# Description of age data and estimated growth for Gray Triggerfish from the northern Gulf of Mexico: 2003–2013

Linda Lombardi, Robert Allman, and Ashley Pacicco

SEDAR43-WP-010

27 March 2015

Please cite this document as:
Lombardi, L. R. Allman, and A. Pacicco.  2015. Description of age data and estimated growth for Gray Triggerfish from the northern Gulf of Mexico: 2003-2013. SEDAR43-WP-10. SEDAR, North Charleston, SC. 34 pp.

# Description of age data and estimated growth for Gray Triggerfish from the northern Gulf of Mexico: 2003-2013

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National Marine Fisheries Service
Southeast Fisheries Science Center
3500 Delwood Beach Road
Panama City, FL 32408

Panama City Library Contribution # 15-02

## Abstract

Gray Triggerfish were sampled for age structure from both the commercial and recreational fisheries from the Gulf of Mexico, primarily (77%) from the west coast of Florida (n = 5762, 2003-2013). Fishery independent surveys collected 27% of all age samples (n = 1537). Gray Triggerfish fully recruited into the commercial fishery by ages 4-6 yrs old (range: 0 – 14 yrs, mean age = 5.2 ± 1.7 yrs, mean size = 42.3 ± 7.6 cm FL) and became rare by age 10 yrs old (<1% of samples). On average, smaller and younger Gray Triggerfish were landed by the recreational fishery (recruited age 3 – 5 yrs; mean age = 4.2 ± 1.4 yrs; mean size = 36.4 ± 5.9 cm FL). Several size-modified von Bertalanffy growth models that taks into account non-random sampling due to minimum size restrictions were attempted, using alternative data sets and variance structures, model convergences were problematic. The model that fit all data the best used a constant coefficient of variation at age variance structure and predicted the following growth parameters: $L_\infty$ = 58.97 FL cm, k = 0.14, to = -1.66.

## Introduction

Because age and growth information are critical to stock assessment, the goal of this report is to characterize Gray Triggerfish age-length structure using 11 years of data collected from the northern Gulf of Mexico: 2003-2013. Gray Triggerfish dorsal spines have been aged at the National Marine Fisheries Service- Southeastern Fisheries Science Center in Panama City, Florida, along with corporative state partners: FLFWCC/Fish and Wildlife Research Institute, St. Petersburg, FL, and the Gulf States Marine Fisheries Commission, Ocean Springs, MS. This report includes a summary of data (2003-2010) that was provided for the 2011 SEDAR update assessment (GMFMC 2011), plus additional age data collected 2011-2013. Age and length data used for SEDAR09 were not used in this analysis (SEDAR 2005). The following are discussed: age and length data and size-modified von Bertalanffy growth model.

## Methods

### Data Collection

Dorsal spines were collected by numerous federal and state sources representing both the commercial and recreational fisheries (Trip Interview Program – TIP, Southeast Recreational Head Boat Survey – HB, Marine Fisheries Recreational Statistical Survey – MRFSS (includes MRIP), Recreational Fisheries Information Network – RECFIN). Gray Triggerfish dorsal spines were also collected from federally funded fishery independent surveys (NMFS Panama City, FL – PCLAB, and NMFS Pascagoula, MS – MSLAB) and state funded fishery independent surveys (Florida Fish and Wildlife Research Institute - Fishery Independent Monitoring, St. Petersburg, FL – FWRI). The Cooperative Research Program (CRP) and Expanded Annual Stock Assessment Survey, NMFS Pascagoula, MS (EASA) also provided dorsal spines and gonads with detailed capture locations. At-sea collection of dorsal spines and gonads from the commercial industry were made possible through two observer programs (NMFS Panama City Shark Bottom Long-line Observer Program – SBLOP and NMFS Galveston Reef fish Observer Program – GOP). Measurements of fish lengths (total and/or fork mm), weights (whole or gutted kg), and removal of dorsal spines and/or gonads were completed in the field. Length is reported as Fork Length for analysis.

## Age Determination

The dorsal spine was used as the primary ageing structure (Johnson and Saloman 1984). Annulus formation has been validated through oxytetracycline staining in Gray Triggerfish ageing structures (Allman et al. 2015). Annual ages, based on the number of translucent zones in thin sectioned dorsal spines, were used for further analysis. Fractional ages were also calculated to obtain decimal age to use in the growth model. A fractional period of a year was determined as the difference from peak spawning date (July 1; Ingram 2001) and capture date.

## Age and Length Data

Age and length data were examined for trends by year, fishing mode, and by region. Differences in age and length data were visually investigated, using frequency plots, box plots, and observed growth, with size-at-age data. Length and age data were also compared among years and by fishing modes. Age and length frequencies were produced for each year by fishing mode with all gears combined to examine annual trends in age structure during the time period. Box plots were used to visually compare patterns of length and age.

Modeling Growth

A growth curve, based on fractional ages and observed fork lengths at capture, was modeled using the von Bertalanffy growth model and was executed in ADMB (Auto Differentiate Model Builder). Since the majority of the data were derived from commercial and recreational samples, a size-modified von Bertalanffy model was used to predict growth parameters that takes into account the non-random sampling due to minimum size restrictions (Diaz et al. 2004). This model can predict growth using a choice of the variance structures in the size-at-age data: constant standard deviation (STDEV) with age, constant coefficient of variation (CV) with age, variance proportion to the mean, coefficient of variation(CV) increase linearly with age, coefficient of variation (CV) increase linearly with size. Multiple model compilations were examined using three different variance structures in the size-at-age data. The model also uses a restrictive maximum likelihood estimation procedure with minimum size (Commercial and Recreational same size limits, 1990-1998: no size limit; 1999-2007: 12 inch Maximum Total Length or 26.25 cm Fork Length; 2008-2013: 14 inch Fork Length or 35.56 cm Fork Length) as the left truncation limit for fisheries dependent observations. Fishery independent fractional ages and observed fork lengths were used to aid the model to predict growth at smaller sizes, not collected in routine fishery dependent sampling (given the minimum size limit).

The size-modified growth model used in this assessment has structural similarities with the model used in the previous assessments (GMFMC 2011), but now the size-modified growth model is compiled in ADMB with alternative variance structures. Since not all species have the same variance structure of variation of sizes-at-age, it is valuable to model growth with the variance structure most representative of the species. Model convergence was based on the value of the model objective function (minimal log-likelihood) and the ability to predict similar growth parameters and coefficients of variation, providing alternative initial growth parameters ($L_\infty$ = 600-900; k = 0.05-0.20; $t_0$ = -2.00-0.00), standard deviations (sigma = 10-70), and coefficients of variation (CV = 10%, 20%, 30%). Model diagnostic plots such as predicted growth compared to observed data and the normalcy of residuals were examined. This growth model has been used in SEDARs to model growth in red snapper (SEDAR07, update, and 31), gag grouper (SEDAR10, update, and 33), greater amberjack (SEDAR33), king mackerel (SEDAR16, 38), and red grouper (SEDAR12, update, and 42).

Alternative model runs

Gray Triggerfish data set proved to be difficult to accurately model population growth. A majority of the model runs had difficulties fitting the data, providing realistic growth parameters (large asymptotic lengths, small growth coefficients, and small sizes at time zero), and in some scenarios initial parameter bounds were reached and the hessian matrix would not converge. There are two options, either there are problems within the model structure or there are issues within the data that is difficult to model. The size-modified von Bertalanffy growth model structure compiled in ADMB has been used for multiple species (snappers, groupers, pelagic species) from the Gulf of Mexico and the model generally has predicted realistic growth parameters. To decipher issues within the data, alternative subsets of the available data (fishery dependent, fishery independent, commercial and/or recreational - only data sets) were applied to the model. These additional model fits used either a constant STDEV or constant CV with age variance structures.

Last, a two-phase size-modified von Bertalanffy growth model was fit to two data sets: all data and only fishery dependent data. This two-phase growth model was used for king mackerel during SEDAR38 and allows for both linear and non-linear growth (Lombardi 2014). The age at which growth changes from linear to non-linear can be assigned in the model input file. Gray Triggerfish exhibit fairly fast growth within their first year; therefore, growth from age 0 to age 0.5 yr was modeled as linear.

Results and Discussion

Data Collection

There was an increase in age structure samples from Gray Triggerfish landed in Alabama and Louisiana in the last few years (2011-2013, Table 1). Overall, Gray Triggerfish were primarily harvested from Florida waters (67%; Table 1), by Gulf States Marine Fisheries Commission, Fisheries Information Network and by Trip Interview Program (TIP) (RECFIN, 34%; TIP, 26%; Table 2). Gray Triggerfish were intercepted more frequently from recreational landings (43%; Table 3), than from other modes. Fishery independent surveys using multiple gear types (traps, hook and line, trawls, and spears) collected approximately a third of the Gray Triggerfish (n = 1537).

To determine if age samples were collected in similar proportion to the amount of Gray Triggerfish landed, commercial age samples were allocated as either east or west of the Mississippi River based on the reported NMFS Shrimp Statistical Grid. Commercial age samples were primarily collected from the eastern Gulf of Mexico (E GOM: 57%, W GOM: 43%; Table 4), as were most of the commercial landings (E GOM: 72%, W GOM 28%; Table 4). There were more Gray Triggerfish age samples (by proportion) collected from the W GOM, in particularly, from the commercial handline fishery (Table 4).

## Age and Length Data

There has been an increase in biological sampling in the last few years (2011-2013), with an additional 2638 dorsal spines (46% of the total sample size) collected by both fishery dependent and independent sources (Table 1-2). The overall length frequencies of Gray Triggerfish showed the smallest and youngest fish collected by fishery independent sources, followed by the recreational fishery, and the commercial fishery, respectively (Figure 1a, 1b, 2, and 3; Table 5). The recreational fishery for most years landed smaller and younger fish, except for the most recent years (2012 and 2013), where length and age frequencies were similar between the commercial and recreational fishery (Figure 4 and 5). During a few years, the commercial fishery length frequencies appear to be bi-model (2003, 2004, 2005, 2007, 2008; Figure 4). For most years, the Gray Triggerfish were most frequently age 3 and/or 4 yrs from the recreational fishery and age 5 from the commercial fishery (Figure 5). Comparing size-at-age of Gray Triggerfish among the fishing modes revealed the faster growing fish were caught by the commercial fishery, specifically, by vessels using longline gear (Figure 6a, 6b).

Modeling Growth

The purpose of modeling growth is to provide Stock Synthesis (SS) predicted growth model parameters (e.g., asymptotic length, growth coefficient). These parameters can be used by SS, as priors, to internally predict growth. Therefore, it is important that the growth model parameters were predicted from data that best represents Gray Triggerfish population from the northern Gulf of Mexico. As described above, the Gray Triggerfish dataset composed of fish collected from throughout the northern Gulf of Mexico from both commercial and recreational fisheries, with additional fish from fishery independent surveys that encompassed a large range of sizes and ages (Table 5, Figures 1, 2, and 3).

The size-modified von Bertalanffy growth model applied to the Gray Triggerfish data set takes into consideration two things: the minimum size limit fishing regulation and the type of variance structure observed in the size-at-age data. There were 966 fishery dependent records that were observed less than the minimum size limit (commercial, n = 233; recreation, n = 733). The model omits these records during model fitting. Gray Triggerfish showed variability in standard deviations in lengths at age (Figure 7a), which corresponded to a constant coefficient of variation at age variance structure for a majority of the age classes (ages 3-9, 88% of the age structure; Figure 7b).

The first model run used the data from SEDAR09 update. This model run was a completed to verify the new model structure (current model compiled in ADMB vs SEDAR09 update compiled in Excel) could replicate the predicted parameters from SEDAR09 update. The resulting growth model parameters were similar ($L_\infty$ = 87 cm FL, k = 0.10), with size at time zero just slightly larger (Table 6). However, a discrepancy in the data used in the SEDAR09 update growth model was revealed. It was evident from the file provided from the SEDAR09 update that fishery independent records (n ~ 900) were not identified in the SEDAR09 update growth model data file and that all fish, regardless of mode of collection, were allocated a minimum size limit. As mentioned above, the size-modified growth model does not use records if the observed fork lengths are less than the size limit; therefore, the predicted growth parameters from these model runs were not calculated using the smaller and youngest fish. These would be those fish collected by fishery independent surveys.

Next, the size-modified von Bertalanffy growth model was fit to all data (2003-2013) applying three of the five different variance structures: constant standard deviation (STDEV) with age, constant coefficient of variation (CV) with age, coefficient of variation (CV) increase linearly with age. The model fits using either the constant STDEV at age or a linear increase in CV at age variance structures predicted very large asymptotic lengths (well outside the range of observed data), fairly fast growth rates and small size at time zero (Table 6, Figure 8). The model fit that used a constant CV with age variance structure predicted more reasonable growth parameters. The recommended model fit used the variance structure matching the observed data, a constant CV at age and resulted in the following growth parameters: $L_\infty$ = 58.97 cm FL, k = 0.1405, $t_0$ = 1.6566 (Table 6, Figure 8). This model had a similar change in its objective function throughout the phases of the model but also, the resulting growth parameters were most realistic (e.g., asymptotic length well within the distribution of lengths). Nonetheless, model diagnostic plots showed similar residual patterns for each model regardless of the variance structure: negatively skewed residuals, negatively skewed distributed residuals for ages 0, 1, 3, 4, and 5, and probability plots showed divergence from normal (Figure 9a, 9b, 9c).

Each of the predicted growth curves for each type of variance structure, appears to pass through the lower distribution of lengths per age (Figure 8b). This is a typical response for this size-modified growth model because this model attempts to normalize the distribution of lengths at age. A majority (73%) of the Gray Triggerfish data has been collected from intercepts of recreational and/or commercial vessels and these fish should be larger than the minimum size limit; therefore, the distributions of lengths at age are routinely skewed to the upper end of size-at-age distributions.

Alternative model runs

Alternative subsets of the available data (fishery dependent, fishery independent, commercial and/or recreational - only data sets) were applied to the model, using either a constant STDEV or constant CV with age variance structure. There were difficulties in model convergence using either variance structure (constant STDEV –recreational data; constant CV – fishery dependent and recreational datasets). Model fits using fishery independent data, regardless of the variance structure, resulted in similar predicted parameters (Tables 7 and 8, Figure 10). Model diagnostic plots showed similar residual patterns for all data and fishery dependent data models: negatively skewed residuals, negatively skewed distributed residuals for ages 0, 1, 3, 4, and 5, and probability plots showed more divergence (Figure 11a, 11b, 11c). Distribution of residuals for fishery independent only data model fit showed more of a normal distribution, but still slightly skewed negatively, age-specific residuals also displayed negative residuals for ages 4, 5, and 6, and probability plots showed less divergence than fishery dependent data (Figure 11a, 11b, 11c).

The final model run used a two-phase size-modified von Bertalanffy growth model and was fit to two data sets: all data and only fishery dependent data. This two-phase growth model was used successfully for king mackerel during SEDAR38 and modeled growth better than other model choices (Lombardi 2014). The two-phase growth model is also similar to that employed by the stock synthesis model. However, the two-phase growth model would not converge using all the data, regardless of the starting age at which growth changes from linear to non-linear (age 0.5 – 2.5 yrs, attempted) or alternative values for initial parameters and/or parameter bounds. The two-phase model did converge using fishery dependent only data and resulted in similar growth model parameters as the non-linear growth model ($L_\infty$= 87.21 mm FL, k = 0.0811, $t_0$ = -1.5264, $CV_1$ = 0.3553, $CV_2$ = 0.0579, obj. func. = $9.2 \times 10^3$, Delta AIC = $-1.7 \times 10^2$).

Possible data issues

The results of growth model rely heavily on the data used to fit the model. The Gray Triggerfish data encompassed a large range of sizes (7 – 70 cm FL) and ages (0 – 14 yrs), but also included some outliers. Outliers were more prominent in the older age classes (ages 7 – 10) and included both larger and smaller than average lengths per age class. For example, age 9 (n

= 61) Gray Triggerfish were reported with fork lengths 23-62 cm (mode = 52 cm, mean = 49 ± 8 cm) with 3 age 9 fish reported as measured < 30 cm FL. These abnormally small age 9 Gray Triggerfish could be easily discarded, but it is difficult to explain 3 fish, interpreted as the same age, collected on different days, were measured incorrectly. In addition to outliers, the Gray Triggerfish data included the largest percentage (20%, compared to 1-5% from other species) of undersized fish from fishery dependent sources. The majority (76%) of the undersized fish were reported from the recreational fishery and of these fish, 50% were collected in 2008-2009; these years correspond to the change in size limit (effective date: July 2008 – federal, Jan 2009 – state of Florida). Finally, ageing error would also contribute to the large variation in size-at-age data, which would affect the model's residuals. Multiple ageing facilities and numerous persons interpreted ages from dorsal spines. Dorsal spines are difficult to age accurately, even among experienced readers (Allman et al. 2015).

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Table 1. Annual number and overall percentage of Gray Triggerfish dorsal spines collected by multiple sources, by state landed (AL – Alabama, FL – Florida, MS – Mississippi, LA – Louisiana, TX – Texas).

| Year | AL | FL | MS | LA | TX | Total |
|---|---|---|---|---|---|---|
| 2003 | | 149 | | | | 149 |
| 2004 | | 169 | | | | 169 |
| 2005 | | 269 | | | 1 | 270 |
| 2006 | | 276 | | | | 276 |
| 2007 | 46 | 233 | 4 | 140 | 69 | 492 |
| 2008 | 34 | 417 | 1 | 119 | 5 | 576 |
| 2009 | 57 | 548 | 6 | 92 | 49 | 752 |
| 2010 | 60 | 322 | | 22 | 36 | 440 |
| 2011 | 131 | 412 | | 65 | 27 | 635 |
| 2012 | 119 | 479 | | 268 | 41 | 907 |
| 2013 | 135 | 589 | | 338 | 34 | 1096 |
| Total | 582 | 3863 | 11 | 1044 | 262 | 5762 |
| Percent | 10% | 67% | 0% | 18% | 5% | |

Table 2. Annual number and overall percentage of Gray Triggerfish dorsal spines collected by multiple sources (fishery dependent: TIP - Trip Interview Program, RECFIN – Gulf States Marine Fisheries Commission, Fisheries Information Network, HB – Southeast Recreational Head Boat Survey, MRFSS - Marine Recreational Fisheries Statistical Survey; fishery independent: PCLAB – NMFS Panama City, FL; MSLAB - NMFS Pascagoula, MS; FWRI - Florida Fish and Wildlife Research Institute; Other: Cooperative Research Proposals, Expanded Annual Stock Assessment Survey, NMFS Reef Fish Observer Program, Galveston, TX; NMFS Shark Bottom Long-line Observer Program, Panama City, FL, ALLIANCE – expanded vertical line survey from MSLAB).

| Year | TIP | RECFIN | HB | MRFSS | PCLAB | FWRI | MSLAB | Other | Total |
|---|---|---|---|---|---|---|---|---|---|
| 2003 | 86 | 14 | 2 | 20 | 13 | | | 34 | 149 |
| 2004 | 40 | 57 | 3 | 10 | 59 | | | 10 | 169 |
| 2005 | 118 | 57 | | 4 | 82 | | | 13 | 270 |
| 2006 | 69 | 78 | | | 118 | 11 | | 0 | 276 |
| 2007 | 65 | 301 | 6 | 4 | 88 | 28 | | 4 | 492 |
| 2008 | 74 | 336 | 6 | 12 | 110 | 30 | 8 | 12 | 576 |
| 2009 | 45 | 350 | 46 | | 113 | 179 | 8 | 11 | 752 |
| 2010 | 27 | 129 | 50 | | 49 | 88 | 75 | 22 | 440 |
| 2011 | 187 | 257 | 20 | 3 | 81 | 47 | 24 | 19 | 635 |
| 2012 | 299 | 128 | 68 | | 269 | 97 | 37 | 9 | 907 |
| 2013 | 503 | 242 | 267 | | 52 | 28 | 1 | 3 | 1096 |
| Total | 1513 | 1949 | 468 | 53 | 1034 | 508 | 153 | 137 | 5762 |
| Percent | 26% | 34% | 8% | 1% | 18% | 9% | 3% | 2% | |

Table 3. Number of Gray Triggerfish dorsal spines collected by mode (CM – commercial, REC – recreational (includes charter boats, headboats, and private vessels), SS – scientific survey) and by gear (HL – handline, LL – longline, SP – spear, VLL – vertical longline, KP – kali pole, TR – trap, TRW – trawl, UNK – unknown), and by state landed (2003-2013).

| Mode & Gear | AL | FL | MS | LA | TX | Total | Percent |
|---|---|---|---|---|---|---|---|
| CM _HL | 12 | 510 | 4 | 624 | 1 | 1151 | 20% |
| CM_LL | | 414 | | | | 414 | 7% |
| CM_SP | | 14 | | | | 14 | 0% |
| CM_VLL | | 3 | | | | 3 | 0% |
| CM_UNK | | | | 81 | | 81 | 1% |
| REC_HL | 562 | 1472 | 1 | 305 | 179 | 2519 | 44% |
| REC_SP | 2 | 25 | 6 | 4 | 6 | 43 | 1% |
| SS_TR | | 826 | | | 2 | 828 | 14% |
| SS_TRW | 2 | 293 | | 28 | 71 | 394 | 7% |
| SS_HL | 4 | 292 | | 2 | 3 | 301 | 5% |
| SS_SP | | 11 | | | | 11 | 0% |
| SS_VLL | | 2 | | | | 2 | 0% |
| SS_KP | | 1 | | | | 1 | 0% |
| Total | 582 | 3863 | 11 | 1044 | 262 | 5762 | |

Table 4. Percentage of Gray Triggerfish dorsal spines collected by commercial (CM) and by gear (handline, longline) by region (East and West of Mississippi River), compared to landings (provided by R. Orhun, NMFS/SEFSC Miami, FL). Fish allocated East and West of Mississippi River based on the NMFS Statistical Shrimp Grid reported (East: grids 1-11; West: grids 12-21). Data combined from 2003-2013.

| Region (all gears combined) | CM landings | Age Samples |
|---|---|---|
| East | 72% | 57% |
| West | 28% | 43% |

| Gear: handline<br>Region | CM landings | Age Samples |
|---|---|---|
| East | 69% | 45% |
| West | 31% | 55% |

| Gear: longline<br>Region | CM landings | Age Samples |
|---|---|---|
| East | 98% | 100% |
| West | 2% | 0% |

Table 5. Summary statistics (range, mean, stddev) of Gray Triggerfish from the northern Gulf of Mexico age and length data by mode (CM – commercial, REC – recreational (includes charter boats, headboats, and private vessels), SS – scientific survey) and by gear (HL – handline, LL – longline, SP – spear, TR – trap, TRW – trawl). Only reported for those modes and gears with at least 40 samples. All years combined (2003-2013).

| Mode and Gear | n | Fork Length (cm) | Annual Age (yr) |
|---|---|---|---|
| CM_HL | 1151 | 20.8 – 58.9 | 2 – 10 |
| | | 40.4 ± 6.3 | 4.9 ± 1.4 |
| CM_LL | 414 | 24.9 – 69.7 | 2 – 14 |
| | | 48.9 ± 7.2 | 6.5 ± 1.8 |
| REC_HL | 2519 | 20.5 – 61.7 | 1 – 11 |
| | | 36.4 ± 5.8 | 4.2 ± 1.4 |
| REC_SP | 43 | 22.9 – 48.8 | 1 – 11 |
| | | 36.4 ± 6.6 | 4.5 ± 2.0 |
| SS_TR | 828 | 14.5 – 50.5 | 0 – 10 |
| | | 30.2 ± 4.8 | 3.6 ± 1.3 |
| SS_TRW | 394 | 7.4 – 45.8 | 0 – 8 |
| | | 20.7 ± 7.3 | 2.0 ± 1.5 |
| SS_HL | 301 | 23.2 – 57.2 | 1 – 8 |
| | | 33.0 ± 6.1 | 4.0 ± 1.4 |

Table 6. Growth model parameters and model likelihood results for Gray Triggerfish from the Gulf of Mexico (2003-2013), along with the previous predicted growth model parameters for SEDAR09 update (2003-2010). During SEDAR09 update, the size-modified growth model was compiled using Solver in Excel and now the model is compiled in ADMB; therefore, a model run was completed using the data from SEDAR09 update. The size-modified growth model compiled in ADMB has alternative variance structures (1) constant standard deviation (STDEV) with age, (2) constant coefficient of variation (CV) with age, and (3) increase in CV with age. Fractional ages and fork lengths were fit to the size-modified growth model. The recommended model is all data with a constant CV with age (in bold).

| Parameters | SEDAR09 update | Replicate SEDAR09 update | All data constant STDEV | **All data constant CV** | All data Increase CV age |
|---|---|---|---|---|---|
| Sample size | 2393 | 2393 | 4796 | **4796** | 4796 |
| Asymptotic length ($L_\infty$) | 87.11 | 86.82 | 89.06 | **58.97** | 79.51 |
| Growth coefficient (k) | 0.1043 | 0.1051 | 0.0744 | **0.1405** | 0.0877 |
| Size at time zero ($t_0$) | 0.0532 | 0.0638 | -2.0640 | **-1.6569** | -1.9425 |
| Sigma or CV | 76.01 | 7.60 | 6.7997 | **0.2185** | 0.2740, 0.0743 |
| Objective function | $9.2 \times 10^3$ | $5.1 \times 10^3$ | $1.4 \times 10^4$ | **$1.4 \times 10^4$** | $1.4 \times 10^4$ |
| Delta AICc (phase 3) | --- | $-3.7 \times 10^2$ | $-1.0 \times 10^4$ | **$-1.0 \times 10^3$** | $-2.8 \times 10^3$ |

Table 7. Growth model parameters and model likelihood results for Gray Triggerfish from the Gulf of Mexico (2003-2013). These models were fit to fractional ages and fork lengths using a constant standard deviation (STDEV) with age and 5 alternative datasets (1) all data, (2) only fishery independent data, (3) only fishery dependent data, (4) only commercial data, and (5) only recreational data.

| Parameters | All data constant STDEV | Fishery independent | Fishery dependent | Commercial | Recreational* |
|---|---|---|---|---|---|
| Sample size | 4796 | 1537 | 3259 | 1663 | 2562 |
| # records not used | 966 | | 966 | 233 | 733 |
| FL (range) | 7.4 – 69.7 | 7.4 – 57.2 | 20.5 – 69.7 | 20.8 – 69.7 | 20.5 – 61.7 |
| Age (range) | 0.0 – 14.3 | 0.0 – 10.3 | 0.5 – 14.3 | 0.5 – 14.3 | 0.5 – 11.2 |
| Asymptotic length ($L_\infty$) | 89.06 | 41.08 | 81.31 | 66.45 | 70.00* |
| Growth coefficient (k) | 0.0744 | 0.2970 | 0.1009 | 0.1416 | 0.0918 |
| Size at time zero ($t_0$) | -2.0640 | -0.9051 | -0.7041 | -1.7716 | -1.0688 |
| Sigma | 6.7997 | 4.7974 | 7.8905 | 6.6989 | 8.2377 |
| Objective function | $1.4 \times 10^4$ | $4.6 \times 10^3$ | $9.2 \times 10^3$ | $4.3 \times 10^3$ | 4.7 x 103 |
| Delta AICc (phase 3) | $-1.0 \times 10^4$ | -3.10 | $-6.8 \times 10^2$ | $-6.6 \times 10^2$ | -13.95 |

*This model run did not converge properly. This model run problems predicting model parameters, regardless of initial estimates and/or bounds for model parameters.

Table 8. Growth model parameters and model likelihood results for Gray Triggerfish from the Gulf of Mexico (2003-2013). These models were fit to fractional ages and fork lengths using a constant coefficient of variation (CV) with age and 5 alternative datasets (1) all data, (2) only fishery independent data, (3) only fishery dependent data, (4) only commercial data, and (5) only recreational data.

| Parameters | All data constant CV | Fishery independent | Fishery Dependent* | Commercial | Recreational* |
|---|---|---|---|---|---|
| Sample size | 4796 | 1537 | 3259 | 1663 | 2562 |
| # records not used | 966 | | 966 | 233 | 733 |
| FL (range) | 7.4 – 69.7 | 7.4 – 57.2 | 20.5 – 69.7 | 20.8 – 69.7 | 20.5 – 61.7 |
| Age (range) | 0.0 – 14.3 | 0.0 – 10.3 | 0.5 – 14.3 | 0.5 – 14.3 | 0.5 – 11.2 |
| Asymptotic length ($L_\infty$) | 58.97 | 40.61 | 80.00* | 83.26 | 54.50 |
| Growth coefficient (k) | 0.1405 | 0.2890 | 0.0698 | 0.0696 | 0.0759 |
| Size at time zero ($t_0$) | -1.6569 | -1.0736 | -3.6497 | -4.8300 | -5.000* |
| Sigma | 0.2185 | 0.1812 | 0.2168 | 0.1571 | 0.3002 |
| Objective function | $1.4 \times 10^4$ | $4.7 \times 10^3$ | $9.3 \times 10^3$ | $4.3 \times 10^3$ | $4.7 \times 10^3$ |
| Delta AICc (phase 3) | $-1.0 \times 10^3$ | -24.25 | -5.77 | $-4.1 \times 10^2$ | -6.03 |

*This model run did not converge properly. This model run problems predicting model parameters, regardless of initial estimates and/or bounds for model parameters.

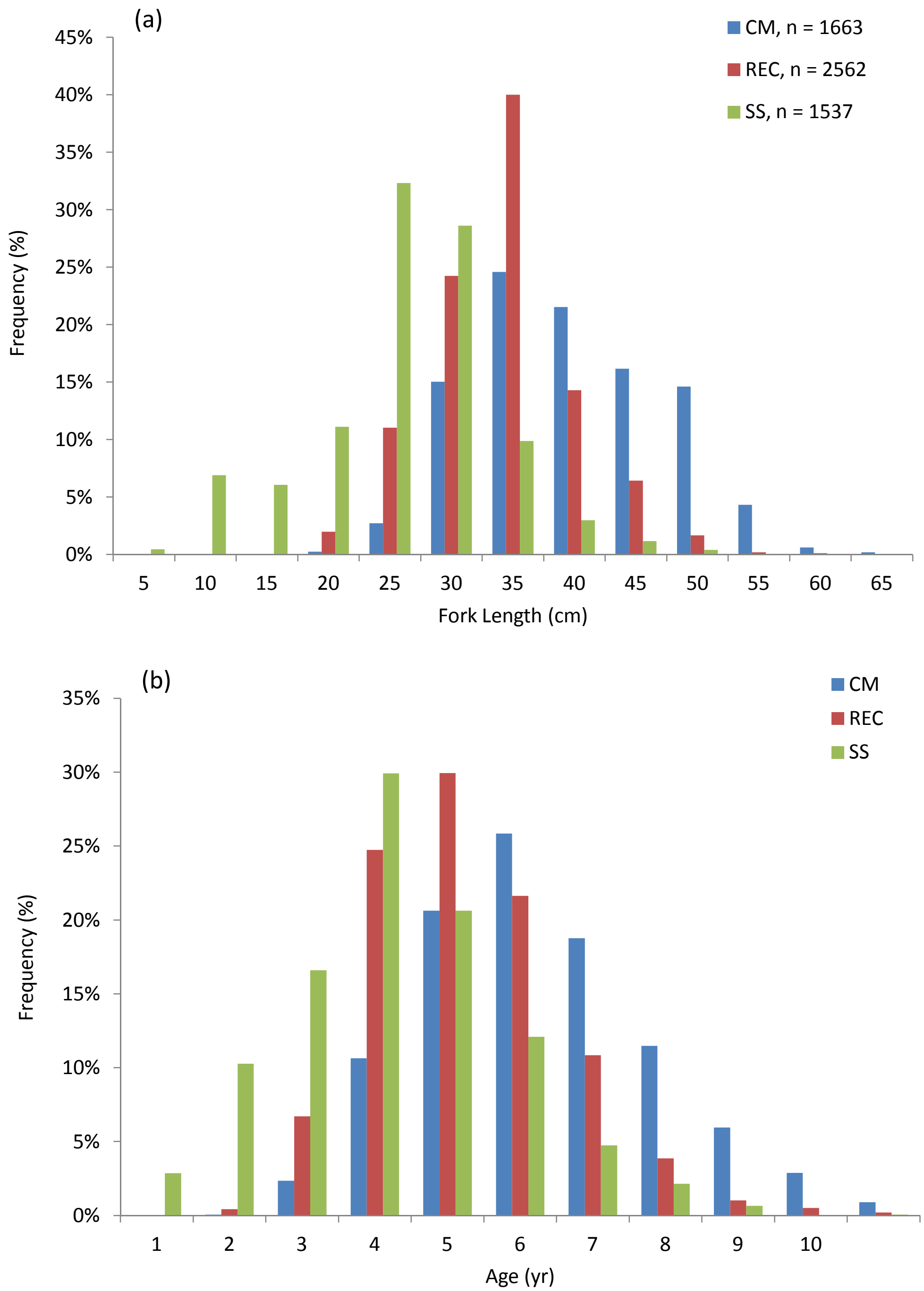



Figure 1. Gray Triggerfish from the northern Gulf of Mexico (a) length and (b) age frequencies by fishing mode (CM - Commercial, REC - Recreation, SS - Scientific Survey) for all years combined (2003-2013).

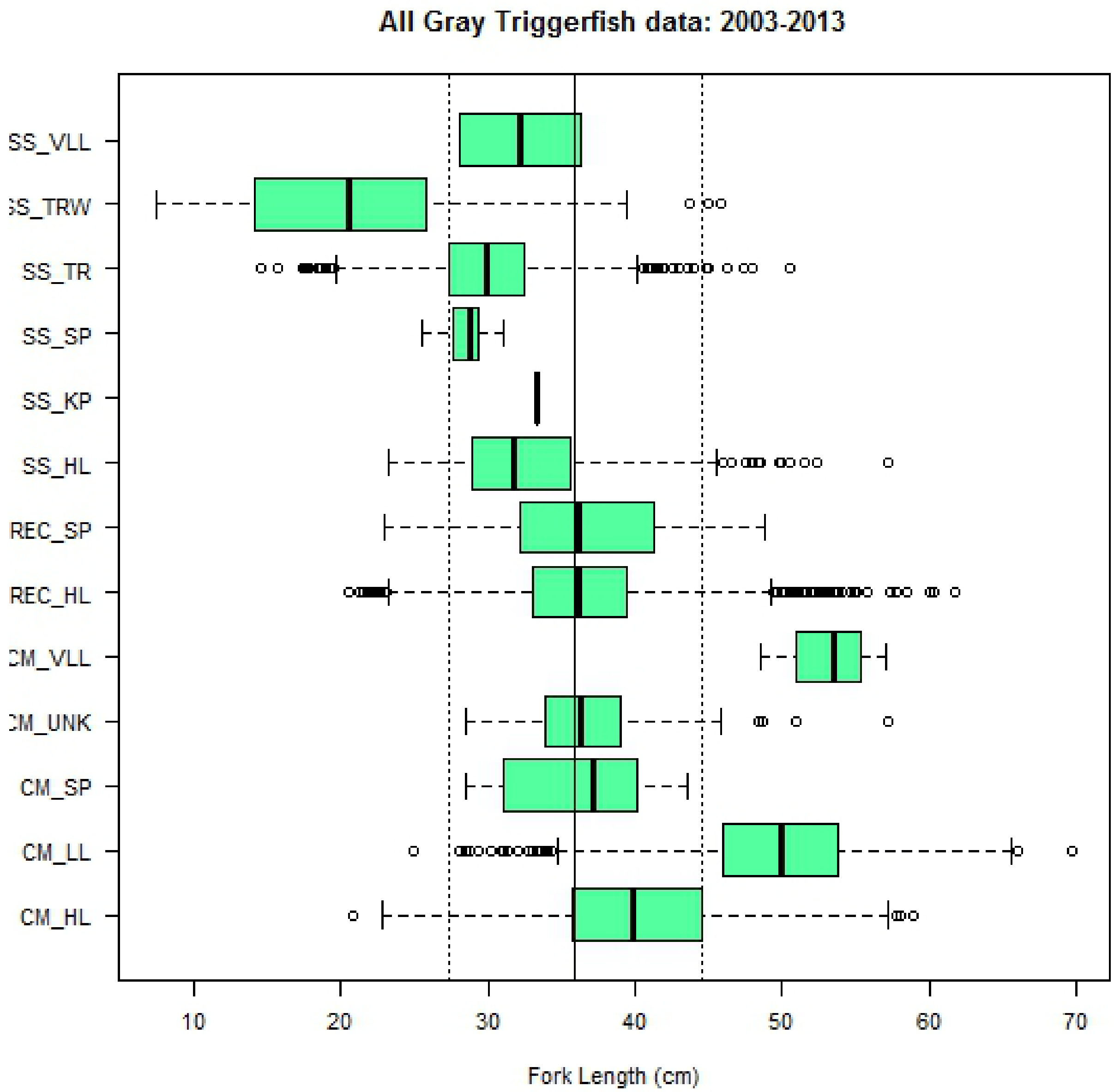



Figure 2. Box plots of Gulf of Mexico Gray Triggerfish (2003-2013) length data by mode and gear, which include the median, upper and lower quartiles (boxes: not drawn in proportion to the sample size), upper and lower range (dashed line), and outliers (open circles). Modes: CM – Commercial, REC- Recreational, SS – Scientific Survey. Gears: HL- handline, LL – longline, VLL – vertical longline, SP- spear, TRW – trawl, TR – trap, KP – kali pole, UNK – unknown. Vertical lines represent the overall mean (solid line) and upper and lower standard deviations (dashed lines).

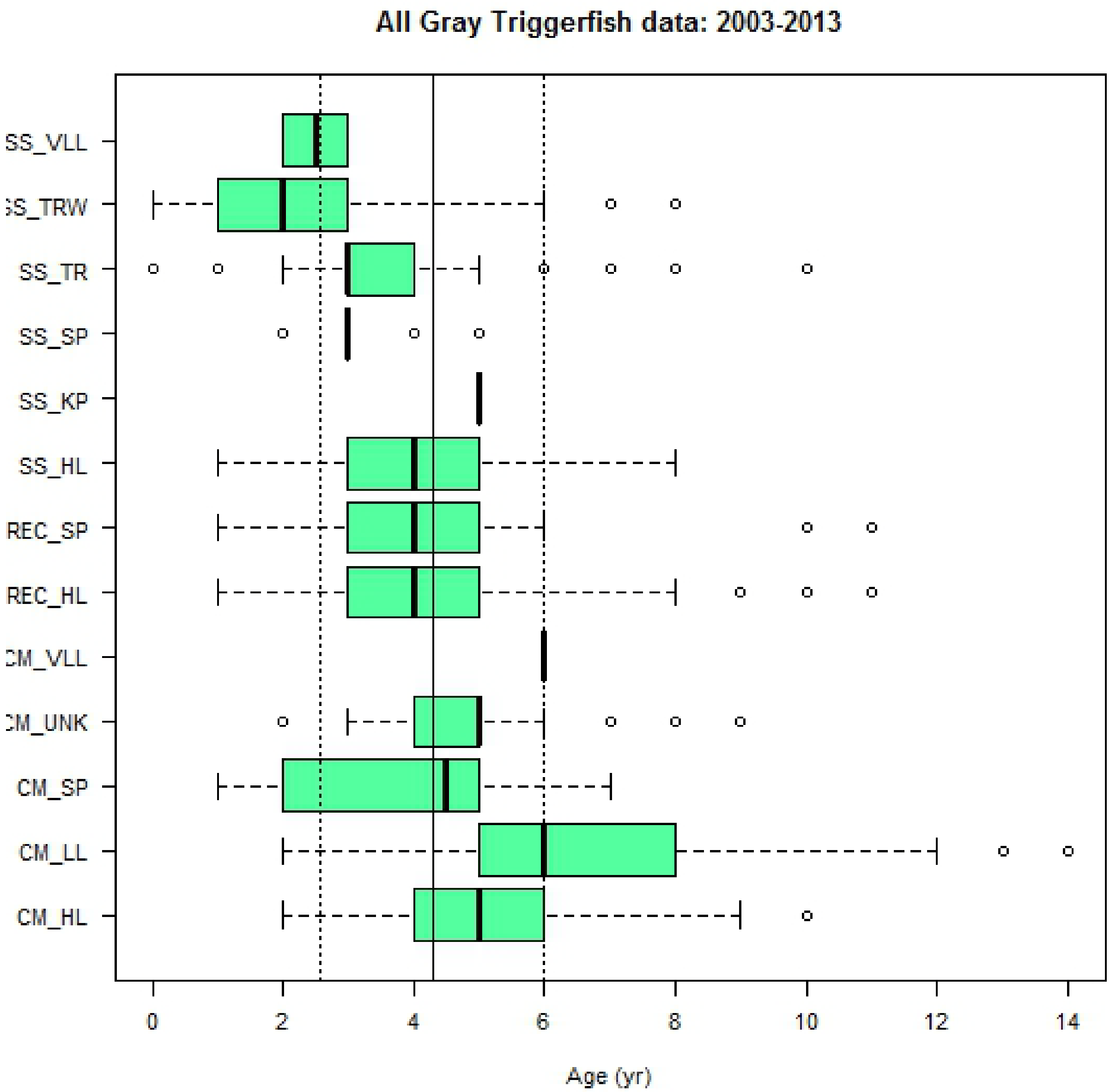



Figure 3. Box plots of Gulf of Mexico Gray Triggerfish (2003-2013) age data by mode and gear, which include the median, upper and lower quartiles (boxes: not drawn in proportion to the sample size), upper and lower range (dashed line), and outliers (open circles). Modes: CM – Commercial, REC- Recreational, SS – Scientific Survey. Gears: HL- handline, LL – longline, VLL – vertical longline, SP- spear, TRW – trawl, TR – trap, KP – kali pole, UNK – unknown. Vertical lines represent the overall mean (solid line) and upper and lower standard deviations (dashed lines).

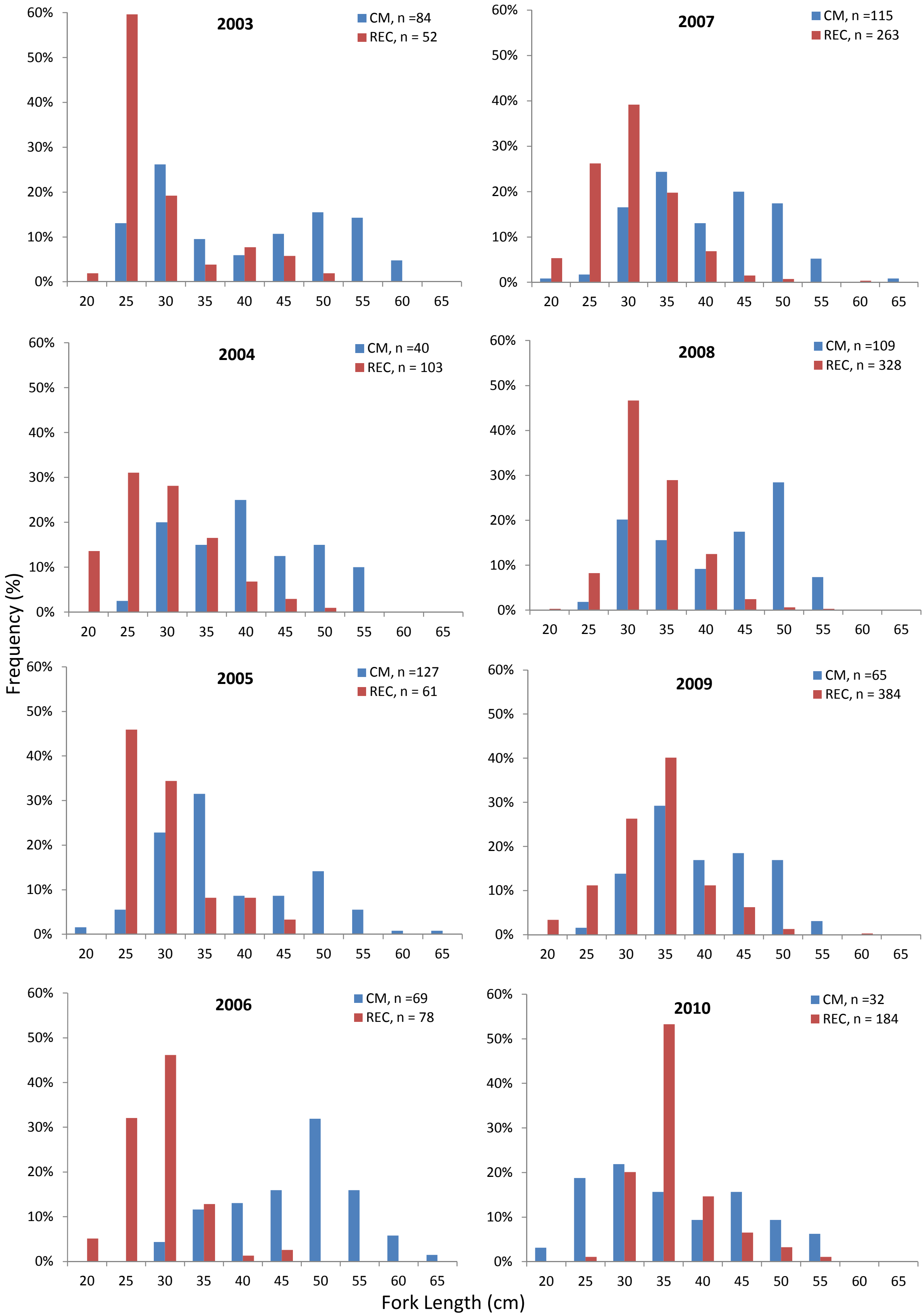



Figure 4. Gray Triggerfish from the northern Gulf of Mexico annual length frequencies by fishery (CM - Commercial, REC - Recreation). Note: both fisheries are governed by the same size limits, which increased in 2008.

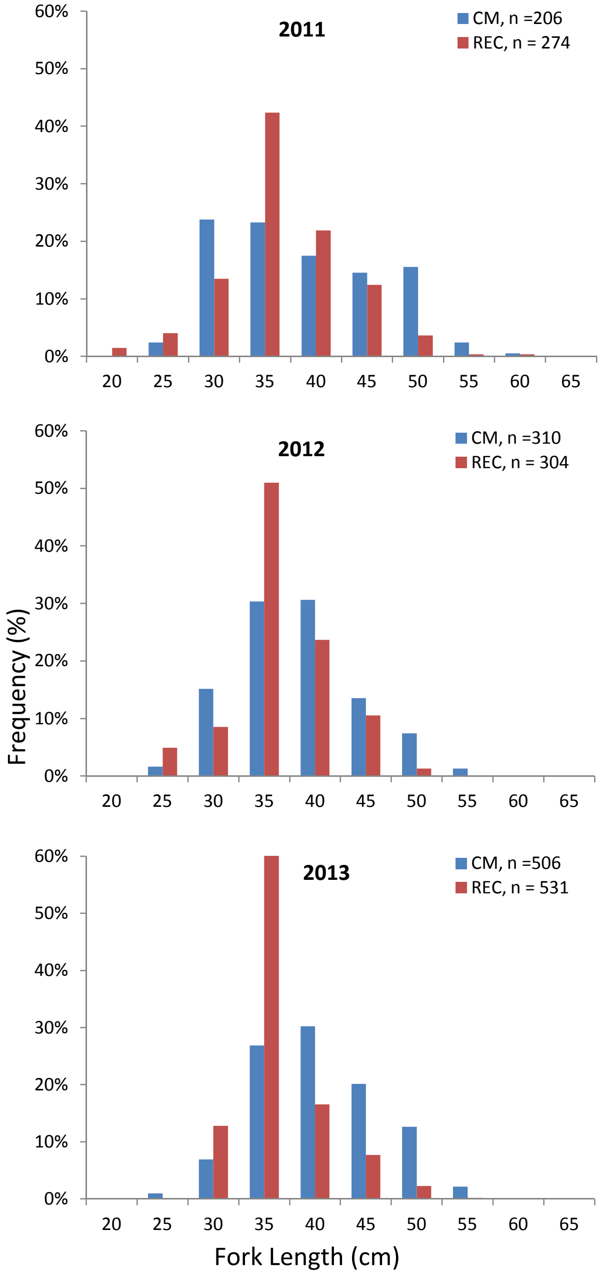



Figure 4. continued

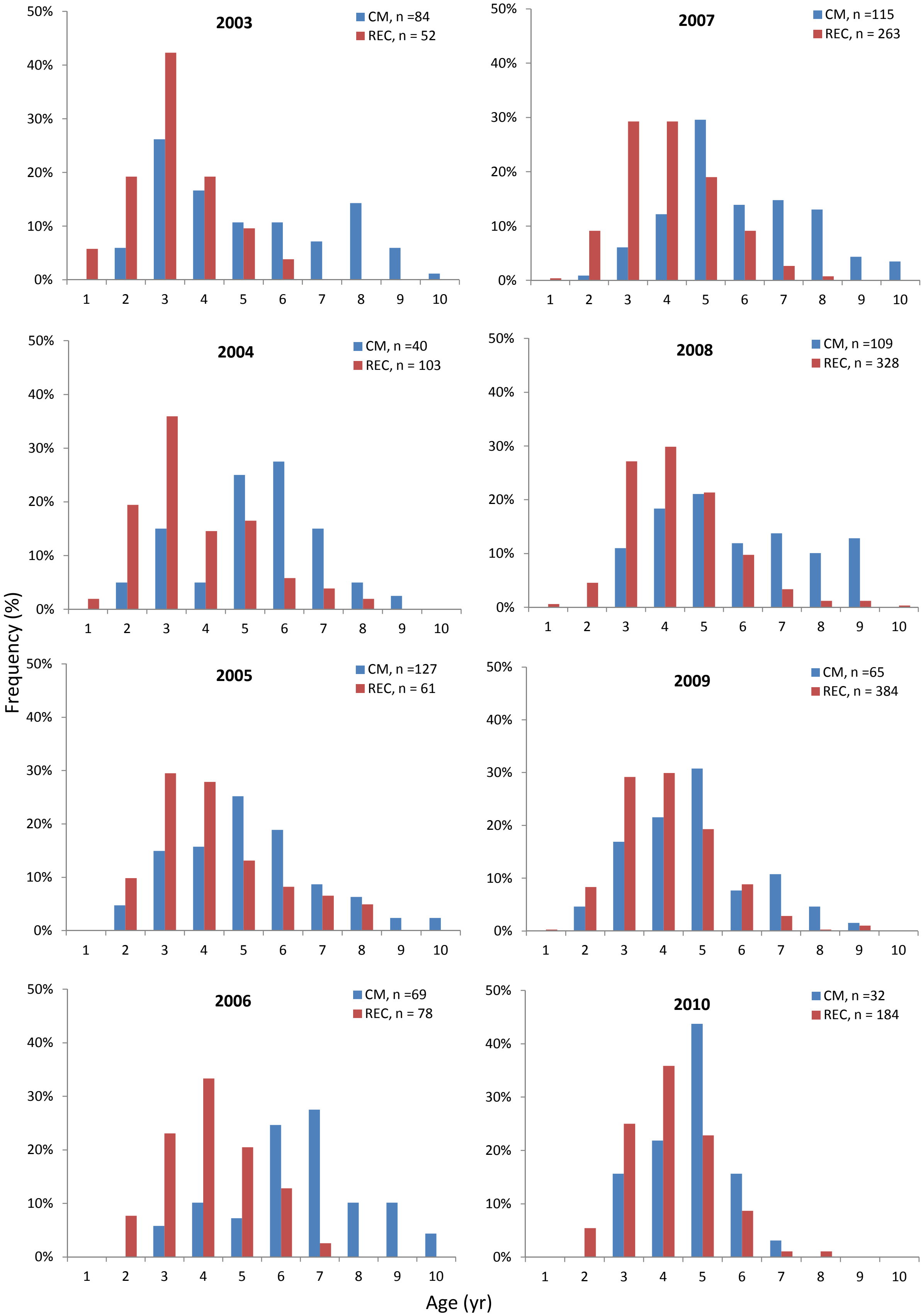



Figure 5. Gray Triggerfish from the northern Gulf of Mexico annual age frequencies by fishery (CM - Commercial, REC - Recreation) .

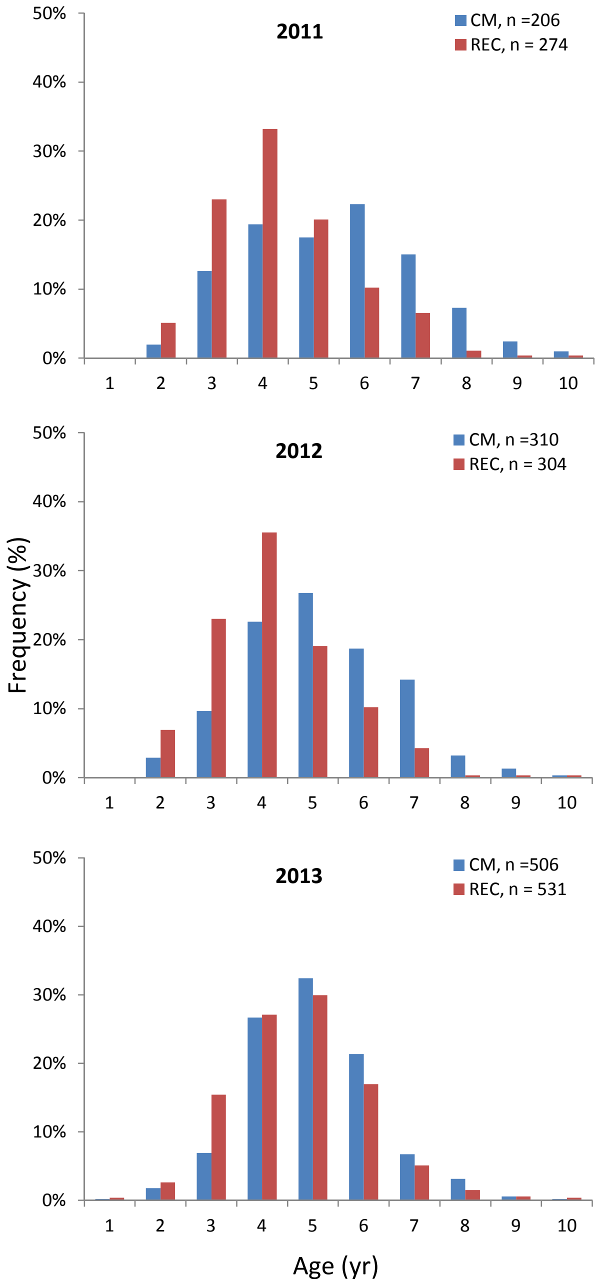



Figure 5. continued

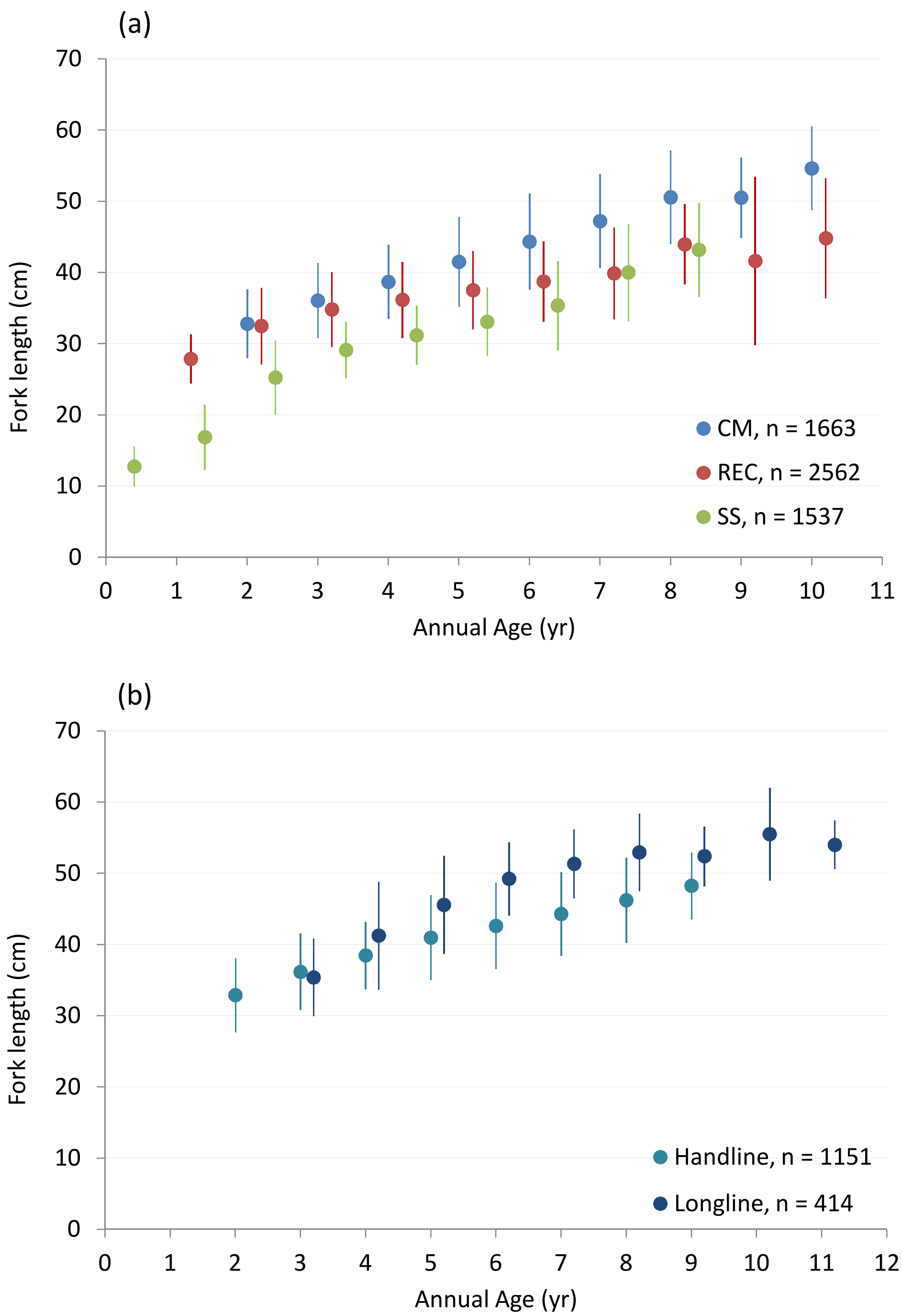



Figure 6. Gray Triggerfish from the northern Gulf of Mexico mean size-at-age ± std dev by (a) fishing mode (CM - Commercial, REC - Recreation, SS - Scientific Survey) and by (b) commercial gear type (handline, longline) for all years combined (2003-2013).

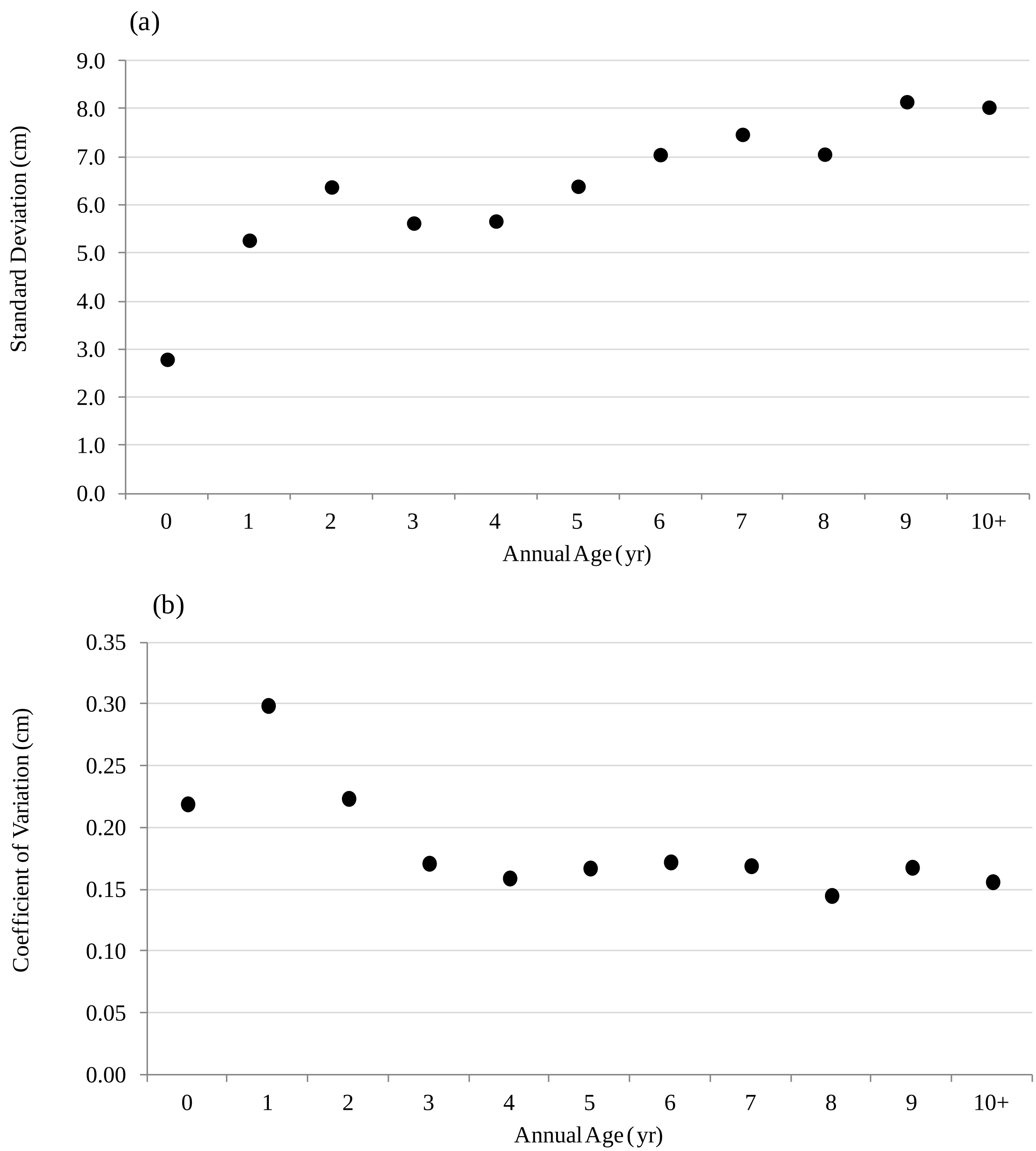
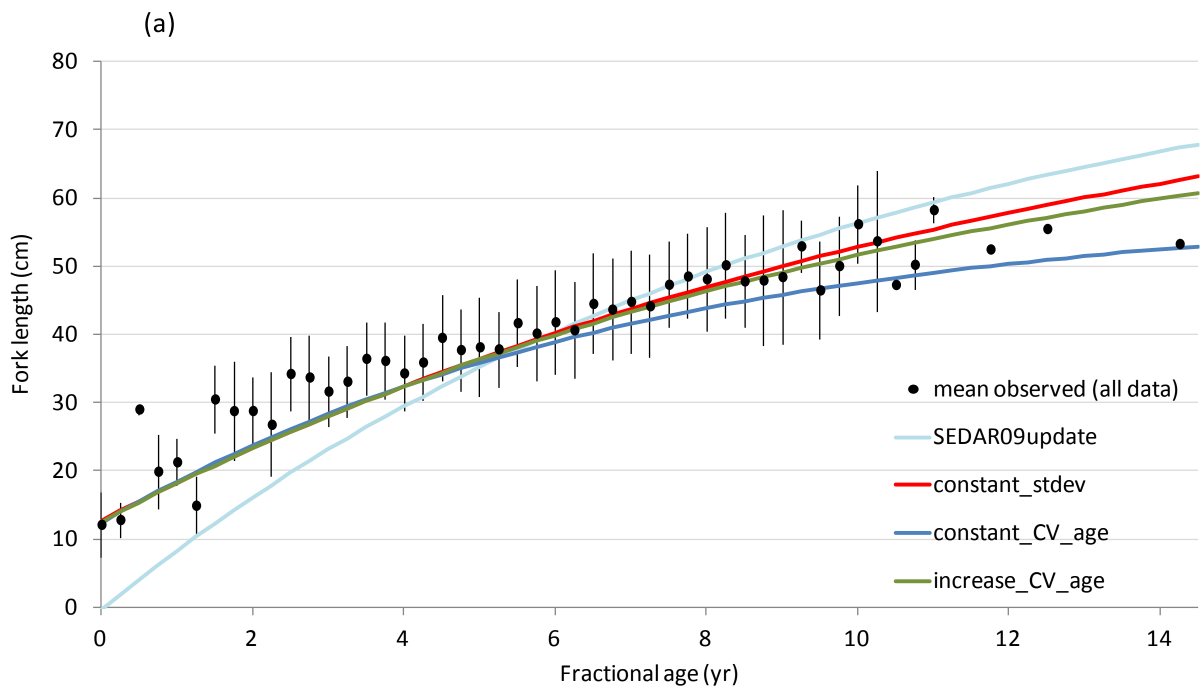



Figure 7. Variance structure for observed size-at-age data for Gray Triggerfish from the northern Gulf of Mexico (2003-2013) (a) standard deviation and (b) coefficient of variation at length for each age. Data combined from all fishing modes and gears.



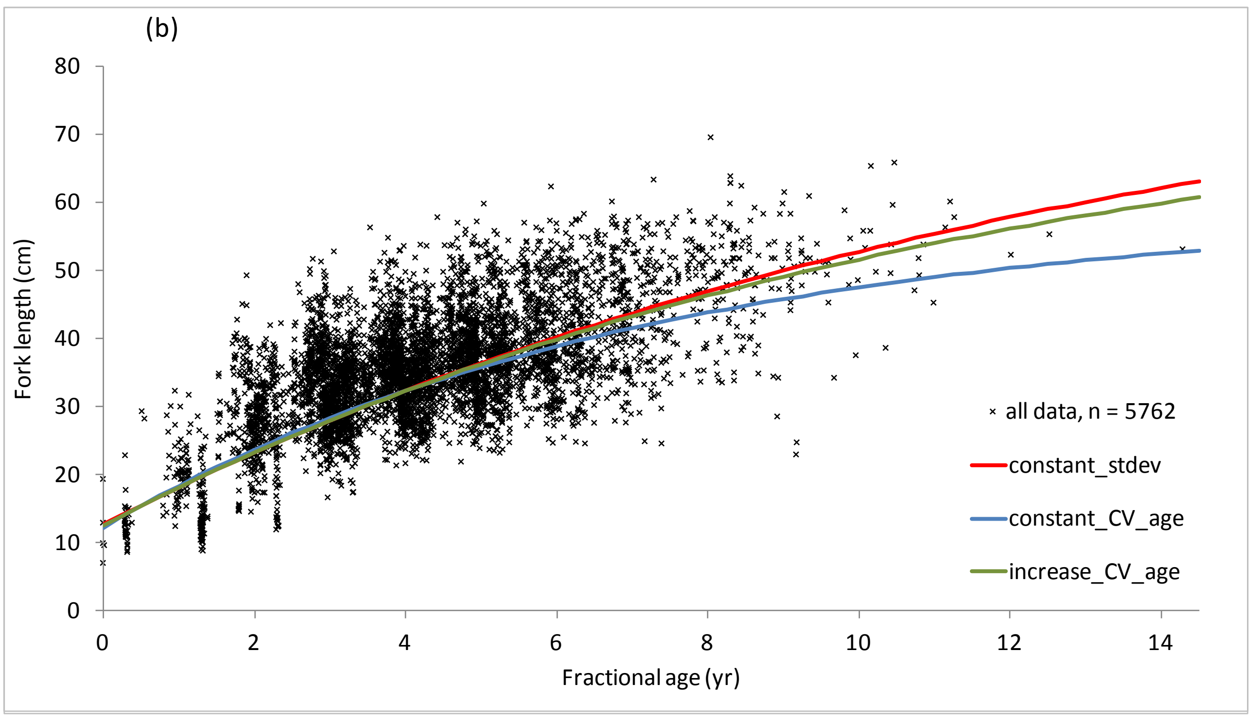




Figure 8. Results of size-modified von Bertalanffy growth model with multiple variance structures for Gray Triggerfish from the northern Gulf of Mexico (2003-2013) plotted with (a) mean observed fork length ± stdev at fractional age (per 0.25 age) and (b) observed size-at-age. Growth models were fit to fractional ages and fork lengths.

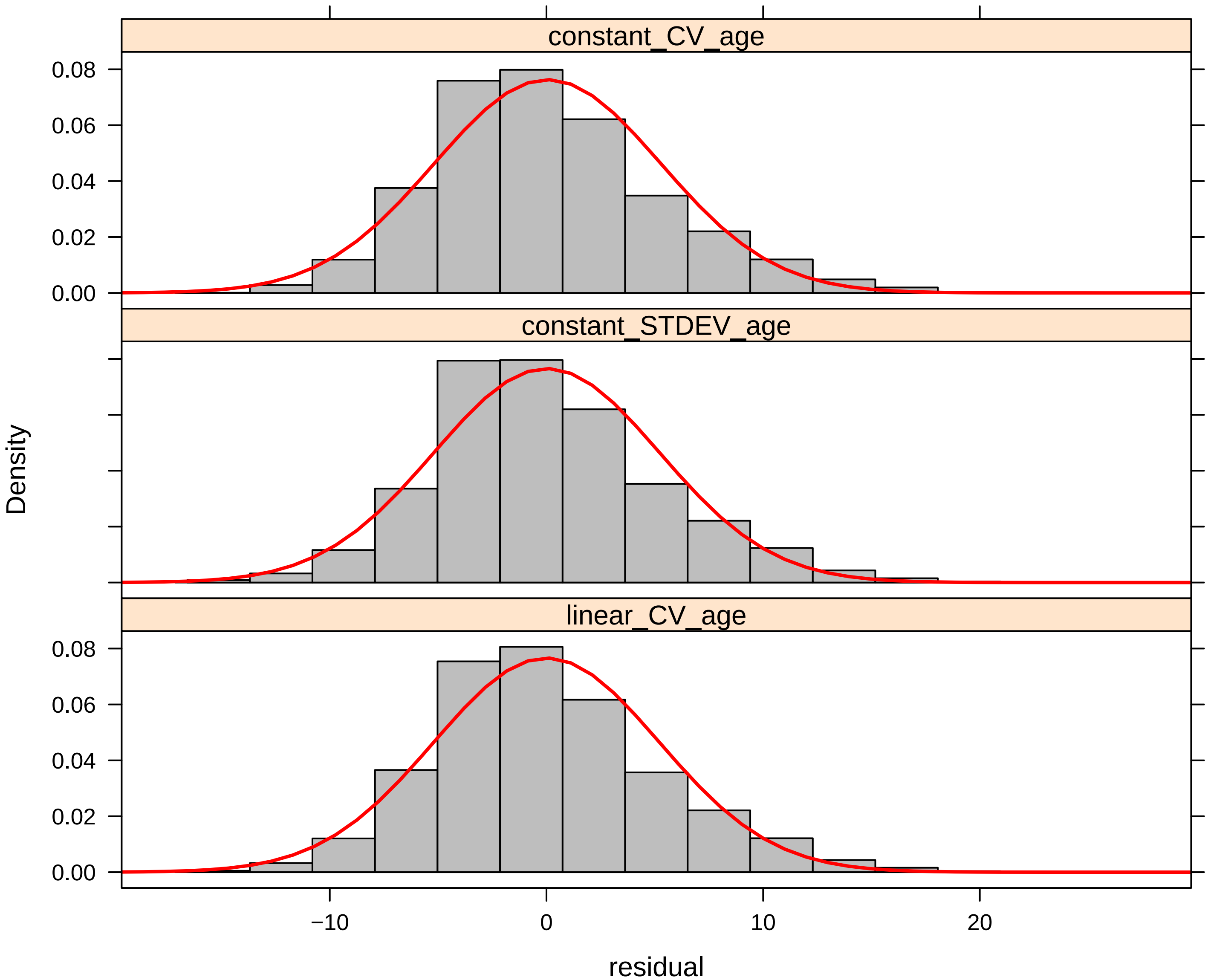



Figure 9a. Distribution of residuals for each size-modified von Bertalanffy growth model using alternative variance structures for Gray Triggerfish from the northern Gulf of Mexico for all data (2003-2013).

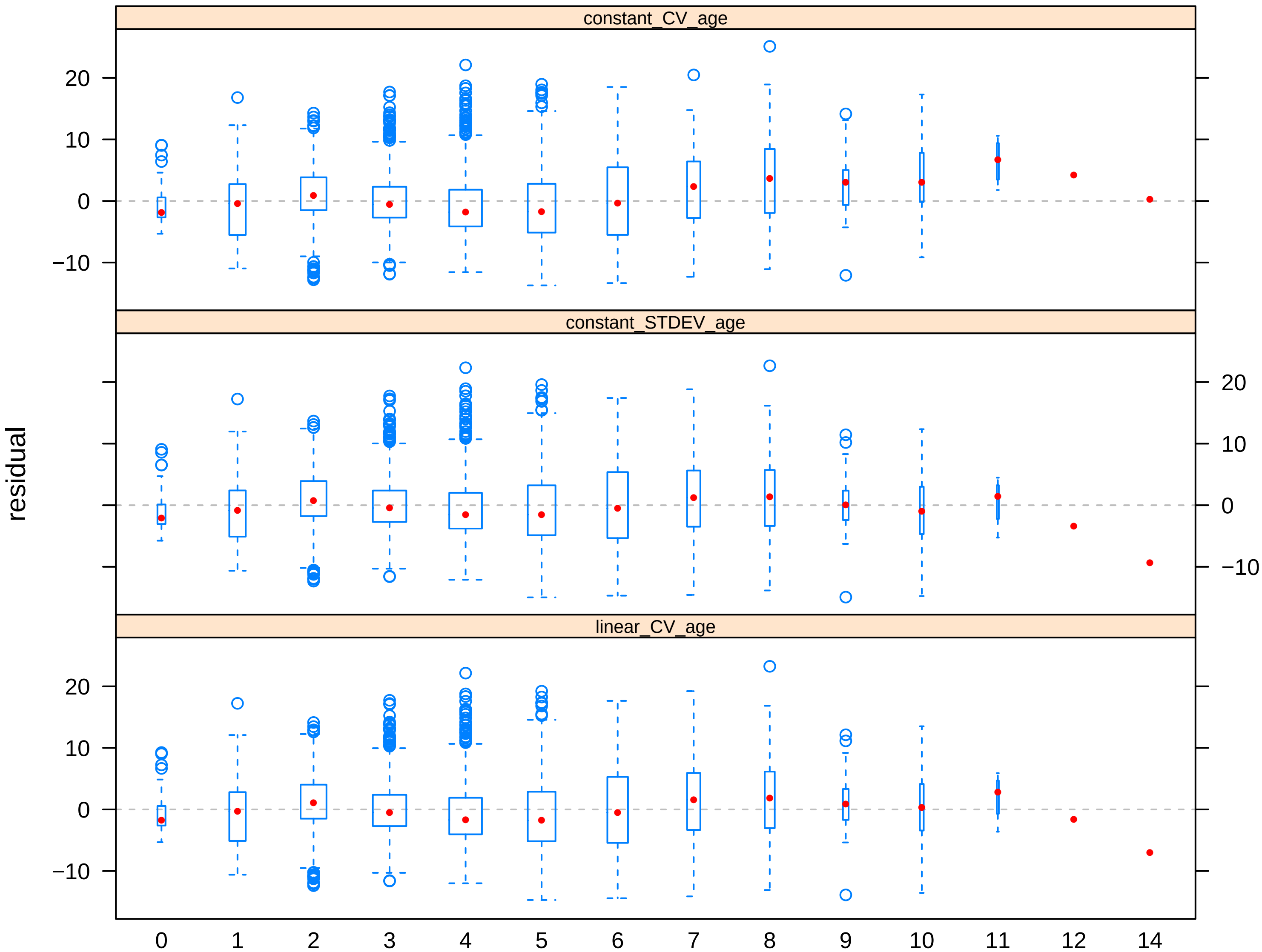



Figure 9b. Residuals by age for each size-modified von Bertalanffy growth model using alternative variance structures for Gray Triggerfish from the northern Gulf of Mexico for all data (2003-2013). See Figure 2 for description of boxplots.

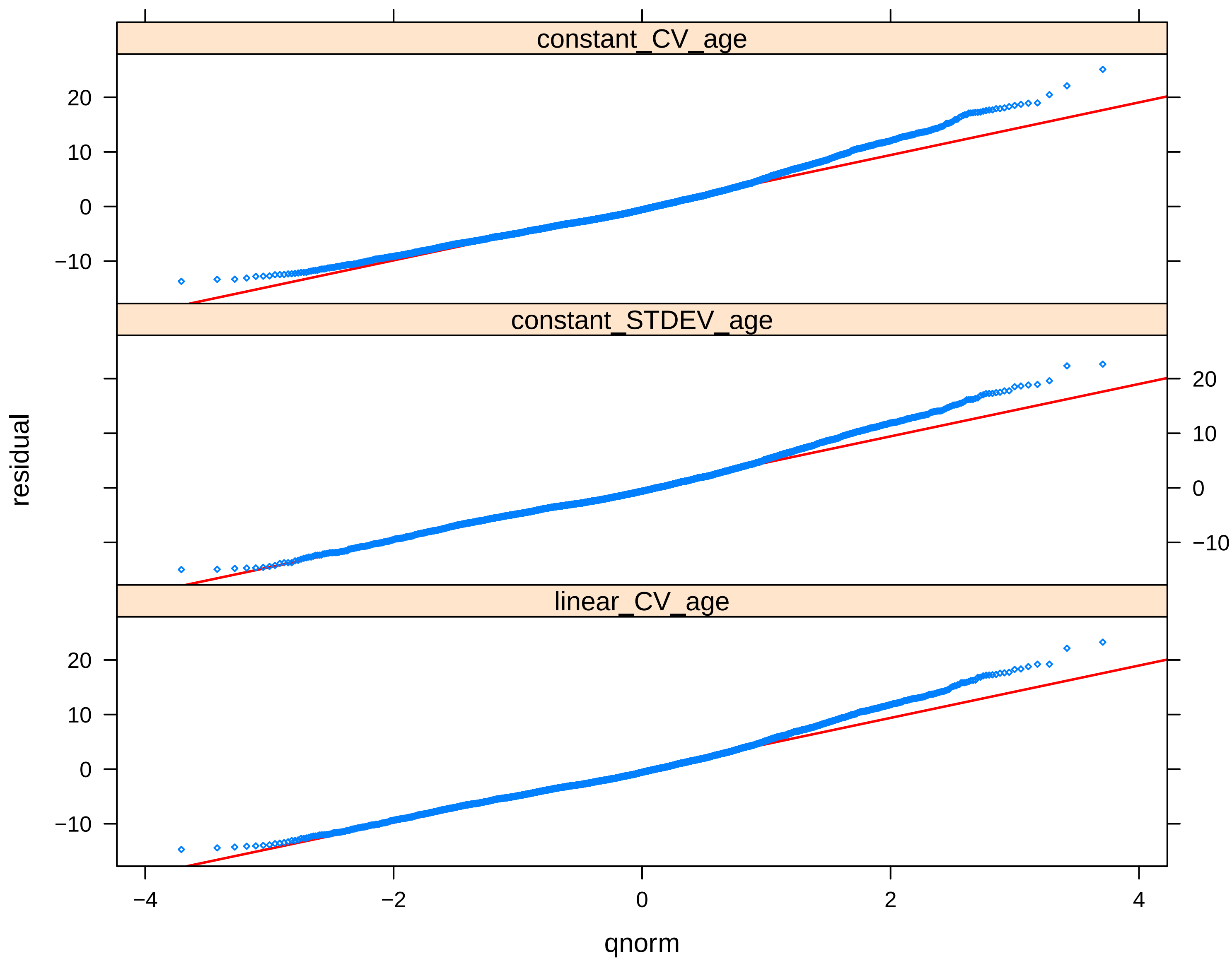



Figure 9c. Normal probability plots (quantiles vs residuals) for each size-modified von Bertalanffy growth model using alternative variance structures for Gray Triggerfish from the northern Gulf of Mexico for all data (2003-2013).

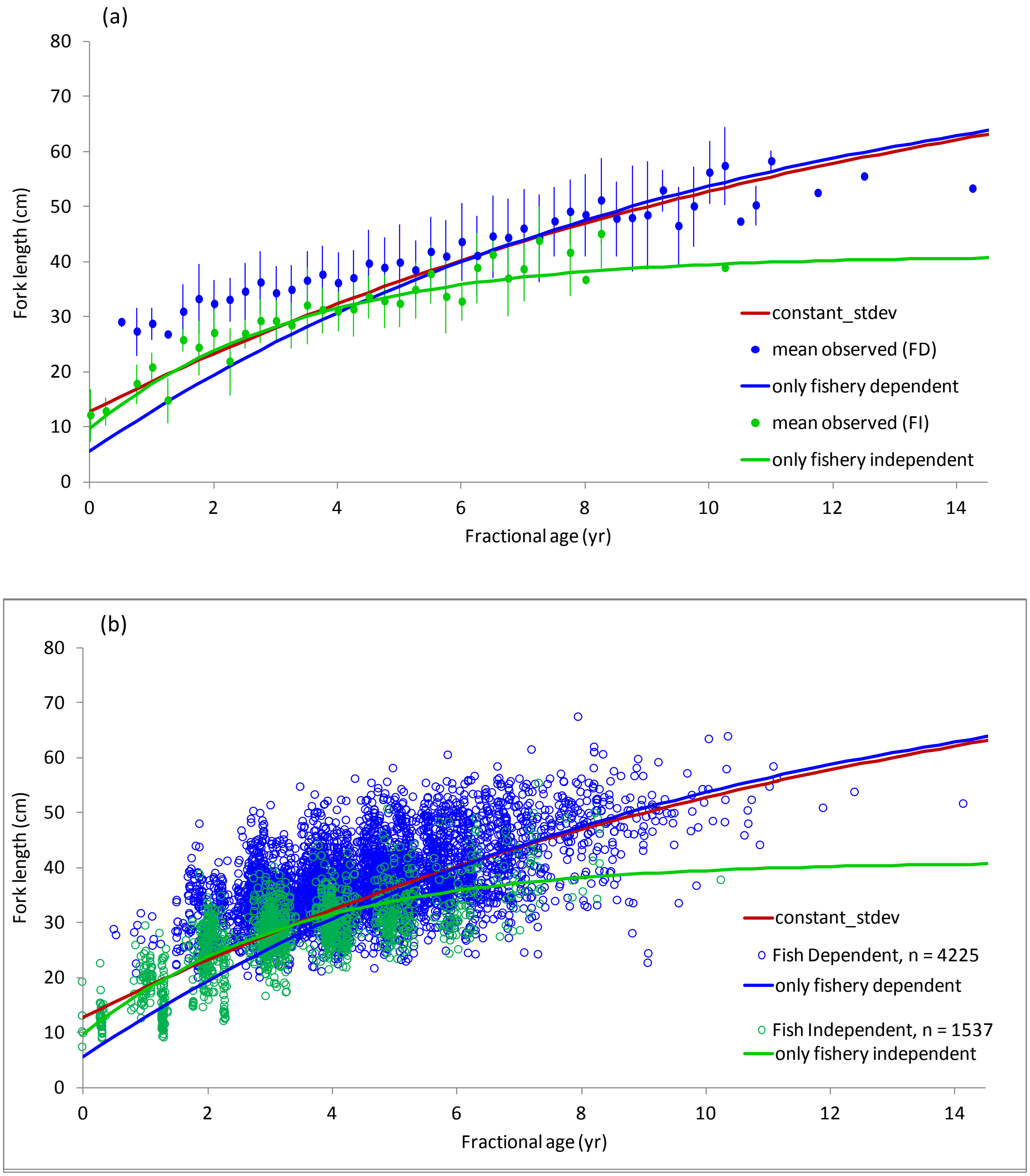



Figure 10. Results of size-modified von Bertalanffy growth model using constant standard deviations at age for Gray Triggerfish from the northern Gulf of Mexico (2003-2013) plotted with (a) mean observed fork length ± stdev at fractional age (per 0.25 age) and (b) observed size-at-age. Growth model fit to 3 different data sets: all data, only fishery dependent data (FD), and only fishery independent (FI) data. Growth models were fit to fractional ages and fork lengths.

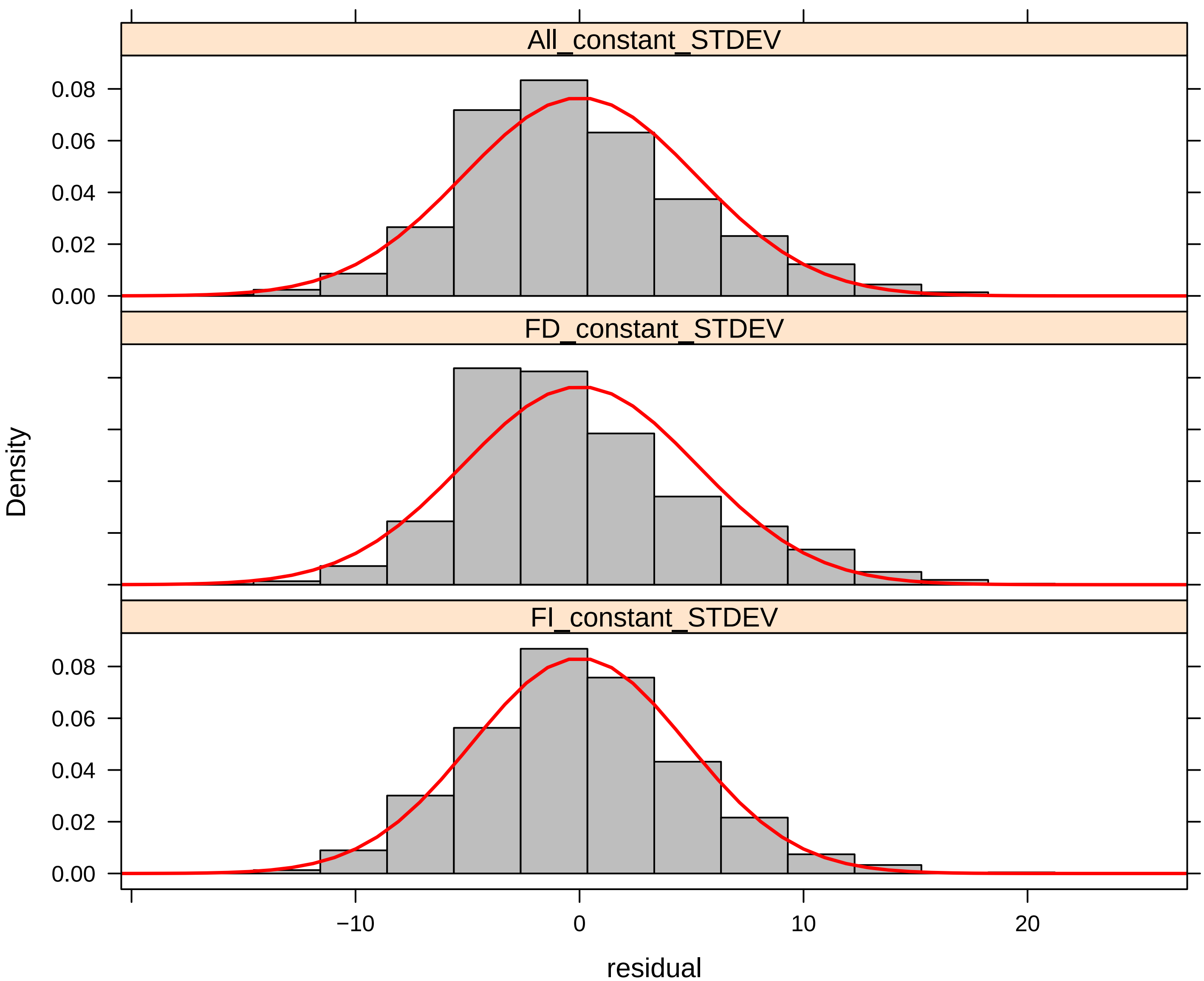



Figure 11a. Distribution of residuals for each size-modified von Bertalanffy growth model using alternative datasets: all data, only fishery dependent data (FD), or only fishery independent data (FI) for Gray Triggerfish from the northern Gulf of Mexico (2003-2013).
Models were fit using a standard deviation at age variance structure.

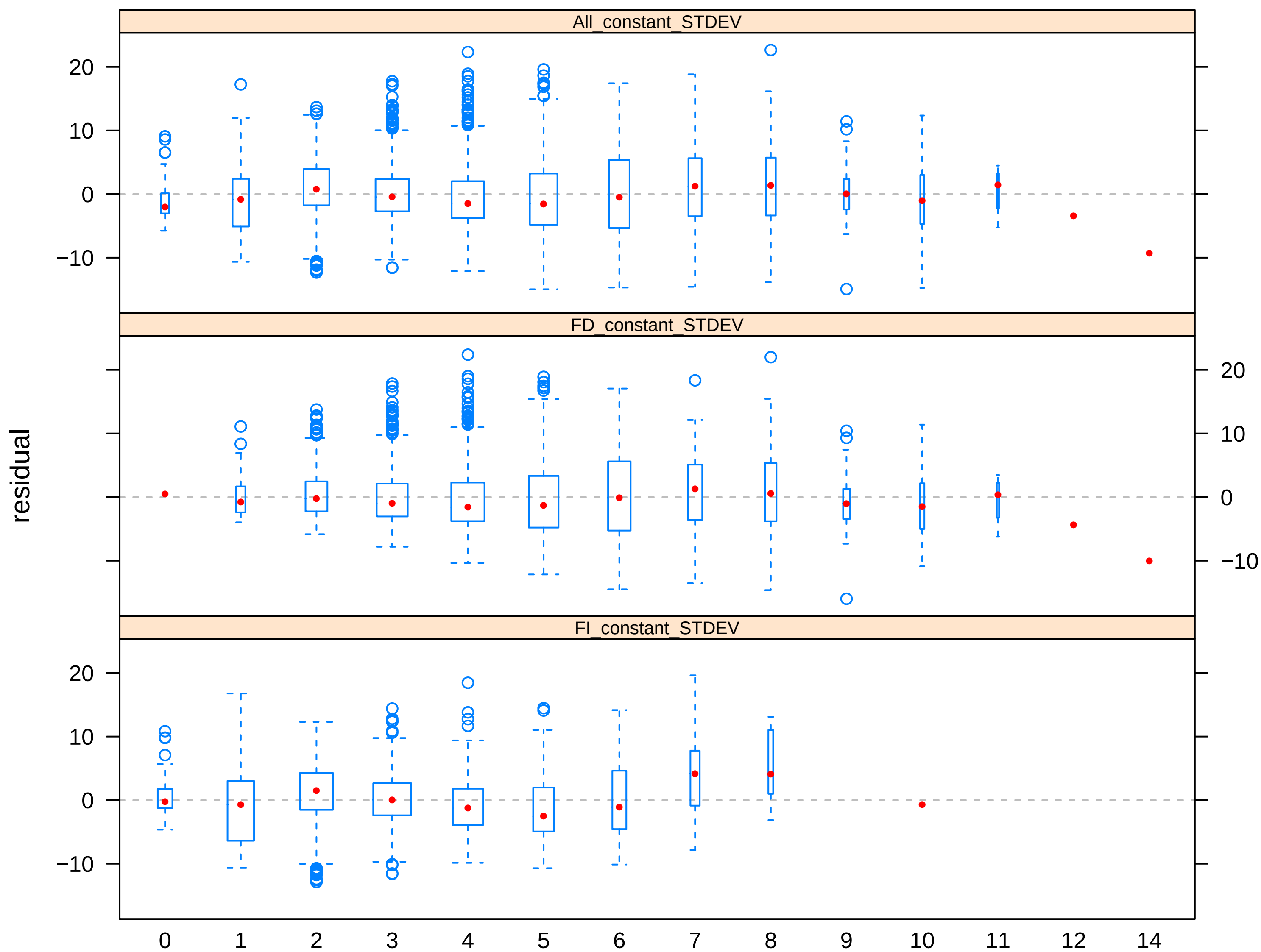



Figure 11b. Residuals by age for each size-modified von Bertalanffy growth model using alternative datasets: all data, only fishery dependent data (FD), or only fishery independent data (FI) for Gray Triggerfish from the northern Gulf of Mexico (2003-2013). Models were fit using a standard deviation at age variance structure. See Figure 2 for description of boxplots.

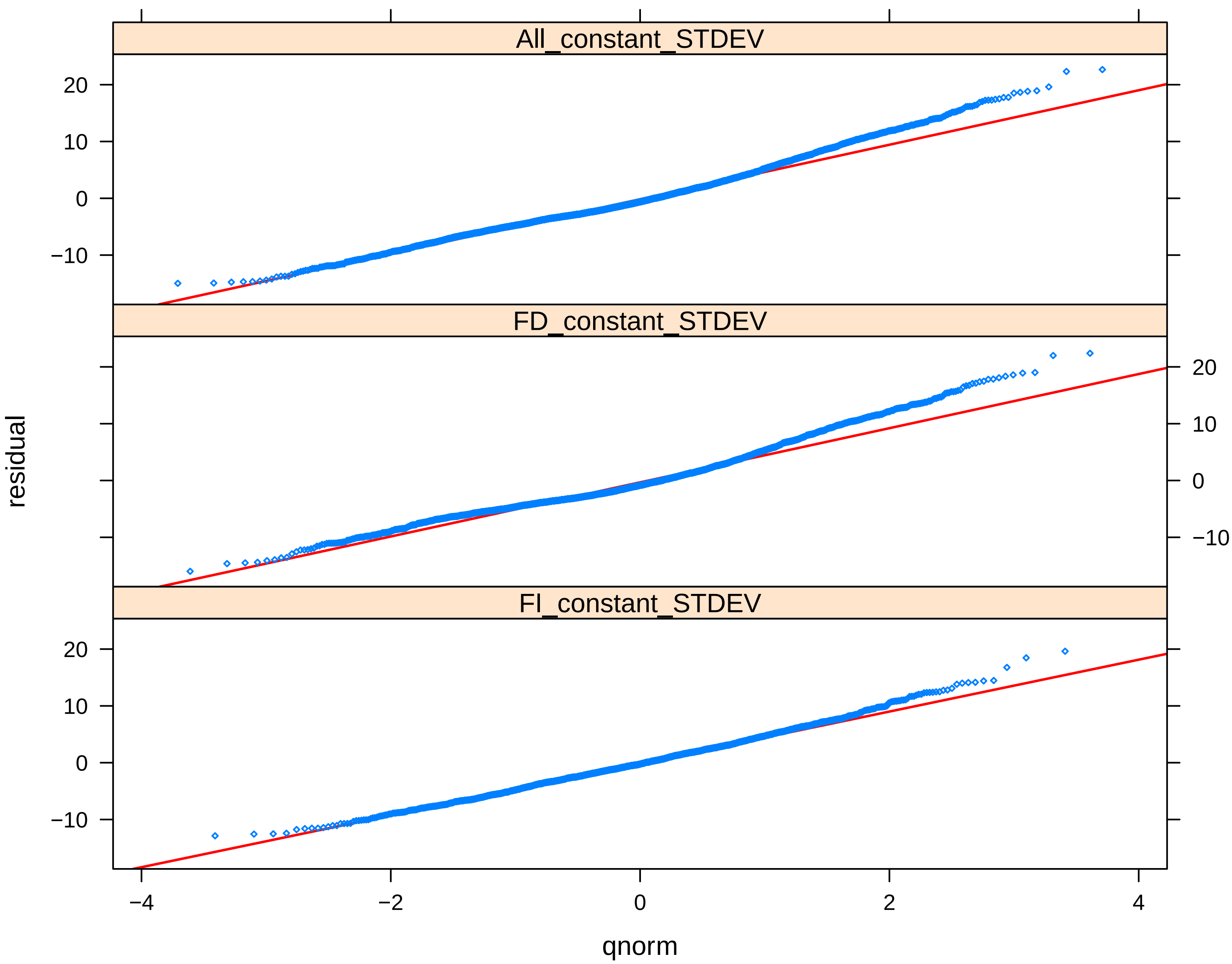



Figure 11c. Normal probability plots (quantiles vs residuals) for each size-modified von Bertalanffy growth model using alternative datasets: all data, only fishery dependent data (FD), or only fishery independent data (FI) for Gray Triggerfish from the northern Gulf of Mexico (2003-2013). Models were fit using a standard deviation at age variance structure.