag (*Mycteroperca microlepis*) that inhabit relatively deep water and possess a physoclistus gas bladder. If CAR regulations create high discard and release mortality rates, they may in fact be conflicting with the goals of management which is to reduce fishing mortality for specific size ranges or ages of fish. Commercial and recreational regulations in the gag fishery have generally focused on implementing annual time closures and minimum size regulations both of which increase the number regulatory discards.

There have been four gag grouper assessments in the Gulf of Mexico (GOM)(Schirripa and Goodyear 1994, Schirripa and Legault 1997, Turner et al. 2001, SEDAR 2006a), two assessments in the South Atlantic (Potts and Manooch 1998, SEDAR 2006a), and one GOM update assessment (SEDAR 2010). The first GOM gag assessment applied a range of discard mortality estimates (0 – 35%) to test model sensitivity to a range of values (Table 1; Schirripa and Goodyear 1994). These values were based on the review of discard mortality estimates for a variety of reef fish from a tag and recapture project but were not specific to gag grouper (Schirripa et al. 1993). The 1997 GOM gag assessment used discard mortality estimates of 20%

(recreational) and 33% (commercial) (Table 1; Schirripa and Legault 1997). These values were slightly higher than what was calculated from observations onboard commercial vessels (SEFSC 1995), but they were similar to values used in other reef fish assessments at that time (e.g. red snapper). The 1998 south Atlantic gag assessment applied two release mortality estimates (20% and 50%) to model runs regardless of fishing sector (Table 1; Potts and Manooch 1998). The lower discard mortality estimate was based on surface observations of gag released on headboats. The investigators felt that a discard estimate of 20% was low; therefore, assessment models were compiled with an additional discard estimate of 50%. The 2001 GOM gag assessment relied on discard mortality values from previous assessments, and was set at 20% for the recreational and 30% for the commercial sector (Table 1; Turner et al. 2001). The most recent assessments for gag in the GOM and South Atlantic used logistic regression to estimate a depth-mortality function, and that function relied on the published estimates of Burns et al. 2002 and McGovern et al. 2005 (Table 1). These estimates were based on both passive tag-recapture and caging studies (Table 1). The tag-recapture estimates from McGovern et al. (2005) were treated as release mortality rates when in fact they were recapture rates and furthermore those estimates did not account for spatio-temporal effects of effort in the fishery. Discard mortality has generally been set at higher rates in the commercial sector because it is believed that commercial vessels fished in deeper waters and had lower opportunities for quick release of gag compared to the recreational sector.

Methods used to derive mortality estimates each have their benefits, biases and shortcomings that require exploration. In general problems associated with estimating mortality typically are associated with the timing of observation, exclusion of predators, insufficient tag returns, or sample size issues (Campbell 2010a). Methods used to derive estimates include surface observation, cage studies, hyperbaric chamber simulations, and tag-recapture models (Table 1). Mortality estimates from these studies are broadly categorized as either immediate (seconds to minutes), or delayed (hours to days). These different types of experiments, and therefore estimates, are often treated as equivalents when used in an assessment. While this aggregate approach is pragmatic, particularly when there is very little data available, it is likely resulting in the use of poorly matched or imprecise estimates. Due to the wide range in reported mortality rates from the various studies, the estimates used to parameterize previous assessment models, and the convoluted nature of the potential interacting factors, a comprehensive evaluation of pertinent research is needed.

Selection of appropriate release mortality estimates to use in a stock assessment requires good knowledge of estimation methods and their associated biases. Meta-analytical methods allow inclusion of all available point estimates, includes a sample size weighting scheme, and allows for the use of covariates in a mixed-effects modeling approach (Viechtbauer 2010). The meta-analysis approach was developed, and is useful, because it reduces the introduction of bias that hinders non-parametric approaches often found in review papers (Sterne et al. 2000, Nakagawa and Santos 2012). The human selection element is reduced thereby allowing data to more properly guide data analysis and decision making processes. We present a meta-analysis approach with the intent of identifying critical issues and deriving a model of release mortality in the Gulf of Mexico gag grouper fishery as a function of important covariates such as depth, estimation type, fishing sector, gear used, and venting procedures employed.

We present a meta-analysis approach with the intent of identifying critical issues and deriving a more precise release mortality estimate. Meta-analysis allows inclusion of all available point estimates, includes a sample size weighting scheme, and allows for the inclusion of explanatory variables in a mixed-effects modeling approach (Viechtbauer 2010). The meta-analysis approach was developed, and is useful, because it reduces the introduction of bias that hinders non-parametric approaches often found in review papers (Sterne et al. 2000, Nakagawa and Santos 2012).

Methods

Data used in this meta-analysis were compiled from 13 sources that produced 35 distinct release mortality estimates the details of which are covered in previous sections. Data were extracted from each publication relating to proportional or percent mortality, water depth (m), study type (surface release, cage, tag-recapture), type of estimate derived (immediate or delayed), fishing sector evaluated (commercial or recreational), season (summer, annual), hook type used in the study (circle or j hook), degree of venting (no venting, intermittent venting, or 100% venting), and sample size (*n*). No data exclusions were made in the original run, however a second model run excluded the McGovern (2005) estimates because it was discovered that they are actually representative of recapture rates rather than release mortality rates.

The meta-analytical model used is a special case of a weighted general linear model as detailed in the metafor R package (Viechtbauer 2010). The analysis was performed on effect size (*es*), where *es* is the logit-transformed proportion and was calculated as:

$$es = \log \left(\frac{x_i}{(n_i - x_i)}\right)$$

where x_i is the total number of individuals experiencing mortality and n_i is the total sample size. The estimate and the corresponding sampling variance were calculated using the escalc function in metafor (Viechtbauer 2010).

We fit *es* estimates in a mixed-effects model to evaluate the effects of depth, estimate type, fishing sector, hook, and venting compliance (Viechtbauer 2010). The nature of binary values (i.e. setting the value to 0 or 1) often fully defines all possible combinations for membership in a treatment group. Therefore it is not necessary to explicitly include all binary variables in a model although they are implicitly represented in the model. For instance, the only estimate type included in the model was delayed, and therefore any values set equal to 0 for the ‘delayed’ variable indicate values associated with immediate estimates. The dummy-coded fishing sector variable was commercial (0 = recreational). Dummy-coded seasonal variables included in the model were annual (0 = summer). The dummy coded hook variables included in the model were circle, and mixed (0 = J hook). Dummy coded venting compliance variables included in the model were venting (100% venting), and intermittent venting (0 = no venting). The full estimated model is shown, below:

$$Prob(mortality) \sim depth\ + estimate\ type\ + hook\ type\ + venting\ treatment$$

Where depth of capture in meters is modeled as a continuous variable and all other variables are modeled as categorical. Estimate type refers to the timing of the mortality observation and is classified as immediate or delayed. Hook type is classified as J, circle or mixed. Venting treatment is categorized as no venting took place or some venting occurred.

Heterogeneity (τ^2) was estimated using restricted maximum-likelihood (REML) then coefficients for μ, $\beta_0,\ldots,\beta_{p'}$ were estimated using weighted least squares in which each *es* estimate is weighted by the inverse of its variance. Wald-type tests and confidence intervals were calculated for μ, $\beta_0,\ldots,\beta_{p'}$ assuming normality. Based on the fitted model we calculated predicted values, and residuals. Cochran’s *Q*-test was used to assess the amount of heterogeneity among studies (i.e. a null hypothesis of $\tau^2 = 0$). Predicted values and associated upper and lower bounds were then converted back to proportions by taking the inverse of the logit transformed effect size data as:

$$Proportion = \frac{exp^{es}}{(1 + exp^{es})}$$

Average model predictions were evaluated by giving equal weighting to the coefficients within fishing sector, venting, season and hook type and inputting a depth range of 10 to 200 m. Venting model predictions were evaluated by toggling the venting effect on. Seasonal model predictions were evaluated by toggling each season variable individually. All other coefficients for the venting and seasonal predictions were set to the intercept and both effects were evaluated for each fishing sector separately.

Results

Meta-analysis of the release mortality estimates when including the McGovern (2005) data showed significant effects (Table 2) for depth, immediate estimates (Ti), both venting treatments (Vs and Vn), and J-hooks (Hj). This run of the model reported an AIC value of 105.05. Model coefficients and graphs indicated that depth, and J-hooks were the most influential factors increasing mortality while venting and immediate estimates showed negative effects on mortality (Table 2, Figures 1-3). The amount of heterogeneity in effect size from the mixed-model was estimated to be τ^2=0.6. Cochran's Q_E test for the mixed-model also shows significant residual heterogeneity (Q_E = 2938, df = 28, p < 0.0001), indicating that the model did not fully explain the observed variation in release mortality estimates. Average model predictions (equal weighting of the coefficients, baseline in the graphs) and inputting a depth range of 10 to 200 m resulted in predicted mortality from 0 to 95% and was heavily dependent on depth and estimate type (Figures 1-3). Graphically represented data from figures 1-3 are available in tabular format in Appendix A.

A second run of the model with McGovern data removed showed significant effects for depth, immediate estimates and for estimates that had some amount of venting. This run of the model reported an improvement in AIC value of 81.36. Similar to the first model run coefficients and graphs show that depth was the most influential factor increasing mortality while venting and immediate estimates showed negative effects on mortality (Table 2, Figures 4-5). However in this second model run the effect of J-hooks was not significant. The amount of heterogeneity in effect size from the mixed-model was estimated to be τ^2=0.67. Cochran's Q_E test for the mixed-model also shows significant residual heterogeneity ($Q_E = 2553$, $df = 19$, $p < 0.0001$), indicating that the model did not fully explain the observed variation in release mortality estimates however this second run explained more variation than the first. Average model predictions (equal weighting of the coefficients, baseline in the graphs) and inputting a depth range of 10 to 200 m resulted in predicted mortality from 0 to 78% and was also heavily dependent on depth and estimate type (Figures 4-5). Graphically represented data from figures 4-5 are available in tabular format in Appendix B.

Discussion

Similar to many other studies, and across many taxa, depth plays a significant role in release mortality showing increasing rates with increasing depth. Presence of a positive correlation between depth and mortality is frequently reported in the literature, and the relationship is thought to be primarily associated with injuries sustained during decompression, including gas bladder overexpansion/rupture, esophageal eversion, cloacal prolapse, exophthalmia, and gas infusion into vital organs (Davis 2002, Rummer and Bennett 2005, Hannah 2008). The effect of depth on release mortality likely interacts with a thermal component as fish are exposed to thermoclines as they are rapidly brought to the surface. Like in the meta-analysis of red snapper the literature used in this report also had a scarcity of water temperature data. Most of the studies simply reported an annual release mortality rate with no information available on even rough seasonal treatments. Evidence of unexplained residual heterogeneity in the mixed-model might be associated with insufficient treatment of these thermal components.

Surface observations underestimate release mortality which is a result that was replicated in a meta-analysis of release mortality in the red snapper fishery (Campbell et al. 2013). Underestimation associated with the immediate measurements of release mortality from surface observations likely indicate that the effects of catch-and-release fishing are manifested over longer time frames than can be measured within minutes. While these surface release estimates are easy to collect and generally produce very large sample sizes they likely should be treated as underestimates of the true mortality rate and emphasis should be placed on methods that measure long term effects of CAR fishing.

The primary difference between the two model runs was the loss in significance of the J-hook effect, although this effect in the original model was largely confounded by the McGovern study in which J-hooks were used exclusively. Reported mortality rates from the McGovern study were estimated using models that did not incorporate spatio-temporal effort and survivorship was estimated outside of the recapture model itself, therefore the effect that is attributed to J-hooks in the original model run may in fact just be a relic of the estimation methodology used by McGovern rather than a true hook effect. The removal of the McGovern data reduces the predicted mortality rates particular for the deepest depths. Finally, other studies available on recapture rate would suggest that there is no difference in survivorship between gag caught on circle versus those caught using J hooks (Sauls and Ayala 2012).

In lieu of finding ways to reduce catch of undersized fish, gas bladder venting is often advocated as a method to reduce the negative impacts of barotrauma. Similar to red snapper there is a positive effect on survival for fish that are vented. Some of this effect might be associated with the impact of the immediate release mortality estimates in the model. Venting clearly enhances submergence ability and therefore the observed differences are likely associated with the frequency of venting, or compliance with recently implemented venting regulations. At this time it is unclear if the effects of venting have significant impacts on survivorship over longer time frames than are measured by surface observation. Minimally, venting allows fish released at the surface to descend to protective habitat and furthermore surface release is currently the most frequently practiced release methodology in the fishery. Recent research in the red snapper fishery has focused attention on bottom-release devices (Diamond et al. 2011, Stunz and Curtis 2012), about which there does not appear to be any current information available for the utility of these devices in the Gag fishery. The concept of using a bottom release device is similar to venting in that the goal is to reverse the effects of barotrauma, but instead of deflating the bladder by puncture it is deflated by recompression at depth. This might represent a fruitful area of research that could prove to be beneficial in the gag fishery.

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Table 1. Meta-data of discard mortality estimates for gag grouper (in order by year of citation). Discard mortality may refer to immediate (surface observation), short-term (cage or experimental study, or long-term (tag-recapture study).

Depth (m)	Season	Region	Method	Size Range (mm) Mean or Range	Discard Mortality	N	Hooks	Mode	Vent	Citation
Unknown	All year	Gulf of Mexico	Surface Observation		7.92% (HL) 2.35% (LL)	89,929 (HL) 9,827 (LL)	Unknown	Commercial, Vertical line	Unknown	Commercial logbooks SEDAR33
11-220 (mean 70)	All year	Gulf of Mexico	Surface Observation	310-1300 800 (mean)	11.9% (LL)	261	Circle and J	Commercial, Long line	Selective	Gulak and Johnson 2013 SEDAR33-DW23
35-115 (majority 40-80)	All year	Gulf of Mexico	Surface Observation	305-1168 (HL) 356-1321 (LL)	2.25% (HL) 11.62% (LL)	3,517 (HL) 1,222 (LL)	Unknown	Commercial, Vertical line	Unknown	Johnson 2013 SEDAR33-DW13
10-70 (mean 38.5)	All year	Eastern Gulf of Mexico – FL, AL	Surface observation	170-980	1.19%	5141	Circle and J	Hook and line, Headboats	Selective	Sauls and Cermak 2013 SEDAR33-DW
10-70 (mean 38.5)	All year	Eastern Gulf of Mexico – FL, AL	Surface observation	260-900	0.52%	1725	Circle and J	Hook and line, Headboats	Selective	Sauls and Cermak 2013 SEDAR33-DW05
0-10	All Year	NE Gulf of Mexico (west FL shelf)	Tag-recapture		2.5%, 11.9%, 21.3%	3,832	Circle or J	Recreational, hook and line	Selective	Sauls 2013 SEDAR33-DW06
11-20	All Year	NE Gulf of Mexico (west FL shelf)	Tag-recapture		1.9%, 11.5%, 21.1%	3,832	Circle or J	Recreational, hook and line	Selective	Sauls 2013 SEDAR33-DW06
21-30	All Year	NE Gulf of Mexico (west FL shelf)	Tag-recapture		9.0%, 16.4%, 23.8%	3,832	Circle or J	Recreational, hook and line	Selective	Sauls 2013 SEDAR33-DW06
31-40	All Year	NE Gulf of Mexico (west FL shelf)	Tag-recapture		21.2%, 24.9%, 28.6%	3,832	Circle or J	Recreational, hook and line	Selective	Sauls 2013 SEDAR33-DW06
41-50	All Year	NE Gulf of Mexico (west FL shelf)	Tag-recapture		25.8%, 28.4%, 31.0%	3,832	Circle or J	Recreational, hook and line	Selective	Sauls 2013 SEDAR33-DW06
51-60	All Year	NE Gulf of Mexico (west FL shelf)	Tag-recapture		20.1%, 24.2%, 28.3%	3,832	Circle or J	Recreational, hook and line	Selective	Sauls 2013 SEDAR33-DW06

Depth (m)	Season	Region	Method	Size Range (mm) Mean or Range	Discard Mortality	N	Hooks	Mode	Vent	Citation
61-90	All Year	NE Gulf of Mexico (west FL shelf)	Tag-recapture		26.3%, 30.4%, 34.5%	3,832	Circle or J	Recreational, hook and line	Selective	Sauls 2013 SEDAR33-DW06
										Sauls 2013 SEDAR33-DW06
Range of depths	All Year	NE Gulf of Mexico (west FL shelf)	Hook location	500	3.77% potentially lethal hook injuries	1,433	Circle	Recreational, hook and line	Selective	Sauls and Ayala 2012
Range of depths	All Year	NE Gulf of Mexico (west FL shelf)	Hook location	500	5.44% potentially lethal hook injuries	772	J	Recreational, hook and line	Selective	Sauls and Ayala 2012
15-45	All Year	South Atlantic - NC	Cage and onboard holding tanks	295-573 476 (SE 14)	21.9 %	33	Circle or J	Recreational, Hook and line	Vented by lowering in cages	Overton et al. 2008 Overton and Zabowski 2003
19-50	All Year	South Atlantic - Onslow Bay, NC	Surface observations		0%	55	J Hooks electric reels	Commercial, vertical line	No	Rudershausen and Buckel 2007
unknown	All Year	NE Gulf of Mexico (west FL shelf)	Surface observations		14.7% dead, 0.9% kept	41,683	Not reported	Commercial, vertical line	Not reported	Commerical logbooks SEDAR 2006b
unknown	All year	NE Gulf of Mexico (west FL shelf)	Tag-recapture		8.98 % recapture N = 569	6336	Not reported	Commercial and Recreational, Gear unknown	Not reported	SEDAR 2006d
unknown	All year	NE Gulf of Mexico (west FL shelf)	Tag-recapture		9.17% recapture N = 504	5495	Not reported	Recreational, Gear unknown	Not reported	SEDAR 2006d
unknown	All year	NE Gulf of Mexico (west FL shelf)	Tag-recapture		7.85% recapture N = 35	446	Not reported	Commercial, Gear unknown	Not reported	SEDAR 2006d

Depth (m)	Season	Region	Method	Size Range (mm) Mean or Range	Discard Mortality	N	Hooks	Mode	Vent	Citation
11-20	All Year	South Atlantic - NC-FL	Tag-recapture	578 (SE 166)	14.2463%	253	Not reported	Commercial, gear unknown	Yes-all	
21-30	All Year	South Atlantic - NC-FL	Tag-recapture	70.9 (SE 119)	23.0274%	1,221	Not reported	Commercial, gear unknown	Yes-all	
31-40	All Year	South Atlantic - NC-FL	Tag-recapture	771 (SE 105)	35.0113%	730	Not reported	Commercial, gear unknown	Yes-all	
41-50	All Year	South Atlantic - NC-FL	Tag-recapture	828 (SE 77)	49.2420%	871	Not reported	Commercial, gear unknown	Yes-all	
51-60	All Year	South Atlantic - NC-FL	Tag-recapture	842 (SE 81)	63.5966%	357	Not reported	Commercial, gear unknown	Yes-all	
61-70	All Year	South Atlantic - NC-FL	Tag-recapture	832 (SE 56)	75.8801%	321	Not reported	Commercial, gear unknown	Yes-all	
71-80	All Year	South Atlantic - NC-FL	Tag-recapture	787 (one length)	84.9966%	39	Not reported	Commercial, gear unknown	Yes-all	
81-90	All Year	South Atlantic - NC-FL	Tag-recapture	Not reported	91.0728%	57	Not reported	Commercial, gear unknown	Yes-all	
91-100	All Year	South Atlantic - NC-FL	Tag-recapture	Not reported	94.8377%	11	Not reported	Commercial, gear unknown	Yes-all	McGovern et al. 2005 SEDAR2006c
18.8-85.2 Mean = 29.2	Summer/ Fall	South Atlantic - NC	Surface observations	683 (SE 119)	0%	29	J Hooks electric reels	Commercial, hook and line	No	Rudershausen et al. 2005
20-50	Sumer	NE Gulf of Mexico (Apalachicola)	Cage	< 500	Estimated LD50 = 43.7 m (50% of the gag die at this depth)	67	Circle	Commercial Gear electric reels	Vented by lowering in cages.	Burns et al. 2002
54 and 75	Summer/ Fall	NE Gulf of Mexico (west FL shelf)	Cage	790-840	100%	3	Not reported, likely J	hook and line	No	Wilson and Burns 1996

Table 2. Meta-analysis model coefficients, standard error about the coefficients and parameter significance values.

	With McGovern (2005)					Without McGovern (2005)				
	estimate	se	zval	pval		estimate	se	zval	pval	
itrcpt	0.2014	0.7449	0.2704	0.7868		0.4515	0.8503	0.531	0.5954	
Dpth	0.0349	0.0071	4.9163	<.0001	***	0.0209	0.0099	2.1194	0.0341	*
Ti	-3.9339	0.5741	-6.852	<.0001	***	-3.6436	0.666	-5.4707	<.0001	***
Hc	-0.4626	0.3604	-1.2837	0.1993		-0.3232	0.3887	-0.8314	0.4058	
Hj	0.7715	0.3774	2.0441	0.0409	*	-1.012	1.812	-0.5585	0.5765	
Vs	-2.5413	0.6359	-3.9965	<.0001	***	-2.4004	0.7029	-3.415	0.0006	***
Vn	-1.8951	0.8612	-2.2004	0.0278	*	-0.4146	1.6193	-0.256	0.7979	

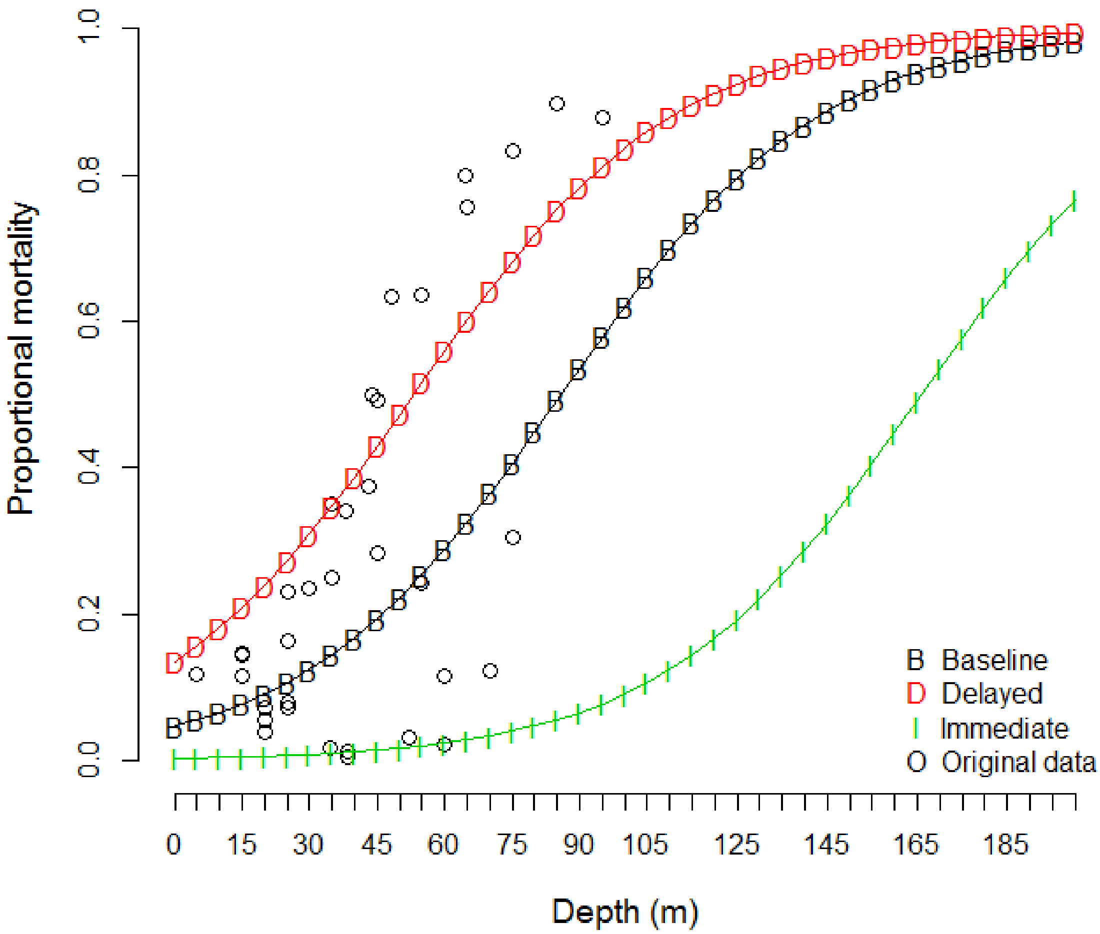

Figure 1. Model run including McGovern (2005) data showing the effect of depth, delayed, and immediate measurement of release mortality.

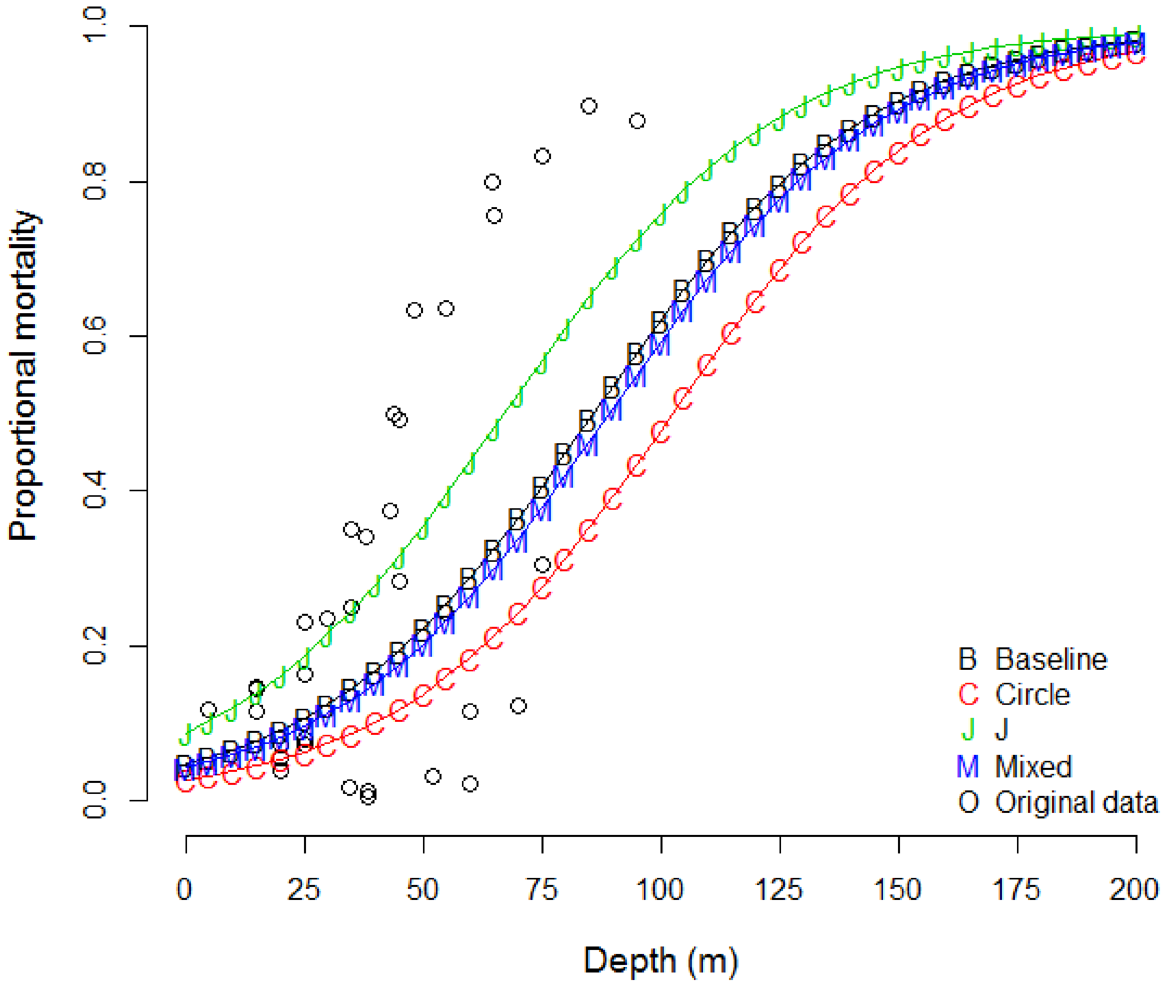

Figure 2. Model run including McGovern (2005) data showing the effects of depth and hook type on release mortality.

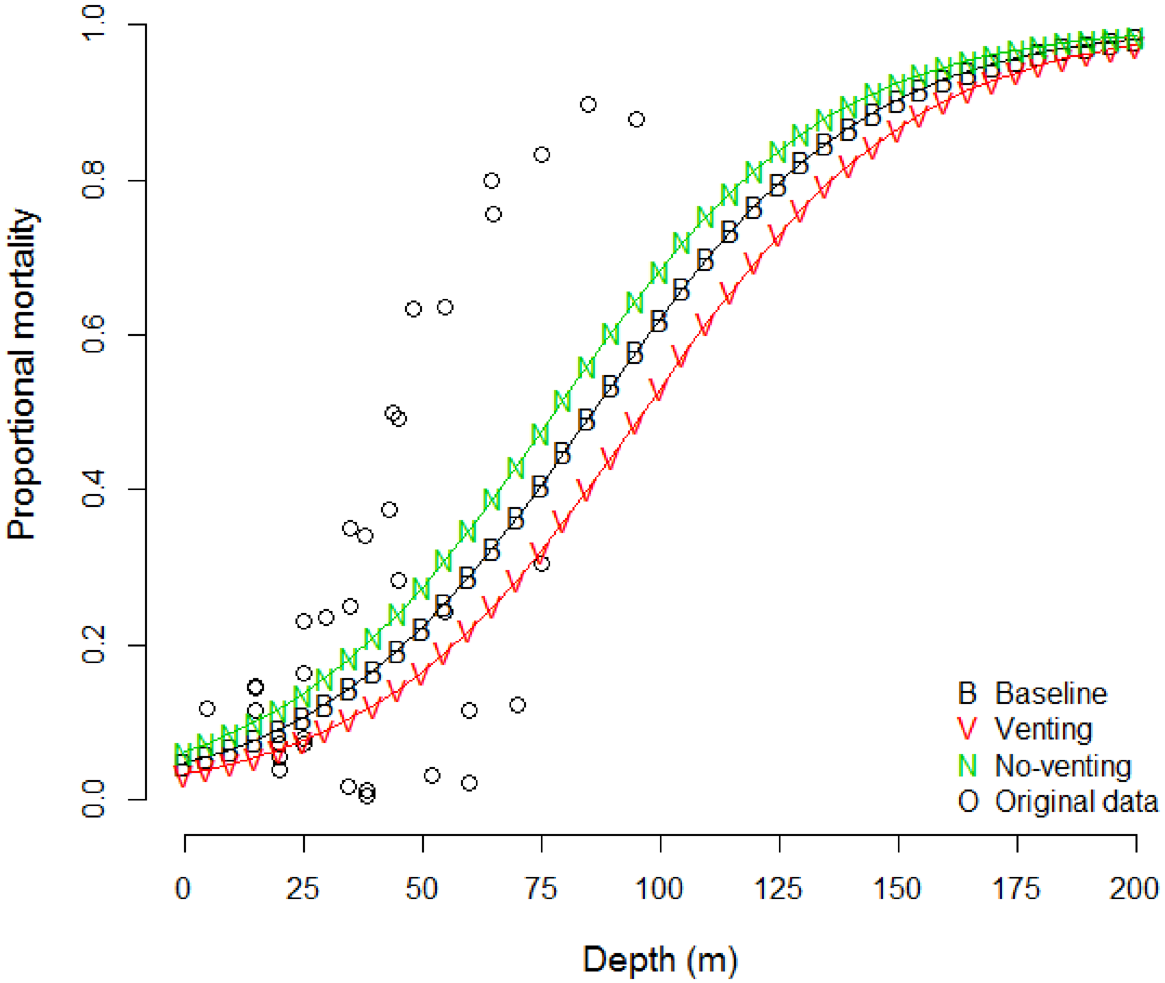

Figure 3. Model run including McGovern (2005) data showing the effect of depth and venting and no-venting treatments on release mortality.

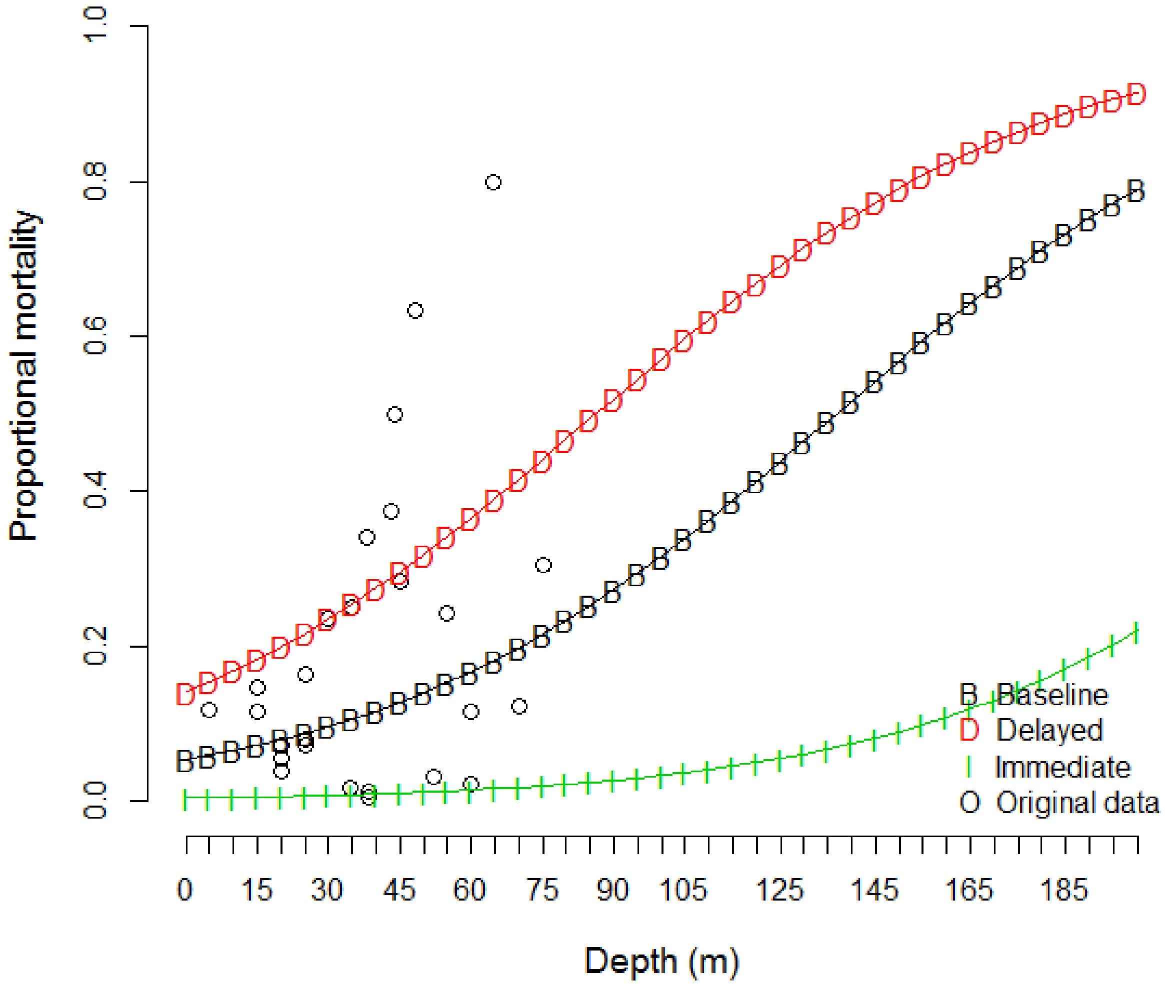

Figure 4. Model run excluding McGovern (2005) data showing the effect of depth and delayed versus immediate measurement of release mortality.

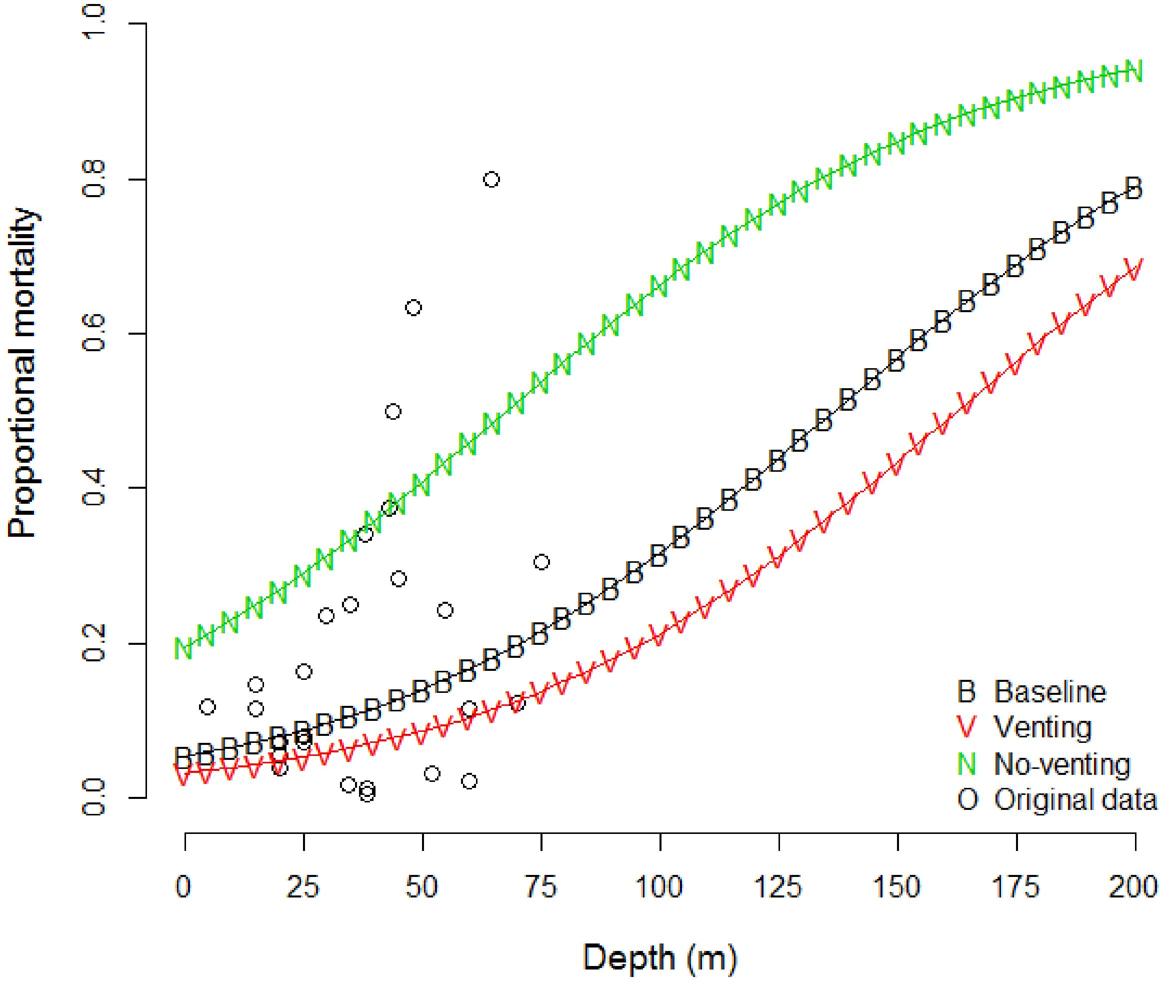

Figure 5. Model run excluding McGovern (2005) data showing the effect of depth, venting and no-venting treatments on release mortality.

Appendix A. Mortality proportions by depth associated with graphs 1-3 (McGovern included).

Depth(m)	Baseline	Delayed	Immediate	Circle hooks	J hooks	Mixed hooks	Vent	No Vent
0	0.048	0.136	0.003	0.027	0.088	0.043	0.034	0.062
5	0.056	0.158	0.004	0.032	0.103	0.050	0.040	0.073
10	0.066	0.182	0.004	0.038	0.120	0.059	0.047	0.086
15	0.078	0.209	0.005	0.045	0.140	0.070	0.055	0.100
20	0.092	0.240	0.006	0.053	0.162	0.082	0.065	0.117
25	0.107	0.273	0.007	0.063	0.187	0.096	0.077	0.137
30	0.125	0.309	0.009	0.074	0.215	0.113	0.090	0.158
35	0.145	0.347	0.010	0.087	0.246	0.131	0.105	0.183
40	0.168	0.388	0.012	0.102	0.280	0.152	0.123	0.211
45	0.194	0.430	0.015	0.119	0.316	0.176	0.143	0.241
50	0.223	0.473	0.017	0.138	0.355	0.203	0.165	0.274
55	0.255	0.517	0.020	0.160	0.396	0.233	0.191	0.310
60	0.289	0.560	0.024	0.185	0.438	0.265	0.219	0.349
65	0.326	0.602	0.029	0.213	0.482	0.301	0.251	0.389
70	0.366	0.643	0.034	0.244	0.525	0.338	0.285	0.432
75	0.407	0.682	0.040	0.277	0.568	0.378	0.321	0.475
80	0.449	0.719	0.048	0.313	0.611	0.420	0.361	0.518
85	0.493	0.753	0.056	0.352	0.651	0.463	0.402	0.562
90	0.536	0.784	0.066	0.393	0.690	0.507	0.444	0.604
95	0.579	0.812	0.078	0.435	0.726	0.550	0.488	0.645
100	0.621	0.837	0.091	0.478	0.759	0.593	0.531	0.684
105	0.661	0.859	0.107	0.522	0.789	0.634	0.574	0.720
110	0.699	0.879	0.125	0.565	0.817	0.674	0.616	0.754
115	0.734	0.896	0.145	0.607	0.842	0.711	0.656	0.785
120	0.767	0.912	0.168	0.648	0.863	0.745	0.695	0.813
125	0.797	0.925	0.194	0.687	0.883	0.777	0.730	0.838
130	0.824	0.936	0.222	0.723	0.900	0.806	0.763	0.860
135	0.847	0.946	0.254	0.756	0.914	0.831	0.793	0.880
140	0.869	0.954	0.288	0.787	0.927	0.854	0.820	0.897
145	0.887	0.961	0.325	0.815	0.938	0.875	0.845	0.912
150	0.904	0.967	0.365	0.840	0.947	0.893	0.866	0.925
155	0.918	0.972	0.406	0.862	0.955	0.908	0.885	0.936
160	0.930	0.977	0.448	0.881	0.962	0.922	0.902	0.946
165	0.941	0.980	0.492	0.898	0.968	0.933	0.916	0.954
170	0.950	0.983	0.535	0.913	0.973	0.944	0.929	0.961
175	0.957	0.986	0.578	0.926	0.977	0.952	0.939	0.967
180	0.964	0.988	0.620	0.937	0.981	0.959	0.949	0.972
185	0.969	0.990	0.660	0.947	0.984	0.966	0.956	0.977
190	0.974	0.992	0.698	0.955	0.986	0.971	0.963	0.980
195	0.978	0.993	0.734	0.962	0.989	0.976	0.969	0.983
200	0.982	0.994	0.766	0.968	0.990	0.979	0.974	0.986

Appendix B. Mortality proportions by depth associated with graphs 4-5 (McGovern excluded).

Depth(m)	Baseline	Delayed	Immediate	Venting	No venting
0	0.054	0.141	0.004	0.032	0.195
5	0.060	0.154	0.005	0.036	0.212
10	0.066	0.169	0.005	0.039	0.230
15	0.073	0.184	0.006	0.044	0.249
20	0.080	0.200	0.006	0.048	0.269
25	0.088	0.217	0.007	0.053	0.290
30	0.097	0.236	0.008	0.059	0.312
35	0.106	0.255	0.009	0.065	0.335
40	0.117	0.275	0.010	0.071	0.359
45	0.128	0.297	0.011	0.079	0.383
50	0.140	0.319	0.012	0.086	0.408
55	0.153	0.342	0.013	0.095	0.434
60	0.167	0.366	0.015	0.105	0.460
65	0.182	0.391	0.016	0.115	0.486
70	0.198	0.416	0.018	0.126	0.512
75	0.215	0.441	0.020	0.138	0.538
80	0.234	0.467	0.022	0.151	0.564
85	0.253	0.493	0.025	0.165	0.589
90	0.273	0.520	0.028	0.179	0.614
95	0.294	0.546	0.030	0.195	0.639
100	0.317	0.571	0.034	0.212	0.663
105	0.340	0.597	0.037	0.230	0.686
110	0.364	0.622	0.041	0.249	0.708
115	0.388	0.646	0.046	0.269	0.729
120	0.413	0.670	0.050	0.291	0.749
125	0.439	0.692	0.056	0.313	0.768
130	0.465	0.714	0.061	0.335	0.786
135	0.491	0.735	0.068	0.359	0.803
140	0.517	0.755	0.075	0.384	0.819
145	0.543	0.774	0.082	0.409	0.834
150	0.569	0.791	0.090	0.434	0.848
155	0.594	0.808	0.099	0.460	0.861
160	0.619	0.824	0.109	0.486	0.873
165	0.644	0.839	0.120	0.512	0.884
170	0.667	0.852	0.131	0.538	0.895
175	0.690	0.865	0.143	0.564	0.904
180	0.712	0.877	0.157	0.590	0.913
185	0.733	0.888	0.171	0.615	0.921
190	0.753	0.898	0.186	0.639	0.928
195	0.772	0.907	0.203	0.663	0.935
200	0.790	0.915	0.220	0.686	0.941