A Categorical Approach to Modeling Catch at Age for Various Sectors of the Gray Triggerfish (*Balistes capriscus*) Fishery in the Gulf of Mexico

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ABSTRACT

Estimation of the age distribution of fish in different fisheries sectors is a necessary tool for age-based modeling and stock assessment. Two methods of estimating ages from fork lengths of gray triggerfish (*Balistes capriscus*) sampled from both commercial and recreational sectors in Gulf of Mexico (Gulf) fisheries are compared and described. A multinomial model was used to estimate the probability (± standard error) of a fish of a particular length class (25 mm length categories) occurring in a particular age class. This model was based on age and growth data derived from hard part analyses combined from numerous studies throughout the Gulf. An age frequency distribution was then developed for each fish in the aforementioned fishery dependent data sets, and those frequencies were aggregated for all fish in a particular data set to form an overall age frequency distribution. The more known technique of estimating age from length using an inverted form of the von Bertalanffy growth function was also used. The categorical modeling technique allowed the calculation of standard error for each age class in the overall frequency distributions, which estimation of age using inverted von Bertalanffy functions does not make possible. Finally, mortality estimates of Gulf gray triggerfish are derived using the slope of the descending limbs of the age frequency histograms.

KEY WORDS: Growth, mortality, *Balistes capriscus*

Un Acercamiento Categórico a Modelar el Retén en la Edad Para los Varios Sectores de la Industria Pesquera Gris del Triggerfish (*Balistes capriscus*) en el Golfo de México

La valoración de la distribución de la edad de pescados en diversos sectores pesqueros es una herramienta necesaria para modelar y el gravamen común edad-basados. Dos métodos de estimar edades de las longitudes de la bifurcación del triggerfish gris (capriscus de Balistes) muestreadas de sectores recreacionales y comerciales en el golfo de las industrias pesqueras de México (golfo) se comparan y se describen. Un modelo multinomial fue utilizado para estimar la probabilidad (error de estándar del ±) de un pescado de una clase particular de la longitud (categorías de 25 milímetros de longitud) que ocurría en un grupo de edad particular. Este modelo fue basado en la edad y los datos del crecimiento basados en los análisis duros de la parte combinados de estudios numerosos a través del golfo. Una distribución de frecuencia de la edad entonces fue desarrollada para cada pescado en los modems dependientes de la industria pesquera ya mencionada, y esas frecuencias fueron apiladas para todos los pescados en un modem particular para formar una distribución de frecuencia total de la edad. La técnica sabida de estimar edad de la longitud que usaba una forma invertida de la función del crecimiento de von Bertalanffy también fue utilizada. La técnica que modelaba categórica permitió el cálculo del error de estándar para cada grupo de edad en las distribuciones de frecuencia totales, que la valoración de usar de la edad invirtió a von Bertalanffy que las funciones no hacen posible. Finalmente, las estimaciones de la mortalidad del triggerfish gris del golfo se derivan usando la cuesta de los miembros descendentes de los histogramas de la frecuencia de la edad y se comparan.

PALABRAS CLAVES: Crecimiento, mortalidad, *Balistes capriscus*

INTRODUCTION

Estimation of the age distribution of fish in different fisheries sectors is a necessary tool for age-based modeling and stock assessment. Traditionally, a random sample of the fish landed by a particular fishery are measured and weighed, and this information is used to infer characteristics and stock structure of the species undergoing assessment. Oftentimes, cohorts are identified by estimating an age for each length using an inverted von Bertalanffy function determined by a study that used hard part analysis to establish the relationship and parameters for that particular species. The effectiveness of this methodology is often contingent on the tightness of fit of the computed relationship between length and age as determined by the hard part analysis. In addition, estimation of age using the inverted von Bertalanffy technique does not account for the standard error inherent in the estimation procedure.

For the gray triggerfish population in the Gulf of Mexico, hard part analysis has identified that a wide range of lengths are possible for any given age (Ingram 2001). The presence of a wide range of lengths for a given age often precludes the possibility of conducting an age-based assessment on a population due to the presence of increased uncertainty. To overcome this problem, a categorical modeling method of estimating length at age was explored for gray triggerfish. The categorical modeling approach uses a multinomial model to estimate the probability of a particular fish within a particular length class occurring in a particular age class. This methodology is not based directly on the von Bertalanffy growth function and therefore the goodness of fit of that relationship is not directly relevant to estimating the catch at age. Further, the categorical modeling approach allows for the calculation of standard error, which is not possible when inferring age from length using an inverted von Bertalanffy function.

METHODS

A categorical model was used to estimate the probability (± standard error) of a fish of a particular length class (i.e. fish were assigned to 25 mm fork length categories) occurring in a particular age class. This procedure analyzes data that is represented by a two-dimensional contingency table. In this case, the rows of the table are formed on the basis of 25 mm size classes, and the columns of the table correspond to age classes 0 through 10+. The frequency in the (i,j)th cell is the number of subjects in the ith size class that occur the jth age class. These frequencies are assumed to follow a product multinomial distribution, corresponding to a sampling design with simple random samples being taken from each size class. For each size class i, the probability of being in the jth age class (π_{ij}) is estimated by the sample proportion, $p_{ij} = n_{ij}/n_i$. The vector (**p**) of all proportions is transformed into a vector of functions, $\mathbf{F} = \mathbf{F}(\mathbf{p})$. If π is the vector of true probabilities for the complete table, then the functions of these true probabilities, $\mathbf{F}(\pi)$, are assumed to follow the linear model $\mathbf{F}(\pi) = \mathbf{X}\beta$, where **X** is the design matrix containing fixed constants, and β is a vector of parameters to be estimated (Agresti 1996).

This model was based on age and growth data collected from hard part analyses combined from numerous studies throughout the Gulf (see Nowlis 2005, Section 2.1.2, Age and Growth Studies). This model allows for the estimation of the probability (± standard error) of an individual fish occurring in an age class depending on the size class in which it occurs. This results in an age probability distribution for an individual fish with corresponding standard error estimates for its probability of occurrence in each age class. When multiple fish are ran through the model, each is one is separated into its own age-probability distribution based on its size class. If these probability distributions for all fish are "stacked" (i.e. summed) by age class, the result is an overall age-frequency distribution based on the number of fish initially entered into the model. Likewise, the estimated standard errors of the probability of occurrence in each age class for each fish can be summed by age class resulting in estimates of standard error for each age class in the overall age-frequency distribution.

Using the described model, an age probability distribution was developed for gray triggerfish captured in the Gulf of Mexico from the commercial and recreational fishing sectors. Data were stratified by fleet (commercial, headboat, MRFSS and Texas), year, and region, where the Eastern Gulf represents fish landed east of the Mississippi River, and the Western Gulf represents fish landed west of the Mississippi. Probabilities calculated for each fish were aggregated by age class within each stratum to form an overall age frequency distribution for each year and sector of the fishery.

The more known technique of estimating age from length using an inverted form of the von Bertalanffy growth function was also used and compared. Von Bertalanffy parameters were estimated during the Southeast Data Assessment and Review (SEDAR) Data Workshop IX (20-24 June 2005, New Orleans, Louisiana); estimations were derived from a study combining age and growth data from Hood and Johnson (1997), Ingram (2001), and unpublished age data from gray trigger spines collected throughout the Gulf from 1992 - 2002 by the NMFS Panama City Lab. Three different sets of parameters were determined for each region: the entire Gulf, Eastern Gulf and Western Gulf. Sloped (also known as linear) von Bertalanffy functions were applied to the Eastern Gulf and Gulfwide, while a traditional von Bertalanffy function was applied to the Western Gulf (Table 1). The categorical modeling technique made possible the calculation of standard error for each age class in the overall frequency distributions, which estimation of age using inverted von Bertalanffy functions does not permit.

Estimates of total mortality were calculated based on the number of survivors of a cohort at the instant t, submitted to the total mortality, Z, during an interval of time:

$$N_t = N_a e^{-Z(t-t_a)}$$

Total mortality estimations assumed fifty percent recruitment to the fishery was achieved at the age where the probability frequency was the greatest for a given year based on the categorically modeled estimates. A value of total mortality was calculated for each year starting from the cohort estimated to be fifty percent recruited to the last age class of individuals 10 years and older. Mortality curves were fit to the catch per age class data estimated using the categorical multinomial approach (Cadima 2003).

Table 1. Von Bertalanffy growth parameters derived for Gray Triggerfish during SEDAR Data Workshop IX using a study combining age and growth data from Hood and Johnson (1997), Ingram (2001), and unpublished age data from gray trigger spines collected throughout the Gulf from 1992-2002 by the NMFS Panama City Lab.

Parameter	Gulfwide	Eastern Gulf	Western Gulf
Linf	336.3792	305.1669	407.2798
k	0.636452	0.741429	0.263649
t-zero	-0.55096	-0.56282	-1.18382
c	11.72933	18.19991	

RESULTS

Percent frequency histograms were generated to compare the categorical binomial approach to estimating catch at age with the traditional use of the inverse von Bertalanffy growth function. Results of the categorically derived age estimations reflect the probability of a particular fish occurring in that age class whereas results of the von Bertalanffy derived age estimations reflect the percentage of individuals falling within that age. A sample of the five most recent years from selected commercial and recreational fleets for the Gulf of Mexico gray triggerfish fishery are presented to illustrate the effectiveness of this modeling technique. The technique was carried out successfully on all fleets and years for which length data was available. Descending lines fit to the categorically modeled catch at age estimations represent the instantaneous mortality estimation for that year and strata. Commercial data presented in this paper was obtained via the Trip Interview Program (TIP) carried out by NOAA Fisheries, while recreational data was obtained by the Marine Recreational Fisheries Statistics Survey (MRFSS) (Figures 1 and 2).

Each fleet was then further divided into the eastern or western Gulf of Mexico to explore the effect of area on population size and age. Dividing the samples by region caused the sample size to be decreased in each region (particularly in the Western Gulf of Mexico), such that for some years, use of the inverse von Bertalanffy equation to estimate catch at age did not provide an even or accurate distribution of catch at age. Employment of the categorical approach for these instances did however yield feasible distributions, while also capturing the fact that sample sizes are low through the use of increased confidence intervals (Figures 3 – 6).

DISCUSSION

The use of an accurate age estimation technique is an important tool necessary in order to follow a cohort across time and space, and conduct an age based population assessment. Traditional use of the inverted von Bertalanffy function is a successful means of assigning a group of fish with known lengths to a particular cohort as long as there exists a tight correlation between the length of a fish and its measured age; such correlation must be determined through hard part analysis. If the relationship between the length of a fish and its measured age is highly variable, then an alternative means of determining the cohort structure of a particular fishery should be considered. For gray triggerfish in the Gulf of Mexico, the correlation between length and age as determined by hard part analysis of samples from the region was found to be variable, in that a given length could be assigned to multiple age classes. This variability existed generally across individuals sampled throughout the Gulf of Mexico. However, variability also existed spatially from one region of the Gulf of Mexico to another.

Given these limitations, the categorical approach to estimating age structure was a more appropriate tool to use as compared to an inverse von Bertalanffy function. The suitability of the categorical approach to these circumstances is due to the fact that the multinomial function estimates the probability that a particular fish could occur within any of the defined cohorts (ages 0 to 10+) rather than stating with absolute certainty that the fish belongs to one given cohort; this allows for estimation of variability for each estimate of frequency of individuals within a given cohort. Using an inverse von Bertalanffy function, we could estimate a range of possible lengths that fall within a given cohort and determine the distance a sample may be from a von Bertalanffy curve, however this still does not account for the fact that a particular fish with a given length could fall within multiple cohorts if a broad variability of lengths per cohort exists. In addition, if sample size is small, the categorical approach will provide a more balanced catch at age frequency distribution.

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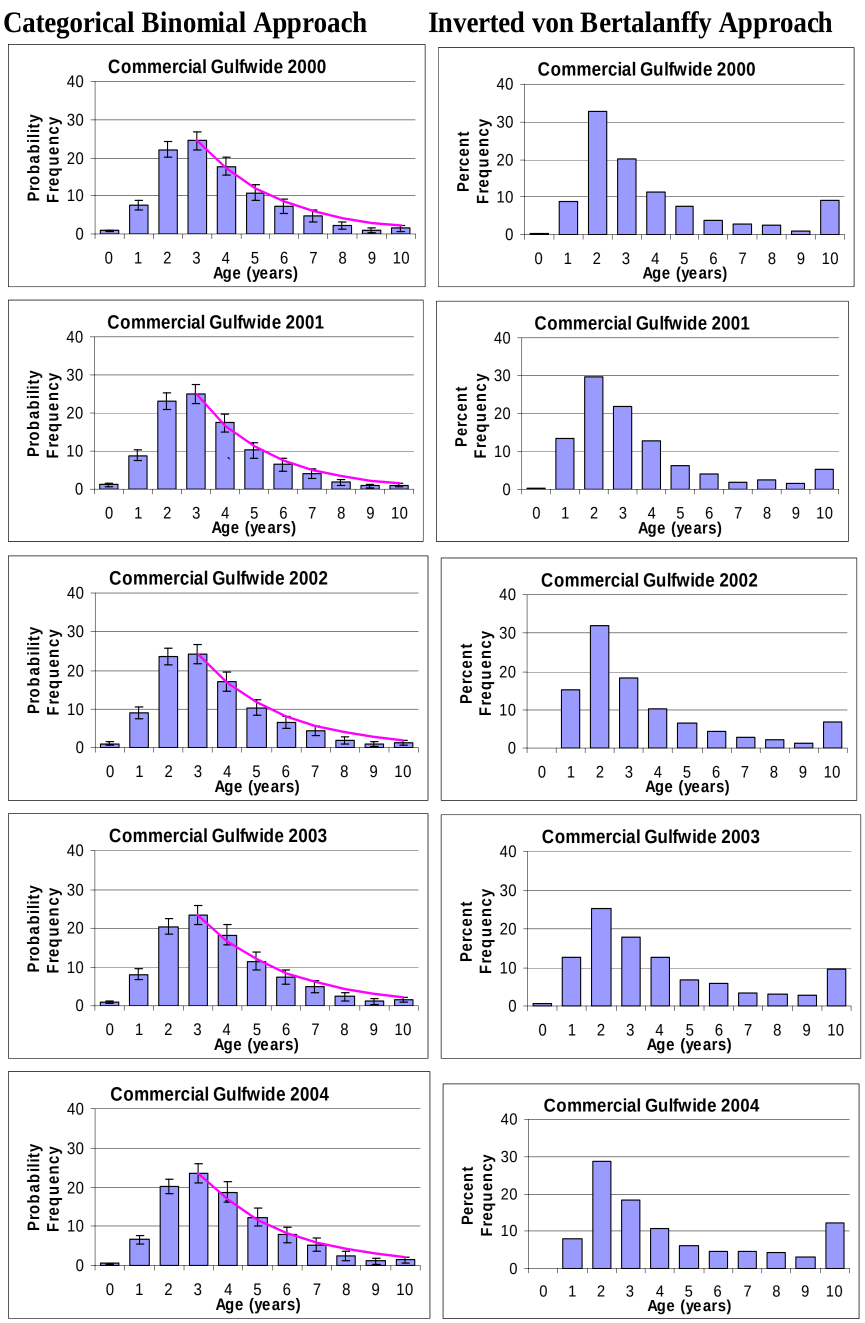

Figure 1. Comparison of categorically modeled catch at age and von Bertalanffy modeled catch at age for selected years of the Gulf-wide commercial gray triggerfish sector.

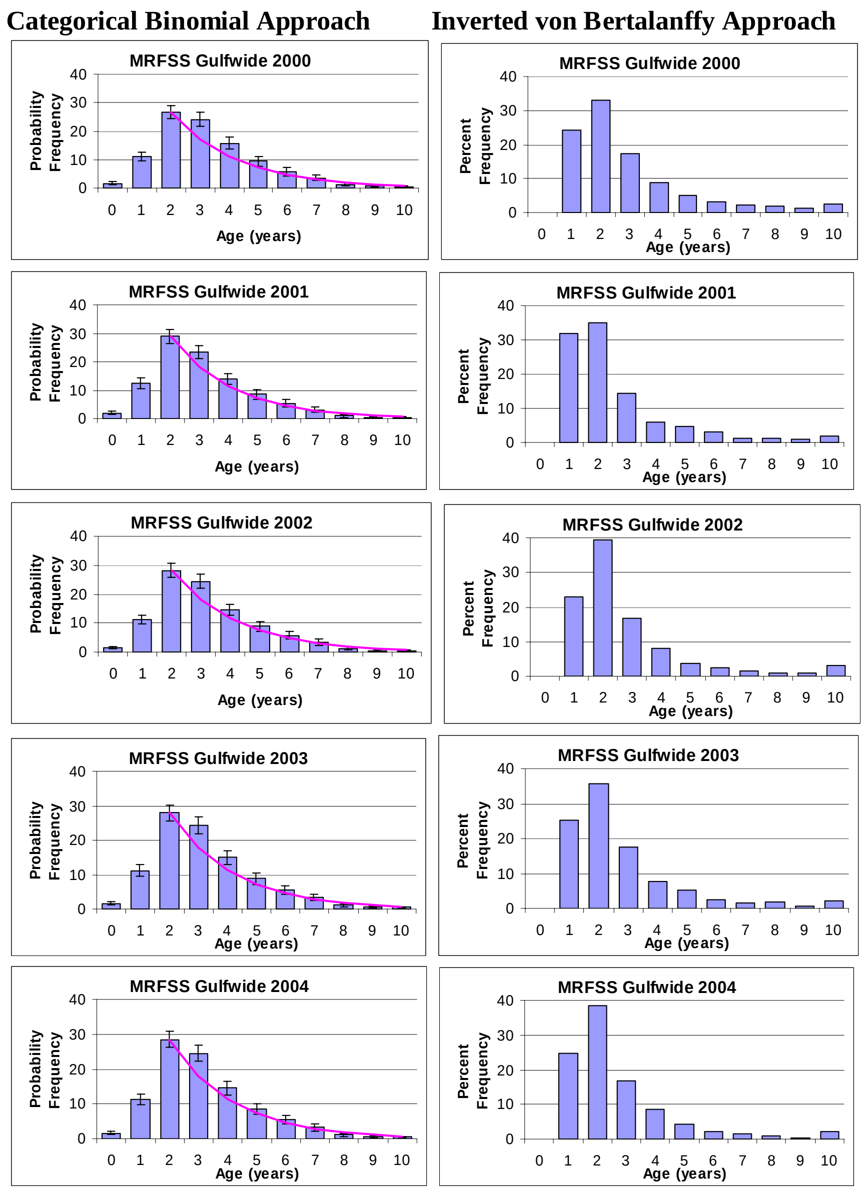

Figure 2. Comparison of categorically modeled catch at age and von Bertalanffy modeled catch at age for selected years of the Gulf-wide recreational gray triggerfish sector.

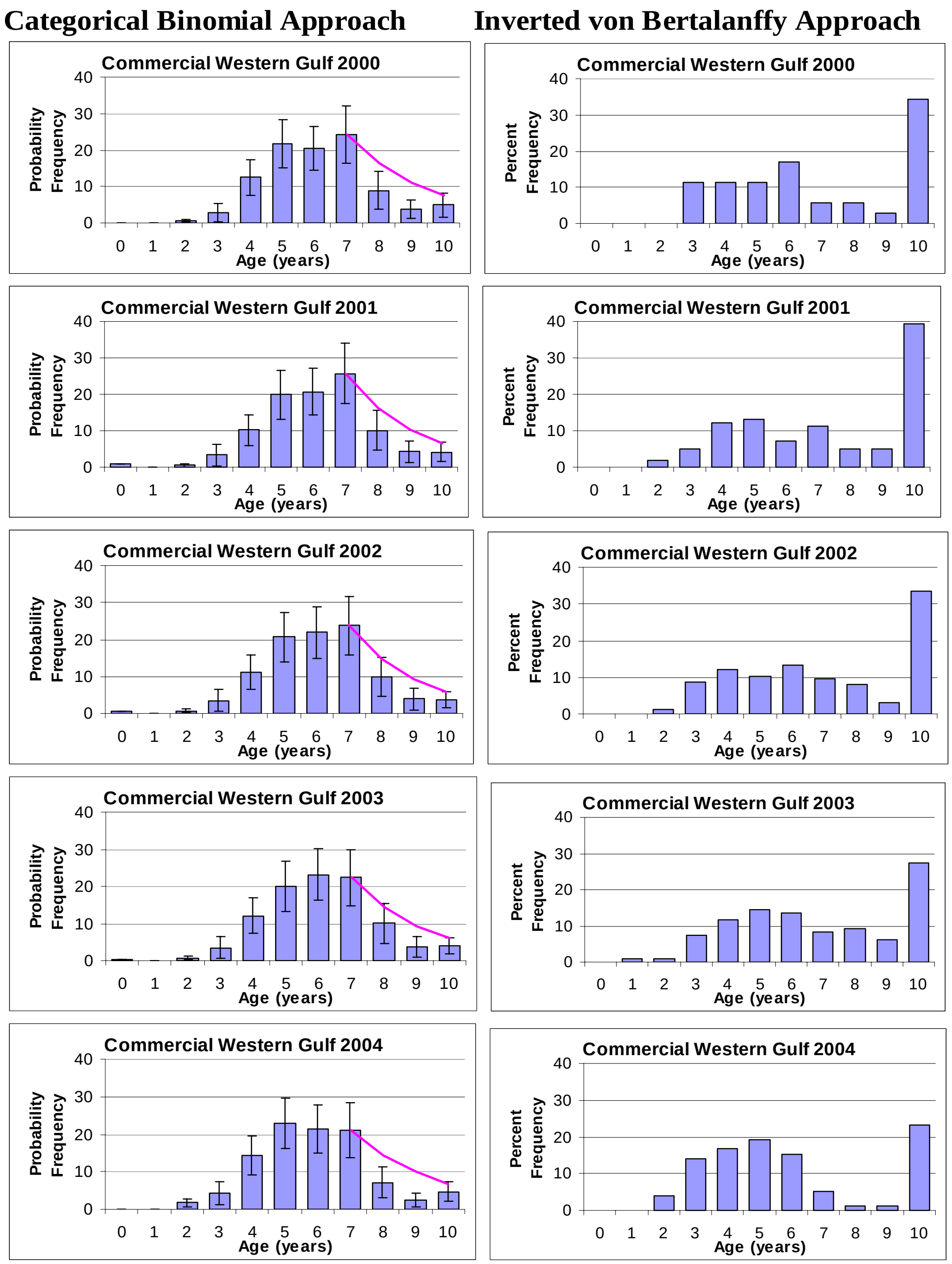

Figure 3. Comparison of categorically modeled catch at age and von Bertalanffy modeled catch at age for selected years of the Western Gulf of Mexico commercial gray triggerfish sector.

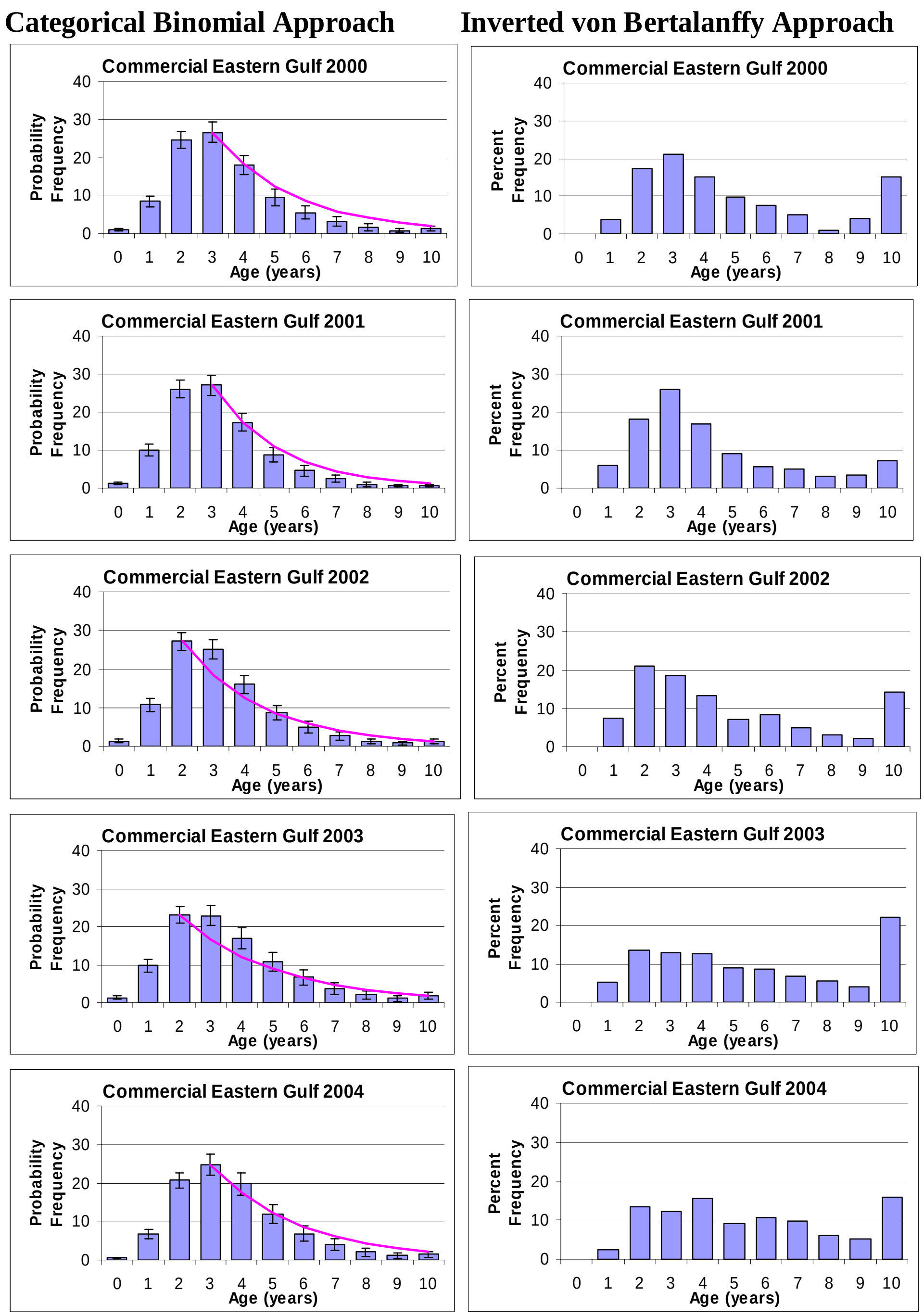

Figure 4. Comparison of categorically modeled catch at age and von Bertalanffy modeled catch at age for selected years of the Eastern Gulf of Mexico commercial gray triggerfish sector.

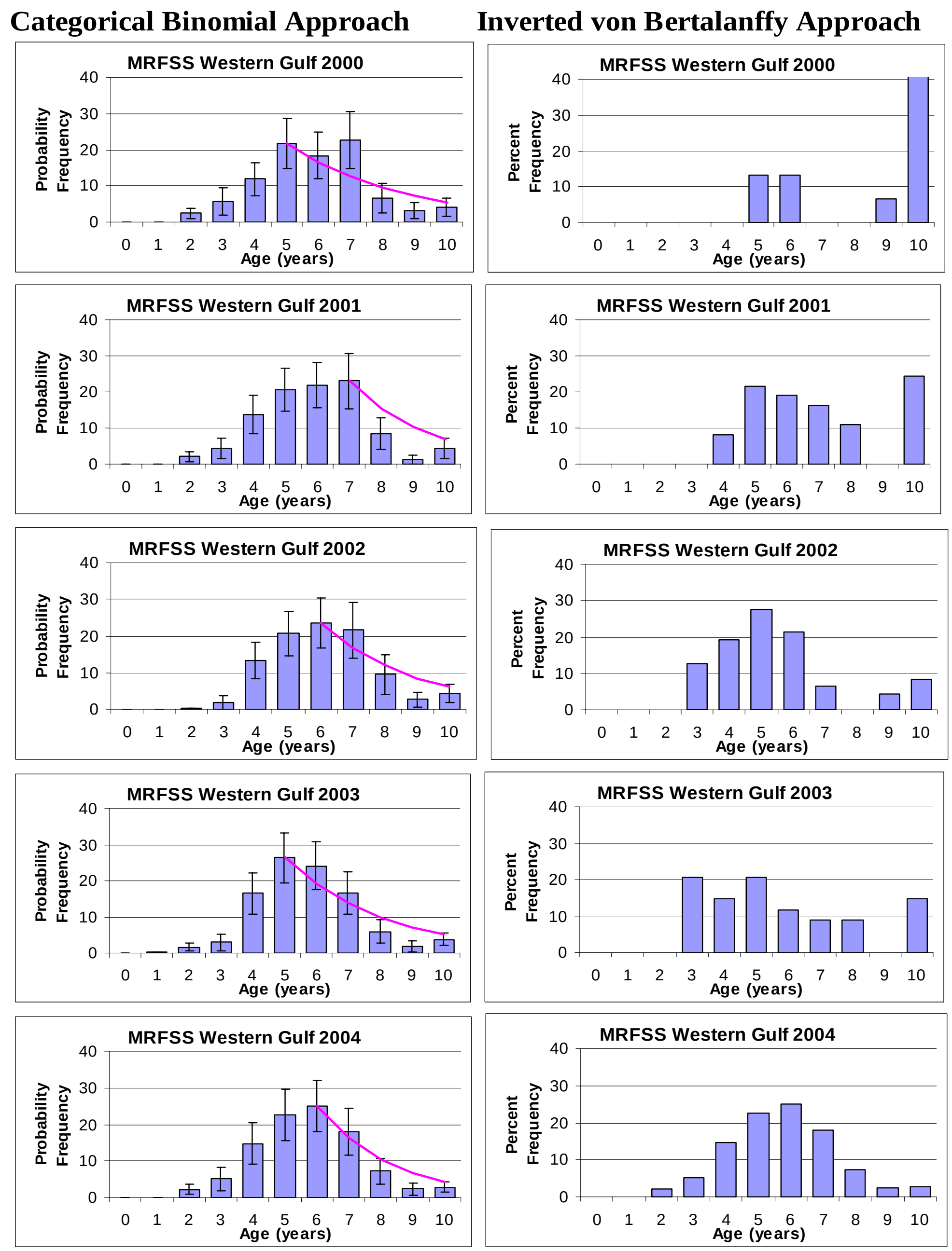

Figure 5. Comparison of categorically modeled catch at age and von Bertalanffy modeled catch at age for selected years of the Western Gulf of Mexico recreational gray triggerfish sector.

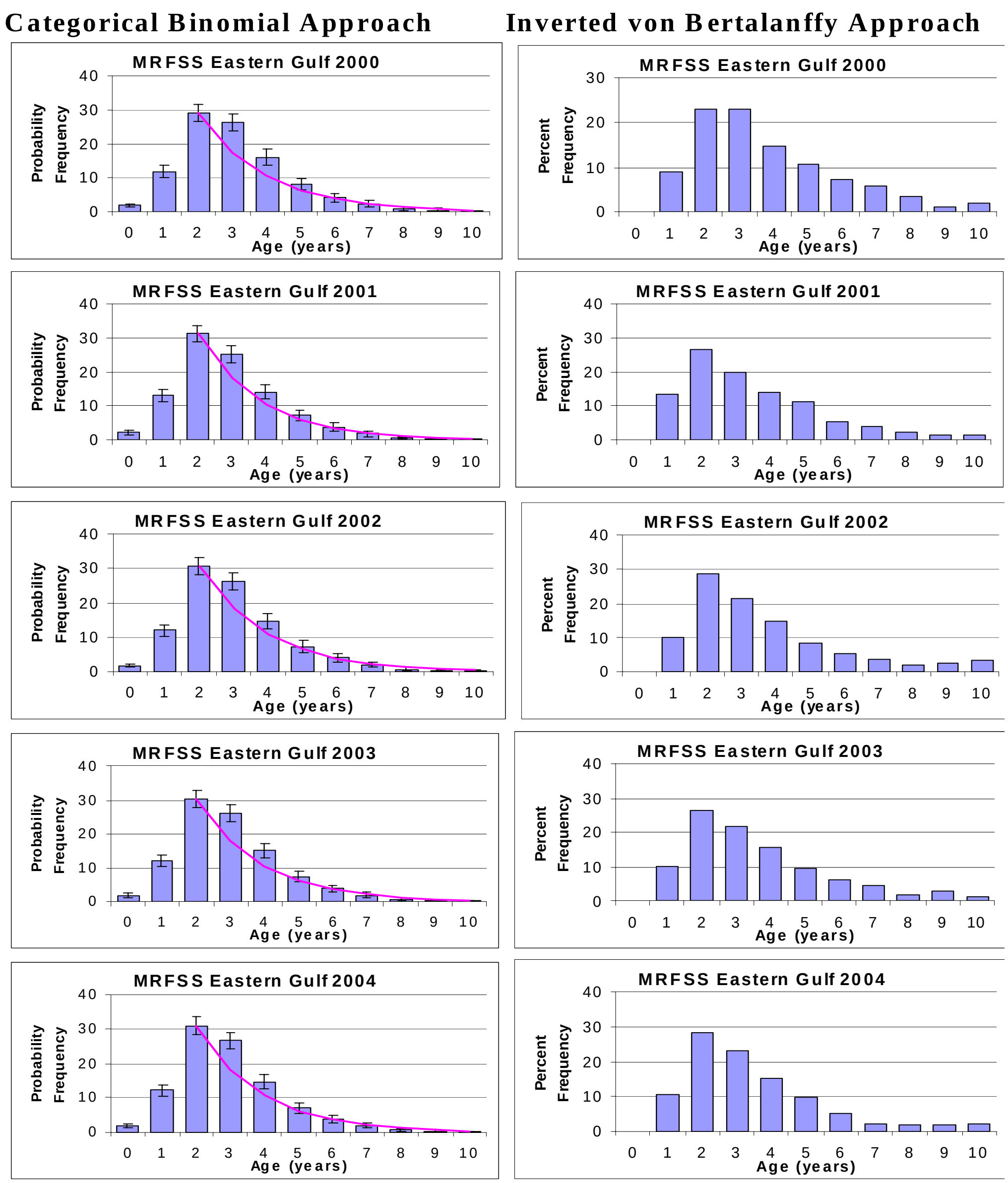

Figure 6. Comparison of categorically modeled catch at age and von Bertalanffy modeled catch at age for selected years of the Eastern Gulf of Mexico recreational gray triggerfish sector.