Estimation of hook selectivity on red snapper (*Lutjanus campechanus*) during a fishery independent survey of natural reefs in the Gulf of Mexico

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Estimation of hook selectivity on red snapper (*Lutjanus campechanus*) during a fishery independent survey of natural reefs in the Gulf of Mexico

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Introduction

Demographic data that informs assessments about the size and age structure of a population are critical for a clear understanding of the status of a fished stock. Equally important is information about selectivity bias of the sampling gears used to collect the demographic data. Ideally the length distribution of the sampled population is known and selectivity can be measured directly. In most cases, the length distributions are not known, which has led to the development of methods that indirectly estimate selectivity (Holt 1963, Regier and Robson 1966, Hamley 1975, Kirkwood and Walker 1986, Boy and Crivelli 1988, Helser et al. 1991, Helser et al. 1994, Henderson and Wong 1991, Millar 1992). Most of these highlighted studies concern gillnet selectivity about which the functional form of the distributions is better established and the assumption about proportionality is more easily evaluated.

Unfortunately, hook selectivity patterns are not well established, and the common approach is to use the methodology outlined for gillnets (Millar and Fryer 1999). This can present a problem since very little is known about hook selectivity in general (Kenchington 1993), and because gill net selectivity operates under the assumption that proportional increases in mesh size select fish of proportionally increasing body size. The same relationship may or may not hold true for mouth gape, which is the limiting factor concerning hook selectivity. Pope et al. (1975) believed that selection curves for hooks are likely very broad, but the general shape is unclear with some suggesting asymptotic (McCracken 1963) or dome-shaped relationships (Millar and Holst 1997). If growth rate for a species demonstrates an asymptotic relationship with age or size, then it follows that at some hook size, selectivity would not be dome shaped but would likely look logistic in form. The fundamental property about the indirect method is that a functional relationship is being fit to catch data with no information about the sampled population. Therefore, a method that tests various functions against catch data might prove useful.

Beginning in 2008 the Gulf of Mexico Fishery Management Council (GMFMC) began requiring recreational anglers fishing in federal waters to use non–stainless steel circle hooks when catching reef fishes with natural bait (50 C.F.R. 622.41), and some Gulf states such as Florida are following suit (Sauls and Ayala 2012). Circle hooks are defined as “a fishing hook designed and manufactured so that the point is turned perpendicularly back to the shank to form a generally circular, or oval, shape.” In gill net selectivity analysis the assumption about proportionality in the gear is well established because mesh is typically square or diamond pattern making sizes and proportions easy to measure. Hooks on the other hand have many different ways of measuring their dimensions including total length, gape, throat, wire diameter, bite, barb, shank, front length, offset, and bend (Figures 1 and 2). All of which could potentially be a limiting factor relative to the size of fish that are selected by the gear.

Objectives of this investigation were to apply the indirect selectivity analysis method to circle hook catches of red snapper from a standardized research survey conducted recently in the northern Gulf of Mexico. We intend to investigate the quality of fit of the data to normal (fixed spread), normal (proportional spread), gamma, and lognormal distributions. We will fit the data to these functional forms assuming fishing power is equal among hook gape size, and again assuming that fishing power is proportional to hook gape size.

Methods

General methods

The congressional supplemental sampling program (CSSP, sometimes incorrectly referred to as EASA) survey was conducted on the continental shelf of the northern Gulf of Mexico (GOM) from Brownsville, Texas to the southwest coast of Florida from April 7 – October 25, 2011. Contract vessels provided captains and deck-crew, while the Southeast Fisheries Science Center (SEFSC) provided scientific crew. Two longline and one vertical line vessel sampled east GOM sites while two longline and one vertical line vessel simultaneously sampled west GOM sites. Vessels were deployed as close in time as possible to ensure temporal overlap and to provide as synoptic a GOM-wide data set as possible. Randomly selected stations are restricted from being chosen within the boundaries of the Flower Garden Banks National Marine Sanctuary (Stetson Bank, West Flower Garden Bank and East Flower Garden Bank), the Madison-Swanson and Steamboat Lumps marine protected areas, the Florida Middle Grounds, within 1 nautical mile (nm) of oil and gas platform structures, and within 1 nm of any other station in the stratum. All gear deployments were monitored using a shipboard SCS/FSCS computer system operated with weatherproof laptop computers with touch screen options. SCS/FSCS software allows for the acquisition of data to describe set and haul-back events (GMT time/date stamp, position and any other connected ship sensors). Environmental data was collected using a Seabird CTD profiler during fishing gear soaks to obtain temperature, salinity and dissolved oxygen profiles.

Vertical line survey

Two different site selection methods were used over the course of the CSSP survey. The first method coupled vertical line vessels with longline vessels (paired sampling) with the intent to evaluate gear selectivity, and was utilized over the first 3 legs of the survey (April 7 – June 29, 2011). Site selection used a stratified random design based on the proportional allocation of stations among 52 strata as defined by 18 longitude and/or latitude spatial zones and 3 depths zones (Figure 3). Allocation of stations is determined by the proportion of the surface area for each stratum with respect to the surface area of all strata (i.e. weighted by area). Each stratum was required to have a minimum of 2 stations with a target of 160 stations per cruise for all strata combined, which was then replicated over 7 total cruises. Once the number of stations was determined for each stratum a GIS model was used to randomly assign stations to latitude/longitude coordinates within each stratum.

During paired sampling cruises the vertical line vessels tracked the bottom longline vessels and fished longline selected sites simultaneously, therefore the site selection design is essentially identical to the longline sampling design (i.e. Mississippi Laboratories bottom longline survey). Vertical line sites however sampled a total of 5 sites at each selected longline station in the 9 to 55 m and >55 to 183 m depth zones, and the initial bottom longline station position was always selected for vertical line sampling. The remaining four randomly selected locations were separated by at least 0.1 nm and were located within a 1 nm radius of the original longline position (Figure 4). Because the longline vessels worked sites much slower, the vertical line vessel also opportunistically sampled reef sites within these randomly selected blocks during this time, but those data are excluded from broader analyses because they do not represent truly random sites.

The second method (independent sampling) was used for the remainder of the legs (July31 – October 16, 2011) and made use of the existing reef fish video survey design (Campbell et al. 2012). Stratified random sampling was used to select 10 min. latitude by 10 min. longitude blocks that contain known reef habitat (Figure 5). Within a selected block 4-6 random transects were chosen to collect side-scan sonar data and identify potential natural reef bottom to sample. Ten sites were randomly selected from the side-scan transects. Those selected sites were located a minimum of 0.10 nautical miles apart, and any sites that appeared to be man-made were not selected (i.e. natural bottom only). Bandit gear was then fished at 8 randomly selected reef sites and 2 randomly selected non-reef sites (i.e. flat bottom).

The vertical line is composed of 300 m of 2 mm light blue 181 kg test monofilament mainline, with a 6.71 meter 181 kg test detachable backbone which is attached to the terminal end of the main line. Ten gangions constructed of 45.36 kg test twisted monofilament line were attached at intervals of 61 cm on the backbone. Each reel, or backbone, exclusively used 1 size of circle hook (Mustad Circle hooks model 39960D, 8/0, 11/0 or 15/0) (Table 1, Figure 2). Hook size to be fished on a reel was determined randomly at the start of each fishing day and then rotated clockwise at each subsequent station. A 5-10 kg weight was placed at the terminal end of the backbone to insure stability and that hooks were not fished directly on the bottom. Hooks were baited with Atlantic mackerel (*Scomber scomberus*) cut to match the size of each hook (heads and tails excluded) and were fished on the bottom for 5 minutes.

Biological Sampling and Processing

Catch was identified to the lowest taxonomic group possible, weighed, and measured (except sharks greater than 1.5 m TL), and otoliths and gonads were removed from a randomly selected subset of fish ensuring spatio-temporal coverage. Otoliths and gonads were initially stored at NMFS-ML but were analyzed at NMFS Panama City Laboratory. Sex and macroscopic classification of gonads were identified for all target species captured (species with federal management plans). Sub-sampling of all target species samples was conducted for quality control of macroscopic identification. A small subsample (approximately 1 cubic cm) of gonads was preserved from 5% of the fish collected for quality control and histological processing and estimation of red snapper spawning fraction. Red snapper hydrated ovaries were subsampled for batch fecundity estimates.

Selectivity analysis

We used log-linear models to indirectly estimate selectivity curves by hook size as outlined in Millar and Holst (1997) and Millar and Fryer (1999). Indirect estimation of selectivity utilizes the size distribution of the catch from each gear type following simultaneous deployment and is therefore limited to the portion of the population coming into contact with the gear (Millar and Fryer 1999). The fitted selectivity curves are also known as contact-selection curves or retention curves. Because the manufacturer hook number (i.e. 8/0, 11/0, 15/0) does not represent an actual measurement those values were not used to estimate proportionality about the gear. Instead a measurement of the hook, in this case gape, was used to estimate the relative proportions of the hooks (Table 1). We fit four families of selection curves are fit to the data using a log-linear approach (Table 2). All of the families observe geometric similarity other than the normal fixed spread, in which the spread of the curve is fixed across hook sizes. One set of fits assumed that fishing power is equal among hook gape size, and a second assumed that fishing power is proportional to hook gape size. Hook model number (Mustad 39960D) was kept static across all circle hook sizes used. Catch for each hook was broken down into 25mm length bins for analysis. Model deviance and Akaike's Information Criteria (AIC) were used to determine the best fitting model.

Results and Discussion

A total of 1,713 red snapper were caught during the CSSP, ranging in length from 154 to 782 mm (Figure 6). The most red snapper were caught on the 11/0 hook (700 fish), followed closely by the 8/0 and 15/0 hook (546 and 467 fish, respectively). Parameters for the eight selectivity curves are presented in Table 2. The best fitting models as determined by model deviance and AIC values were the fixed spread normal with equal fishing power (AIC = 443.2, deviance = 74.0), followed by both of the lognormal models (AIC = 452.3, deviance = 83.2), fixed spread normal model with proportional fishing power (AIC = 462.3, deviance =93.1). Normal fixed spread models appear to suggest that red snapper would be at least partially selected by all the hook types at very small size (0 mm), and plots of the residuals show no discernible pattern (Figure 7). The two properties are likely associated with fixing the spread of the model. While this model shows the lowest deviance, other properties about the model do not suggest that a normal fit with fixed spread is appropriate. For all of the proportional spread models, regardless of functional form, the residuals showed very similar patters across hook sizes (Figures 7-10). The smallest hook (8/0) is over-selected for the largest size fish, however evaluation of the catch, shows that the largest fish was captured on the smallest hook. The medium hook (11/0) is over-selected on small sized fish, and under-selected for large size fish. The largest hook (15/0) is under-selected for small sized fish, and slightly over-selected for the largest size fish. Both log-normal models showed an AIC and deviance fairly close in value to the normal fixed spread model (Table 2). Furthermore the fits shows the hooks are non-selective on the smallest fish (Figure 10), which is a result that makes sense relative to the actual catch (i.e. selection on larvae by the normal model is nonsensical). The log-normal model assuming equivalent fishing power over hooks makes the most sense relative to the observed catch. That model shows full selection at ~ 250 mm for the 8/0, ~ 410 mm for the 11/0, and ~ 800mm for the 15/0 hook. In all of the models except the normal fixed spread the fits suggest that 15/0 hook selectivity might be logistic rather than a dome shaped function.

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Table 1. Dimensions (mm) for the three Mustad circle hooks used during the CSSP vertical line survey.

Hook Size	Hook Series	Total Length	Gape	Throat	Wire Diameter
8/0	39960D	27.1	6.75	16.1	1.7
11/0	39960D	33.45	10.7	22.6	2.2
15/0	39960D	56.3	20.0	39.15	3.5

Table 2. Log-linear fits to the red snapper data from the CSSP vertical line catch. The model deviance has 48 degrees of freedom for each of the models shown.

	Equal Fishing Intensity			Proportional Fishing Intensity		
Model	Parameters	Model Deviance	AIC	Parameters	Model Deviance	AIC
Normal:						
Fixed Spread	$(k, \sigma) = (36.9791, 264.008)$	74.0	443.2	$(k, \sigma) = (49.2053, 325.584)$	93.1	462.3
Spread α m_j	$(k_1, k_2) = (50.1197, 883.138)$	168.6	537.8	$(k_1, k_2) = (64.1556, 616.255)$	202.2	571.3
Gamma:						
Spread α m_j	$(\alpha, k) = (3.84155, 15.4751)$	106.0	475.1	$(\alpha, k) = (4.84155, 15.4751)$	106.0	475.1
Lognormal:						
Spread α m_j	$(\mu_1, \sigma) = (5.97221, 0.59237)$	83.2	452.3	$(\mu_1, \sigma) = (6.32311, 0.59237)$	83.2	452.3

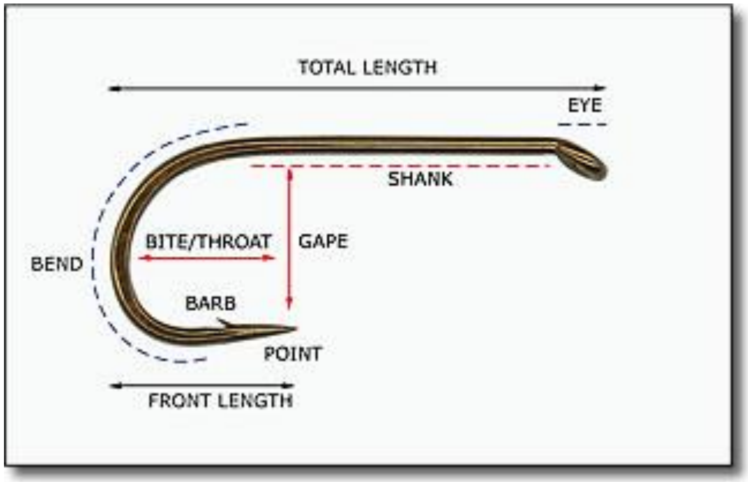

Figure 1.Various measurements that can be taken about the properties of a hook. Photo credit:

Figure 2. Three hook sizes used in the experiment from smallest to largest, 8/0, 11/0, and 15/0 Mustad series 39960D.

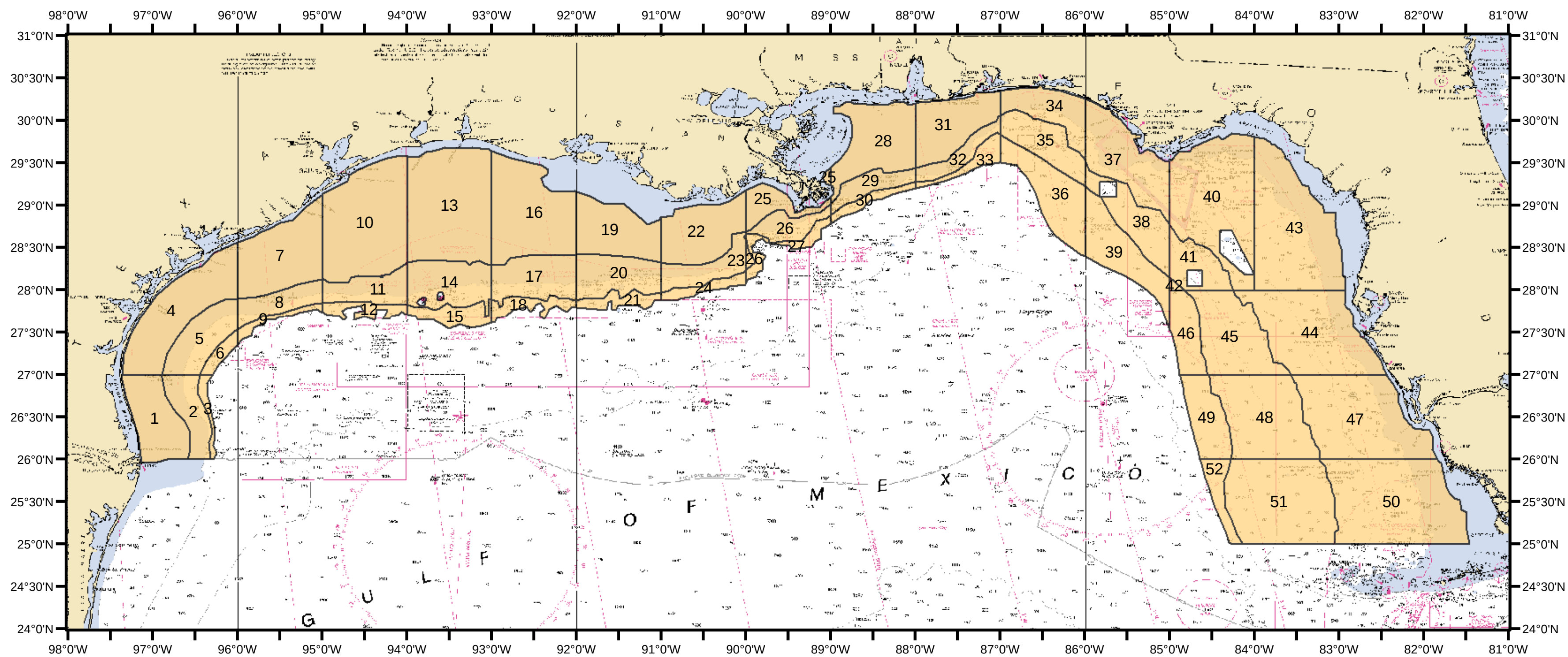

Figure 3. Congressional supplemental sampling longline sampling strata. Stratified by lat/lon and depth zone, and weighted by area.

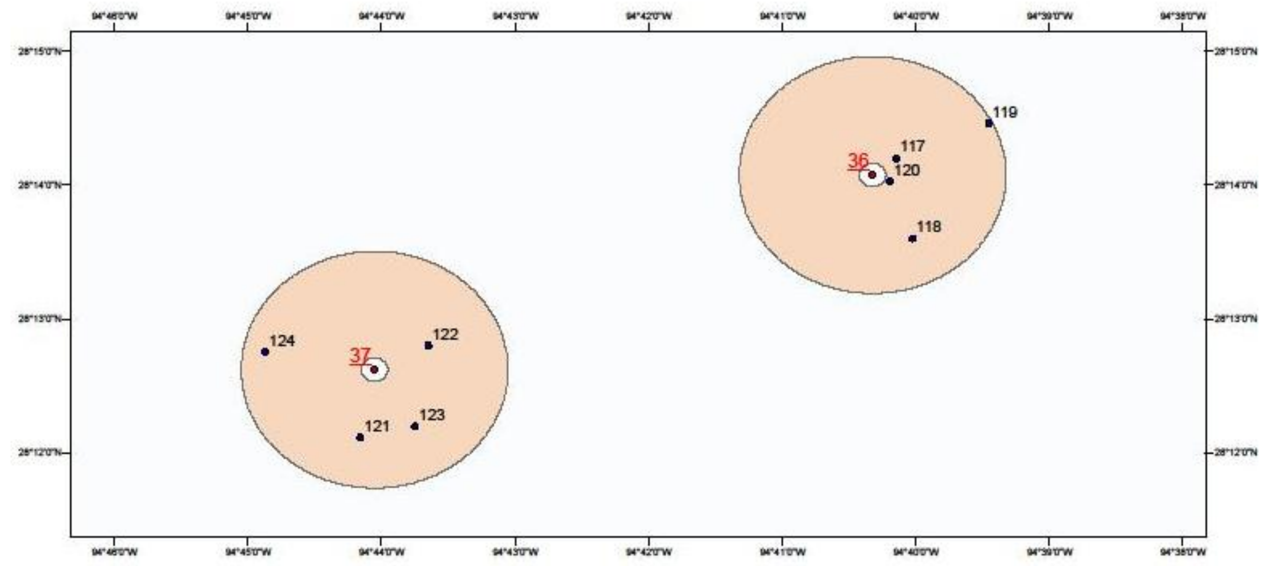

Figure 4. Paired vertical line (black) and bottom longline stations (red) used during cruises 1-3 (April 7 – June 29, 2011).

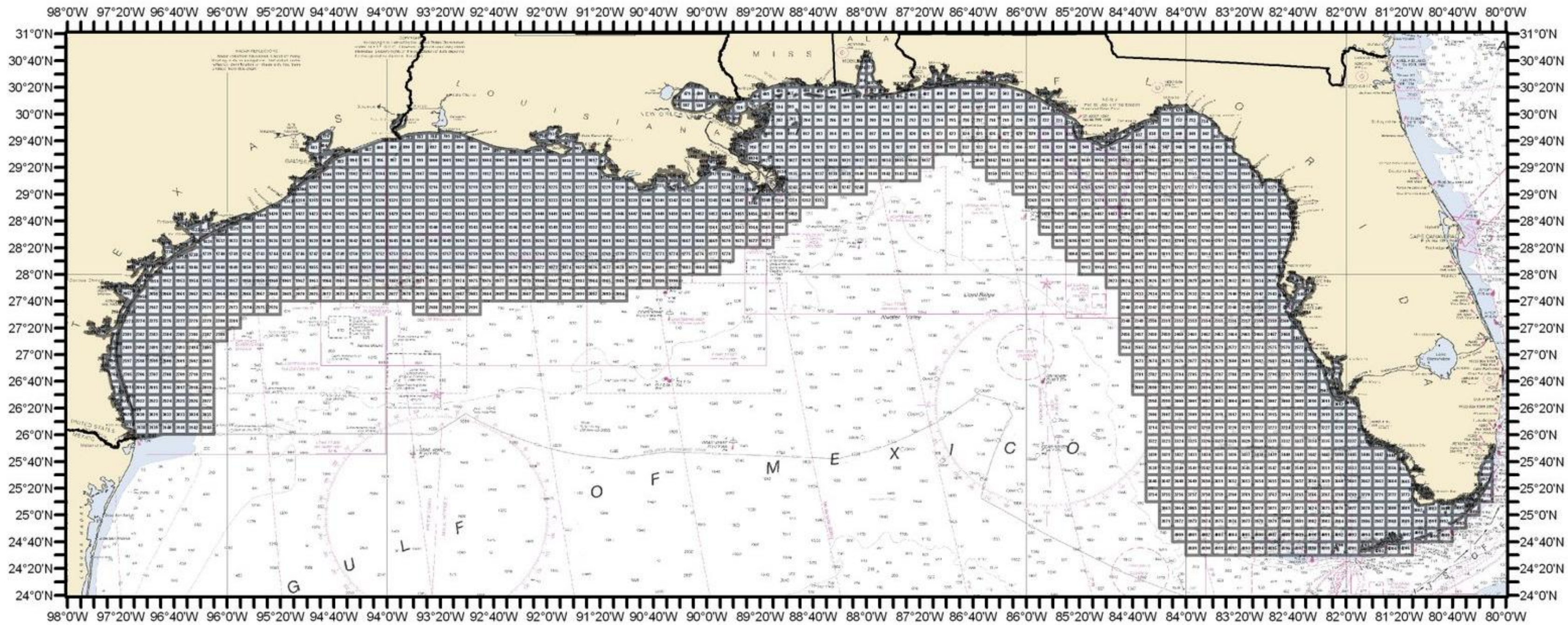

Figure 5. Map of the northern Gulf of Mexico divided into 10’ x 10’ grids from which grids containing reef were identified, and from which vertical line sampling sites were randomly selected.

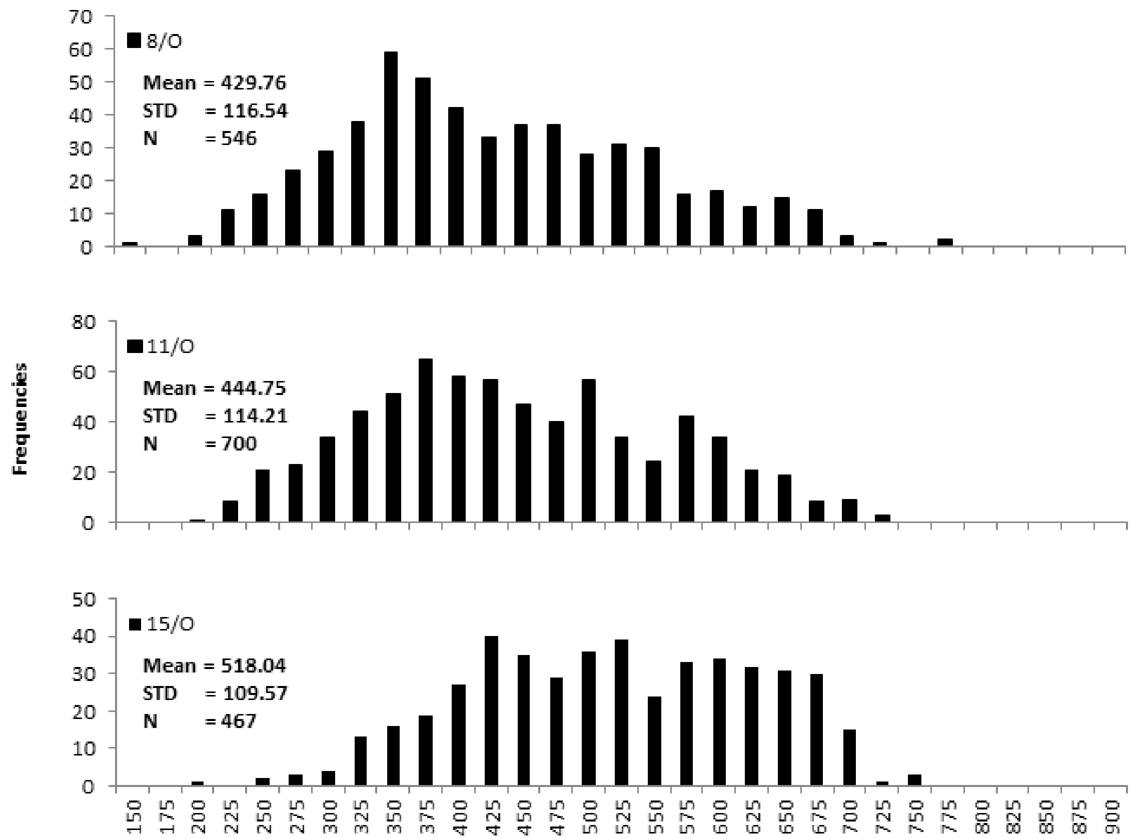

Figure 6. Length frequency histograms and descriptive statistics of GOM red snapper by circle hook size (8/0, 11/0, and 15/0) from CSSP vertical line catch.

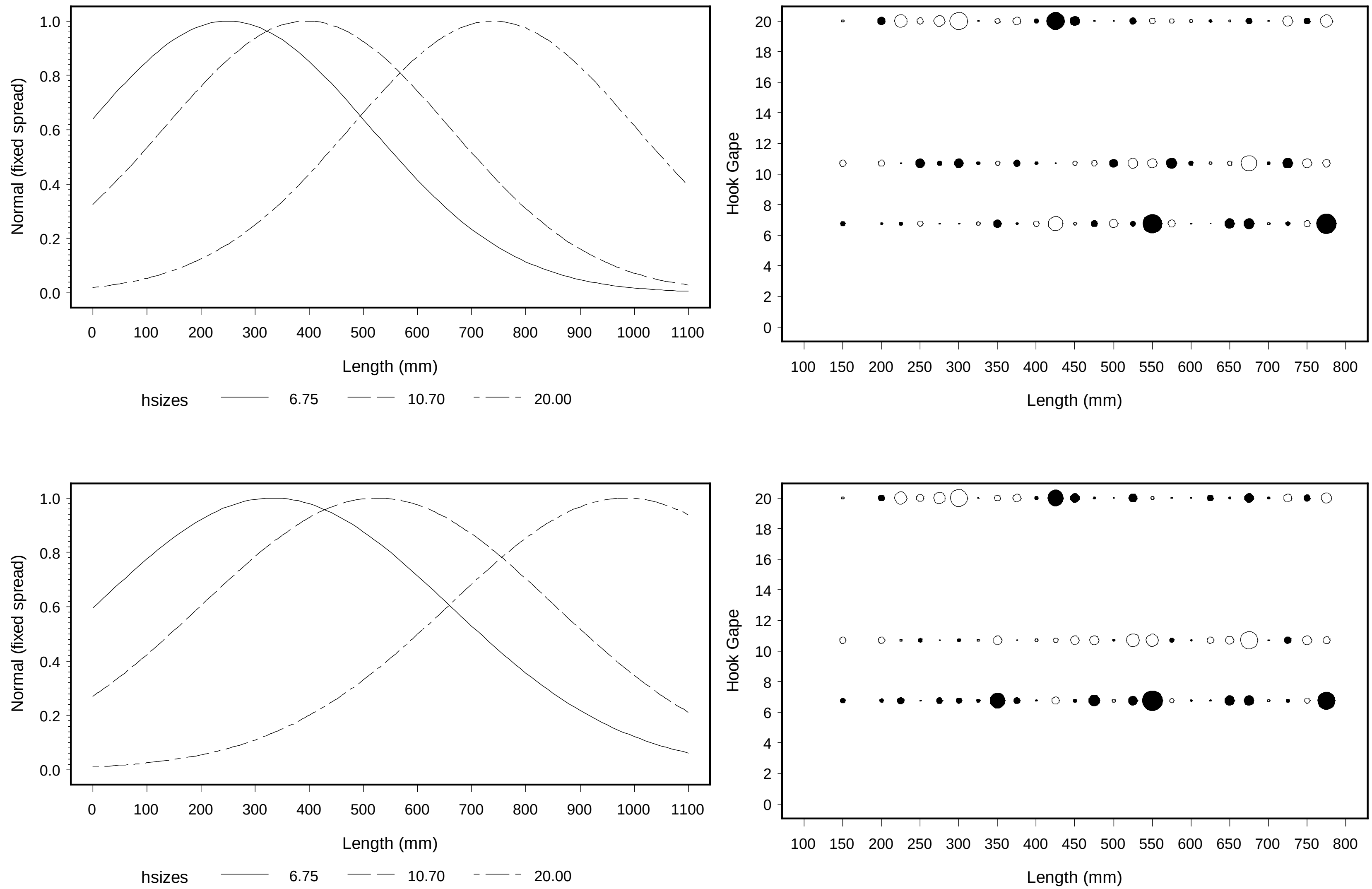

Figure 7. Selection curves and deviance residual plots for the normal (fixed spread) model with equal fishing intensity (top) and fishing power proportional to hook size (bottom). Solid and open circles represent positive and negative residuals, respectively, with the area of the circle proportional to the square of the residual. Hook sizes (8/0, 11/0 and 15/0) are represented by the gape (mm) of the hook.

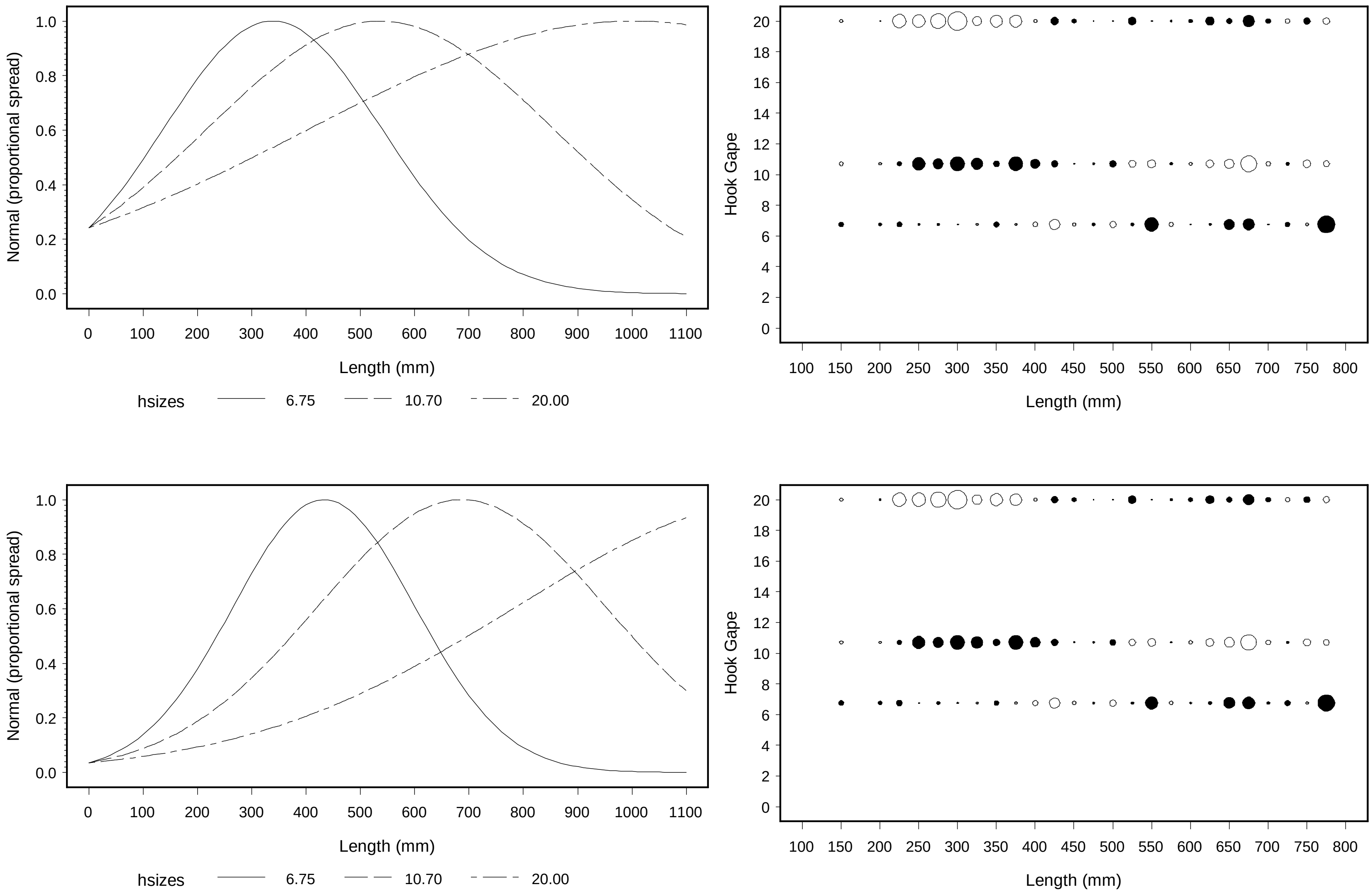

Figure 8. Selection curves and deviance residual plots for the normal (proportional spread) model with equal fishing intensity (top) and fishing power proportional to hook size (bottom). Solid and open circles represent positive and negative residuals, respectively, with the area of the circle proportional to the square of the residual. Hook sizes (8/0, 11/0 and 15/0) are represented by the gape (mm) of the hook.

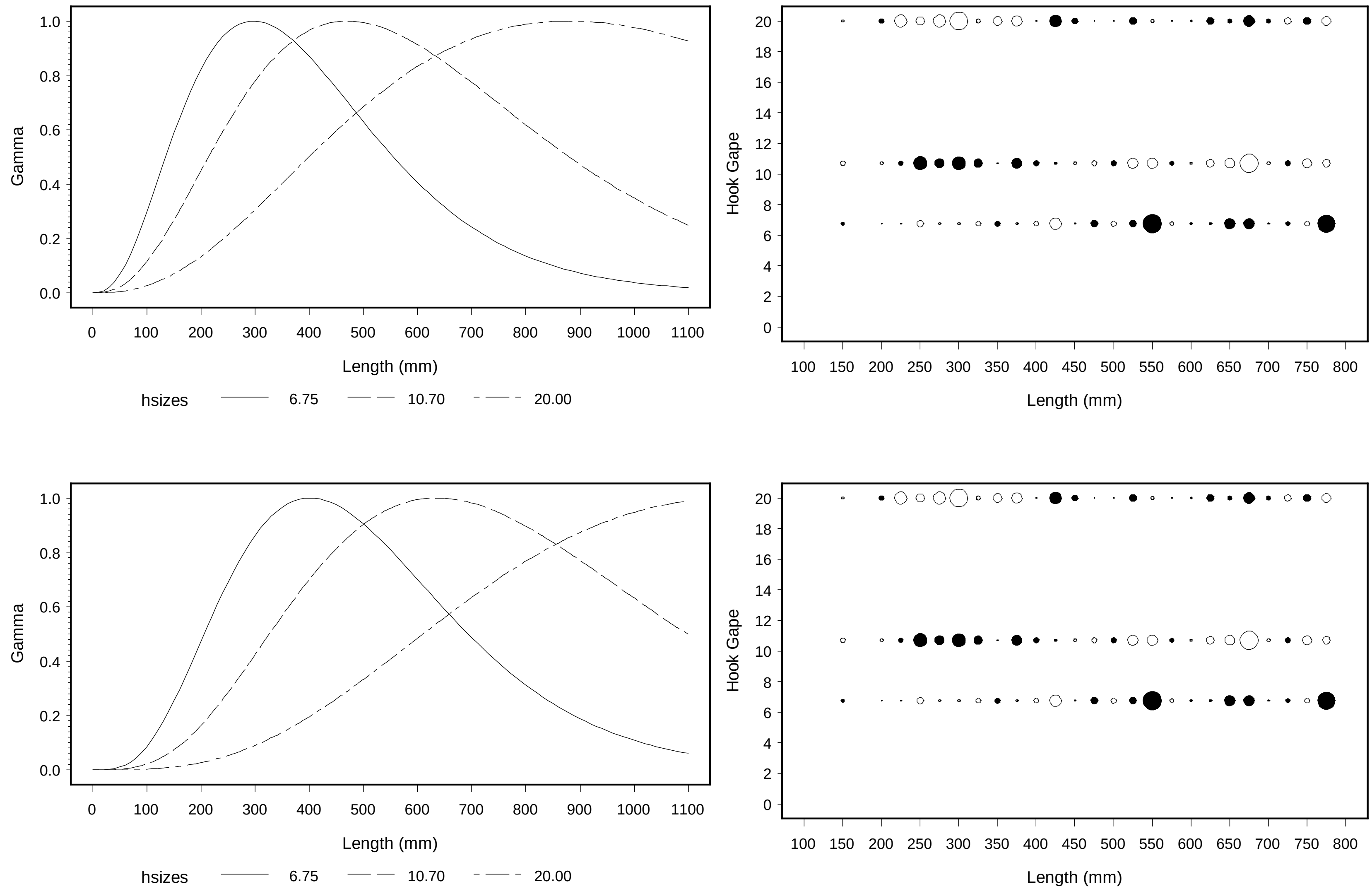

Figure 9. Selection curves and deviance residual plots for the gamma model with equal fishing intensity (top) and fishing power proportional to hook size (bottom). Solid and open circles represent positive and negative residuals, respectively, with the area of the circle proportional to the square of the residual. Hook sizes (8/0, 11/0 and 15/0) are represented by the gape (mm) of the hook.

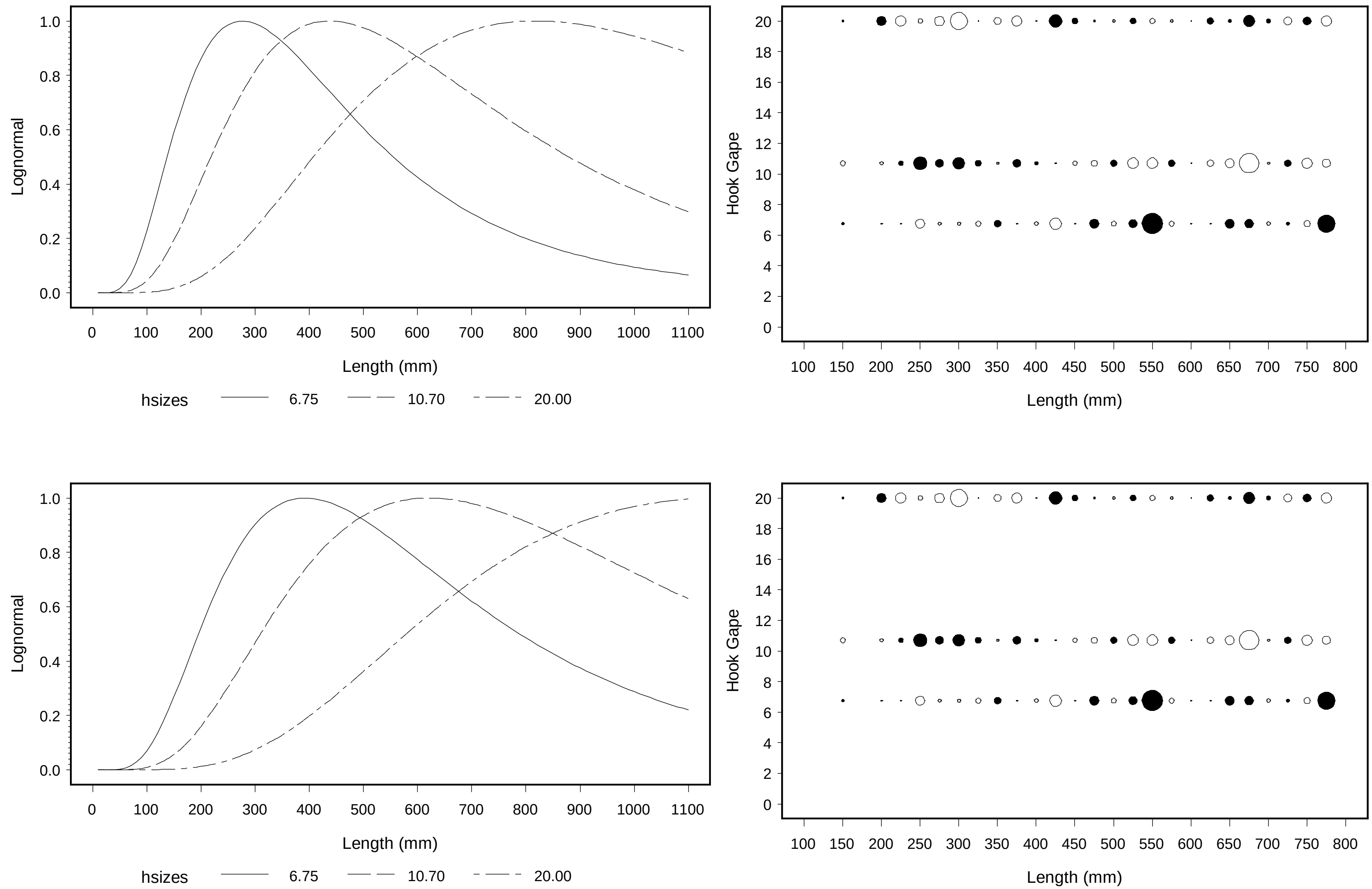

Figure 10. Selection curves and deviance residual plots for the lognormal model with equal fishing intensity (top) and fishing power proportional to hook size (bottom). Solid and open circles represent positive and negative residuals, respectively, where circle area is proportional to the square of the residual. Hook sizes (8/0, 11/0 and 15/0) are represented by the gape (mm) of the hook.