Gag (*Mycteroperca microlepis*) age-structure from the eastern Gulf of Mexico: 1991-2000

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Abstract

Based on estimation of age structure from catches derived from the west Florida shelf, gag (*Mycteroperca microlepis*) stocks exhibit alternating strong and weak year classes. Four year classes (1985, 1989, 1993, 1996) were observed to exceed 40% of the total annual age structure by ages 4-6, the ages at full recruitment to the fishery. However, there were no apparent differences in growth between strong and weak years based on scatterplots of size-at-capture by age. When sample locations were more closely reported during 1998-1999, there was a slight trend towards older ages and increased ratio of males from the southwest Florida coast versus north of Tampa, the area where the fishery has historically been concentrated. The influence of gear on age-structure was quite apparent. In general, recreational hook and line gear captured the youngest fish, with increasing proportions of older ages occurring in commercial hook and line and longline gears. Because of the catch patterns resulting from a strong 1993 year class, we suggest that gear selectivity by age is determined more by location and depths fished relative to the population distribution and less due to direct attributes of the gear such as hook size, or differences in fish behavior and susceptibility by size.

Introduction

The broad shelf of the west coast of Florida is a highly productive source of economically important reef fish. Nearly 95% of the groupers and over 50% of the snappers taken from the U.S. Gulf of Mexico are landed on the west coast of Florida. Of the grouper species, gag grouper (*Mycteroperca microlepis*) is one of the more economically important in the south Atlantic and Gulf of Mexico (Sadovy 1990). Gag comprise about 31% of the approximately 10 million lb shallow-water grouper quota for the Gulf of Mexico (GMFMC 1999).

However, gag are currently approaching an overfished condition in the Gulf of Mexico (GMFMC 1999, NMFS, 2000). A recent assessment of the gag fishery has particularly identified a need for age and growth information and annual age-structure data for future assessments (Schirripa and Legault 1997). Our goal was to characterize available age data, their source, point out notable patterns, recommend areas where more complete growth analyses may be beneficial and identify some future needs. Our particular aim was to organize and present all of the available annual age structure data in order to detect any patterns in year-class variation over time. Expanded sampling and increased reporting of capture locations and gears used in 1998 and 1999 allowed us to examine differences in age structure by gear type and region; north versus south of 28 degrees (approximately the latitude of Tampa, Florida).

Methods

To examine interannual patterns of age structure, an age data base from otolith samples was available from National Marine Fisheries Service sampling programs (Trip Interview Program, Beaufort NMFS Headboat Program and Panama City NMFS Charter Boat Survey). Otoliths were also provided by the Florida Marine Research Institute. Age frequencies from 1991 through 1994 were taken from Johnson and Koenig (in Press) and were primarily based on hook and line caught fish from the commercial and recreational headboat and charter boat fisheries. Unpublished age data from Allyn Johnson (retired, NMFS Panama City Laboratory) were also available for years 1995 and 1996 from similar sources targeting catches from the northeast Gulf of Mexico. In 1997, otolith sample collections were reduced and were primarily available from the TIP sampling program. During December 1997 through 1999, we were able to obtain otolith samples across a better defined geographic gradient. Adult gag were sampled by NMFS and state port agents in cooperation with a MARFIN study (through Florida State University) of gag reproduction along a geographic gradient. Port agents recorded lengths, weights, gear used, and endeavored to determine the depth and location of capture to the nearest minute of latitude/longitude from interviews with fishermen. Often, however, only approximate locations were given. After 1997, collections differed from previous years in that many gag were being sampled from the west Florida shelf south of Tampa and more otolith samples were being taken from commercial long-liners. In the past, there has been some confusion between gag (*Mycteroperca microlepis*) and black grouper (*Mycteroperca bonaci*) with both species being commonly referred to as "black grouper" and this confusion has hampered assessments (Schirripa and Legault 1997). This confusion has been particularly acute for areas of the southwest Florida coast where there is broad overlap in the distribution of the two species (Schirripa and Legault 1997). In recent years, port agents have been careful to make the distinction between these two species.

We generally followed earlier aging methods used in northeastern Gulf studies (Johnson et al. 1993, Johnson and Koenig, in Press) and determined the ages of gag from whole otoliths following the original interpretation in McErlean (1963). Older gag (greater than about 8 annuli present) are difficult to age using whole otoliths and these otoliths were sectioned. We followed the processing method of Cowan et al. (1995). Whole and sectioned otoliths were assigned an age based on the count of annuli (opaque zones observed with reflected light) and the degree of marginal edge completion. For example, otoliths were advanced a year in age after January 1st if their edge-type was a nearly complete translucent zone. Typically, marine fish in the southeastern U.S. complete annulus formation (opaque zone formation) by late-spring to early summer. Therefore an otolith with two completed annuli and a large translucent zone would be classified as age 3 if the fish was caught during spring in expectation that a 3rd (opaque) annulus would have soon formed. After June 30, when opaque zone formation is underway or complete for gag in the Gulf of Mexico (Hood and Schlieder 1992, Johnson and Koenig, in Press), all fish were assigned an age equal to the annulus count by convention. By this traditional method, an annual age cohort is based on a calender year rather than time since spawning (Jearld 1983).

Results and Discussion

Gag can be aged at relatively low cost as agreement between ages determined from whole and sectioned otoliths is high (Johnson and Koenig, in Press) and most age determinations can be made reliably from whole otoliths. Opaque bands, enumerated as annuli, are visibly distinct in either whole or sectioned otoliths (Figures 1 and 2). Although we have not completed an updated marginal increment analysis, the timing of opaque zone formation is consistent with earlier observations, being completed from spring to summer (Hood and Schlieder 1992, Johnson and Koenig, in Press). By 2000, two readers (GRF and NME) each had aged in excess of 1000 gag otoliths, and so by gaining moderate experience, could make independent estimates of age for comparison. The resulting measure of precision, average percent error (APE; Beamish and Fournier 1981), was 2.8 for the year-2000 age samples. This is a lower value than that determined during recent red snapper aging efforts (APE ranging 5.2 - 8, Allman et al. 2000) and less than the threshold (APE= 5) recommended for production aging (Morison et al. 1998). As aging precision is high, “readability” of the gag otoliths is relatively good.

The gag sample sizes for age frequency varied from about 300 to 800 fish each year (with the exception of 1997). Sources of the age-structure samples have been consistent over the years with most samples taken from commercial landings via the NMFS Trip Interview Program (Johnson et al. 1993, Johnson and Koenig in press). Starting in 1997, we recorded the sources of each sample provided and in recent years, sample sources have been more diverse, with continued focus on commercial modes (i.e., TIP) but reflecting increased sampling of recreational modes (Table 1). Overall however, the number of otolith samples collected as a fraction of the total landings (in number) of gag from the Gulf of Mexico is low (about 0.07% in 1999) compared to production fish aging programs elsewhere.

Although these are not large data sets for understanding age structure, the lengths of the aged gag correspond to the lengths reported in a recent stock assessment. For example, in 1996, a dominant mode of small-sized gag, just reaching the minimum legal size limit (20"), was observed in the handline and powerline fishing gears (Schirripa and Legault 1997) and was detected among the aged gag as well (500-600 mm TL, Figure 3). Generally during the 1990s, the sizes sampled reflect the 20" (508 mm) legal size limit and often the annual modes are between 600-800 mm TL (25-30 inches) for the hook and line gear (Schirripa and Legault 1997, Figure 3). That the gag fishery in the Gulf of Mexico is almost exclusively confined to the west Florida shelf and that the sizes of the aged gag match the length distributions reported in the last assessment, gives us some confidence to infer age structure from the fishery with the sample sizes of otoliths available to us.

Gag appear to be fully recruiting to the commercial fishery by age-4 or 5 and dominant year classes were observed to exceed 40% of the annual age structure at this age during some years (Figure 4). Specifically, dominant year classes were those apparent for at least 3-4 years and include the 1985, 1989, 1993 and 1996 year classes based on the available age data (Figure 4). An apparently strong 1993 year class, detectable as age-3 fish entering the fishery in 1996, provides an explanation of the notable 20" size mode reported in a previous assessment (Schirripa and Legault 1997). Based on a juvenile survey, the 1993 year class was predicted to be a particularly strong year class (Koening and Coleman 1999, Johnson and Koenig in Press) and appears to be the dominant year class harvested from 1996 through 1999 (Figure 4).

The pattern of strong and weak year classes detectable among the adult age structure monitored over time supports earlier findings of highly variable annual recruitment from juvenile surveys (Koenig and Coleman 1999, Johnson and Koenig in Press). Two previous age studies; one in the south Atlantic (Harris and Collins 2000) and one in the Gulf (Johnson et al., 1993) also detected changes in age-structure from age data sets collected at two intervals over 10 years apart. In both studies, the age-structure changes were hypothesized to be a result of changes in levels of fishing. Our results indicate that a likely explanation for change in adult age-structure is recruitment variation.

Since there was such an notable pattern of strong and weak year classes, we were interested to know if there would be obvious differences in growth rate between year classes which might indicate density dependent growth response. As we had several years of otolith collections to make this comparison, we plotted longitudinal growth trajectories for each year class (Figure 5). This differs from more common growth curve analyses which take "snapshots" of size-at-age data from among several year classes at a particular time but require assumptions regarding back-calculation to last annulus or estimation of spawning time. Longitudinal plots avoids these assumptions and allow us to visualize growth among year classes separately. For the oldest year classes (1989-1992), it was apparent that asymptotic size was achieved by about age-8 with the largest age-8 fish reaching about 1200 mm in length (Figure 5). Any differences in the distribution of size-at-age was not visibly apparent between strong and weak year classes. For example, the first fully recruited age-class, 4 year olds, ranged from about 500 to 900 mm for each year-class we observed.

We also wished to examine regional differences, and particularly compare an area where the fishery has been recently active (north of Tampa; Schirripa and Legault 1997) to an area where gag landings are much smaller (south of Tampa), possibly reflecting a geographic difference in the fishing effort experienced by the stock. From December 1997 through December 1999, gag were sampled by port agents returning otoliths, lengths, weights, and in most cases, gonads and information about gear, position and depth of capture in cooperation with a MARFIN study (Fitzhugh et al. 2000). Although samples were taken year-round, most of the sampling effort occurred during two spawning seasons, December through June, with an emphasis on catches from depths greater than 30 m. Each analysis is based on a subset of variable sample size as not all of the information we wanted was available for each fish sampled. This is a common case for fishery-dependent sampling. But port agents and fishermen often exhibited high levels of cooperation to record details of the catch that are typically not available. Of 950 gag, 588 gag from 155 sites were sampled with enough information to map their position of capture (Figure 6). Our purpose in mapping the gag samples was to make inferences about sample sources (e.g., by gear type and region) and we could group the location information into three levels of confidence. For 65% of the 588 gag, port agents were able to obtain LORAN coordinates or were given latitude/longitude to the nearest minute and these had the highest confidence for mapping. For about 22% of the gag, locations were inferred from depth and ancillary information such as distance and bearing from port or a place name. For 13% of the 588 gag, location was inferred from depth and approximation by TIP area or grid number. But for most of the 950 gag, we were provided enough information to distinguish catches from north and south of Tampa (about 28 degrees N latitude).

Several fishing sectors are represented among the mapped samples from 1998-1999. Twenty eight samples (192 gag) are commercial hook and line, 82 samples (250 gag) are commercial longline, 26 samples (109 gag) are recreational hook and line, and 16 samples (37 gag) are from miscellaneous sources (scientific survey, trap and spear gears). Of the long-line caught gag, most were caught near the 75 m contour (Figure 6). Not surprisingly, recreational samples were often from depths shallower than commercial samples but recreational fishermen did fish the outer continental shelf. Of relevance to our analysis is the fact that most of the gag were caught from the outer continental shelf south of Tampa (Figure 6). This is a result of our requests and extra efforts on the part of port agents from the Tampa/St. Petersburg, Fort Meyers and Key West locations. This differs from previous Gulf of Mexico gag research where gag samples were taken from the mid to outer continental shelf north of Tampa (see Hood and Schlieder 1992, Coleman et al. 1996 and Collins et al. 1998), the general location where the fishery was known to primarily exist (Schirripa and Legault 1997). To our knowledge, these data represent the first substantial effort in sampling adult gag so far south along the west Florida shelf.

When we examined the age data for 1998, 1999, and updated through 2000, there were apparent differences in the age structure by gear. Recreational-caught gag were the youngest each year with dominant modes at age-4 (1998 and 2000) and age-3 (1999) (Figure 7). Commercial hook and line gear and long-line gear showed dominant modes at age 5 (1998) and age 6 (1999) still tracking the strong 1993 year class. But long-line gear was tending to harvest older individuals with age-class frequencies not dropping below 1% until age 15 or 16 (1998, Figure 7). On the west Florida shelf, bottom long-lining for reef fish is allowed to a depth as shallow as 20 fathoms. Since commercial hook and line and long line fisheries broadly overlap depth zones from the mid to outer shelf, the similarity in age structure between the two commercial fishing gears may not be surprising, particularly if a strong year class is present at the depths where the two gears overlap. However, by 2000, the previously dominant 1993 year class was only apparent as 7-year olds in the long-line fishery while the younger 1996 year class was appearing to dominate in the commercial and recreational hook and line fishery. The patterns clearly seem to reflect the fishing gauntlet across depth, that is - youngest ages taken in the recreational sector, followed by commercial hook and line and finally commercial long-line sectors. These findings support earlier studies showing larger and older gag tend to be sampled from deeper water depths (Manooch and Haimovici 1978, Hood and Schlieder 1992).

Because 1998 and 1999 sampling targeted gag from the Florida shelf south of Tampa in comparison to earlier studies, we wanted to look for any possible regional differences in size and age structure. Gag captured by hook and line (commercial and recreational) north of Tampa showed a notably skewed size distribution with a mode at 600-700 mm TL and with individuals ranging to greater than 1300 mm TL (Figure 8). Of the 256 gag, 215 were identified to sex with 4.65% being male. More larger gag were captured by hook and line gear south of Tampa with much higher frequencies of gag from size-classes greater than 900 mm TL (Figure 8). Of the 218 gag from this category, 125 were identified to sex, of which 14 % were male. Long-line gag from south of Tampa were generally larger than hook and line fish with a mode at 800-900 mm TL (Figure 8). This category represents the largest sample with 409 gag, of which, 231 were identified to sex and 17% were male. Only 7 gag were sampled from long line catches north of Tampa and are not shown.

We compared age structure north and south of Tampa for commercial hook and line gag.

Subdividing the data resulted in a much reduced sample size but some trends may be robust. Age structure between regions was similar but more older gag were evident from the southern hook-and-line catch (Figure 9). In 1998, most fish sampled in the north were age-4 and age-5 in contrast to a more evenly distributed age structure from samples taken south of Tampa. For both regions, the progression of year classes was notable as age-4 and age-5 fish dominated in 1998 and age-5 and age-6 fish dominated the age structure in 1999 (Figure 9).

By observing the alternating pattern of strong and weaker year classes progressing through the various fisheries, and by observing the pattern of catch from gears which tend to harvest at different depths, a hypothesis can be derived for gear selectivity. The largest factor affecting selectivity appears to be gag age and size differences occurring at depth and locality where a gear is fished, and to lesser degrees age/size differences in behavior, gear susceptibility or gear effects (hook size etc.). An example which highlights the size/age-by-locality effect is the domination of 3-year olds in the commercial hook and line catch occurring only once within the decade. In 1996, the 3-year olds (1993 year class), independently observed to be a large year class via a juvenile survey, recruited to mid-shelf depths and frustrated many fishermen due to the high number of undersized discards (Fable, 1996, Johnson et al. 1997). To clarify these age/size patterns, future research should focus on increased sampling for age and compare geographic differences between age-structure for long-line gear and similar components of the recreational fishery (e.g., private, head boat and charter) related to regional differences in fishing effort.

Acknowledgments

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Table 1. Percentage of of otoliths provided each year by various sampling programs.   TIP refers to the trip interview program of the National Marine Fisheries Service. Florida Department of Environmental Protection (DEP) also has port agents which contribute to TIP. Other samples were contributed by the NMFS Beaufort Headboat Survey, the NMFS Panama City Laboratory and via contractors with the NMFS Marine Recreational Fisheries Statistical Survey (MRFSS).

Source	**1997**	**1998**	**1999**	**2000**
NMFS TIP	53	59	40	80
FL DEP/FL TIP	4	9	32	12
Headboat Survey	43	7	2	3
Panama City Lab.		24	17	5
MRFSS		1	9	

A.

B.

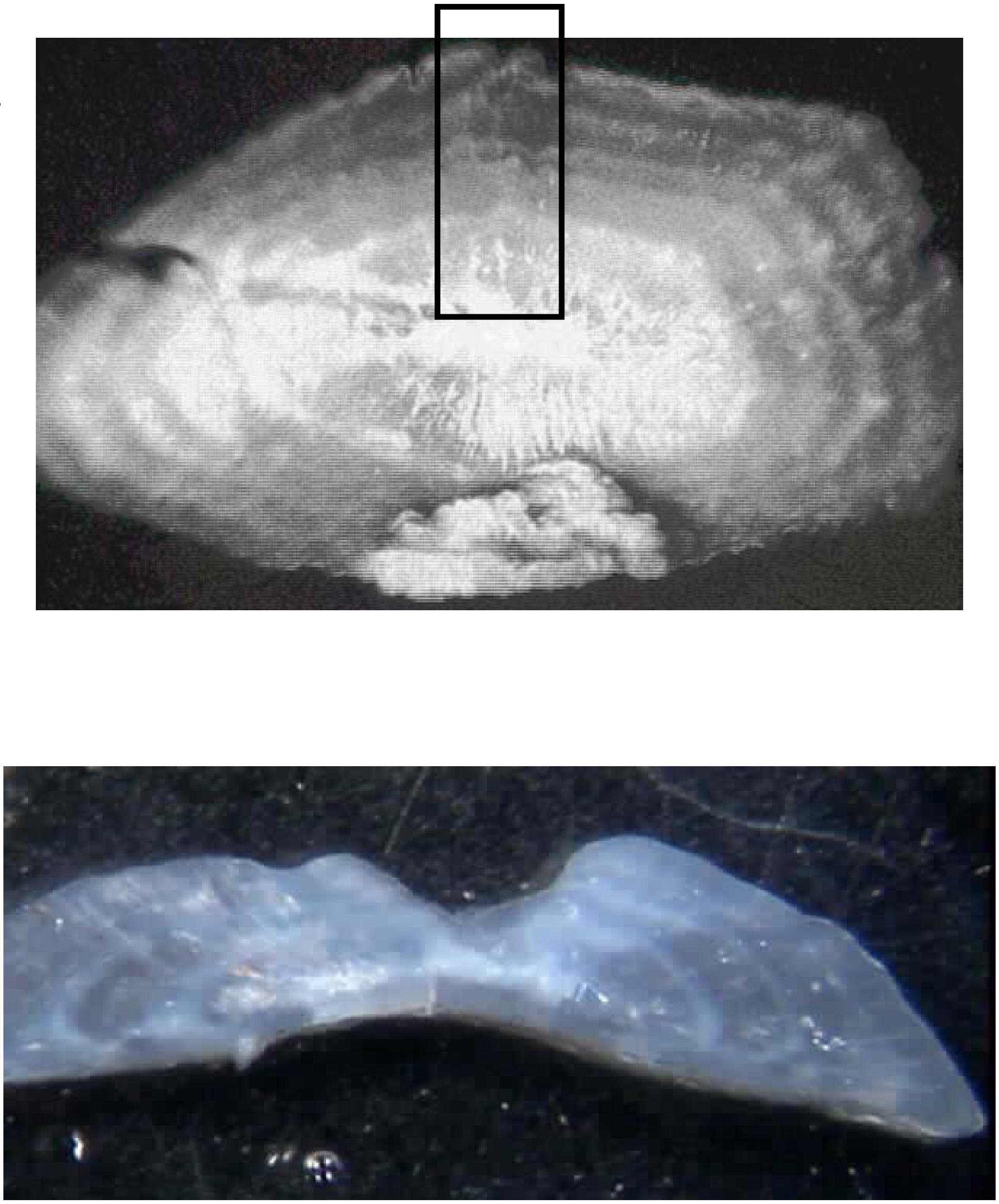

Figure 1. (A.) Distal surface of a whole sagitta from a 660 mm TL gag with 5 annuli. The box illustrates the counting zone along the dorsal edge. (B.) Cross section of a sagitta from a 716 mm TL gag with 4 annuli, the fourth occurring at the margin.

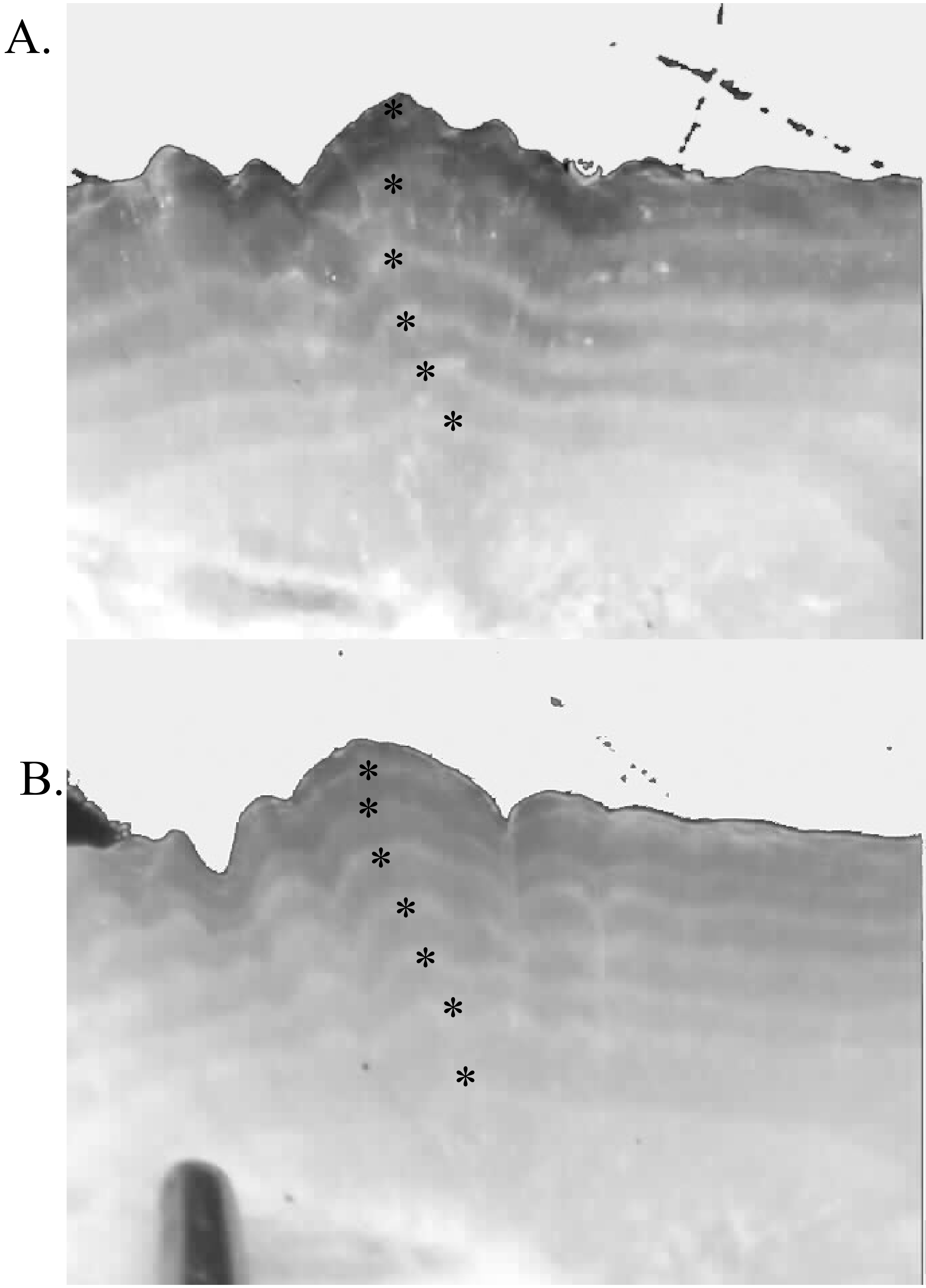

Figure 2. Asterisks denote opaque zones used for annulus counts. (A.) whole sagitta with opaque margin, count = 6 annuli. (B.) whole sagitta with partially completed translucent margin, count = 7 annuli.

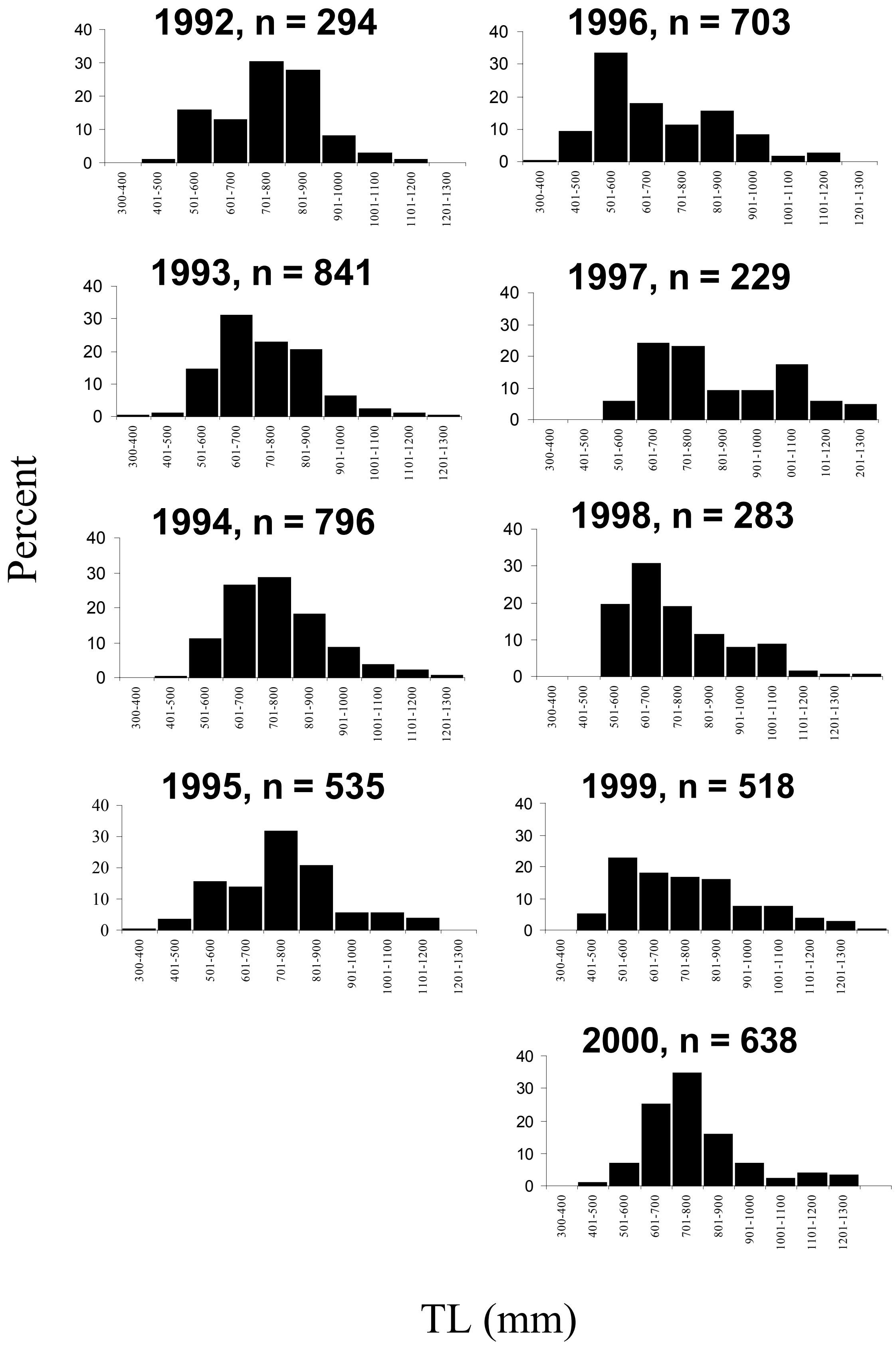

Figure 3. Size distribution of gag sampled for age. All gears and fishing modes are combined.

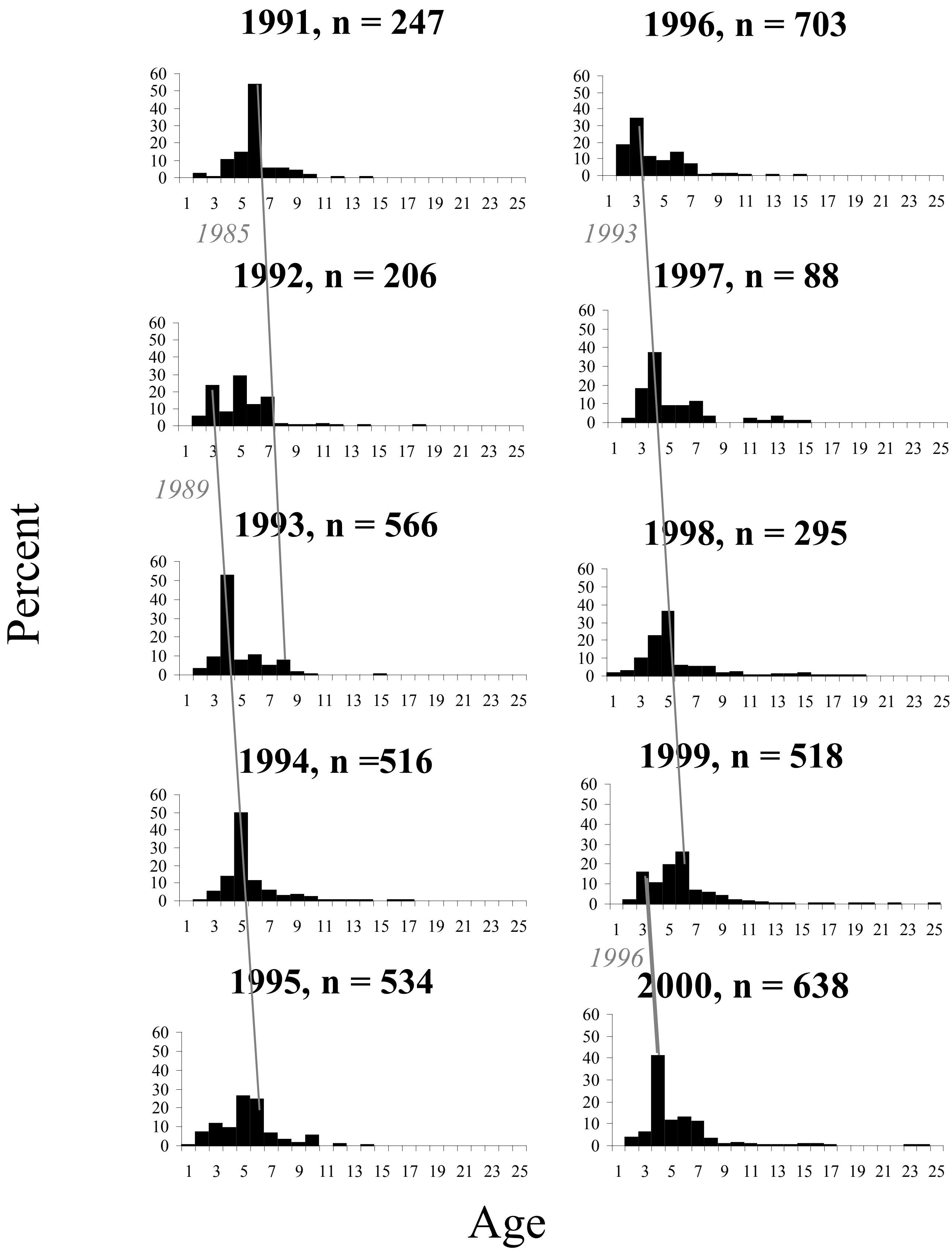

Figure 4. Gag age distribution for all gears combined. Dominant year classes (1985, 1989, 1993, 1996) are denoted by lines.

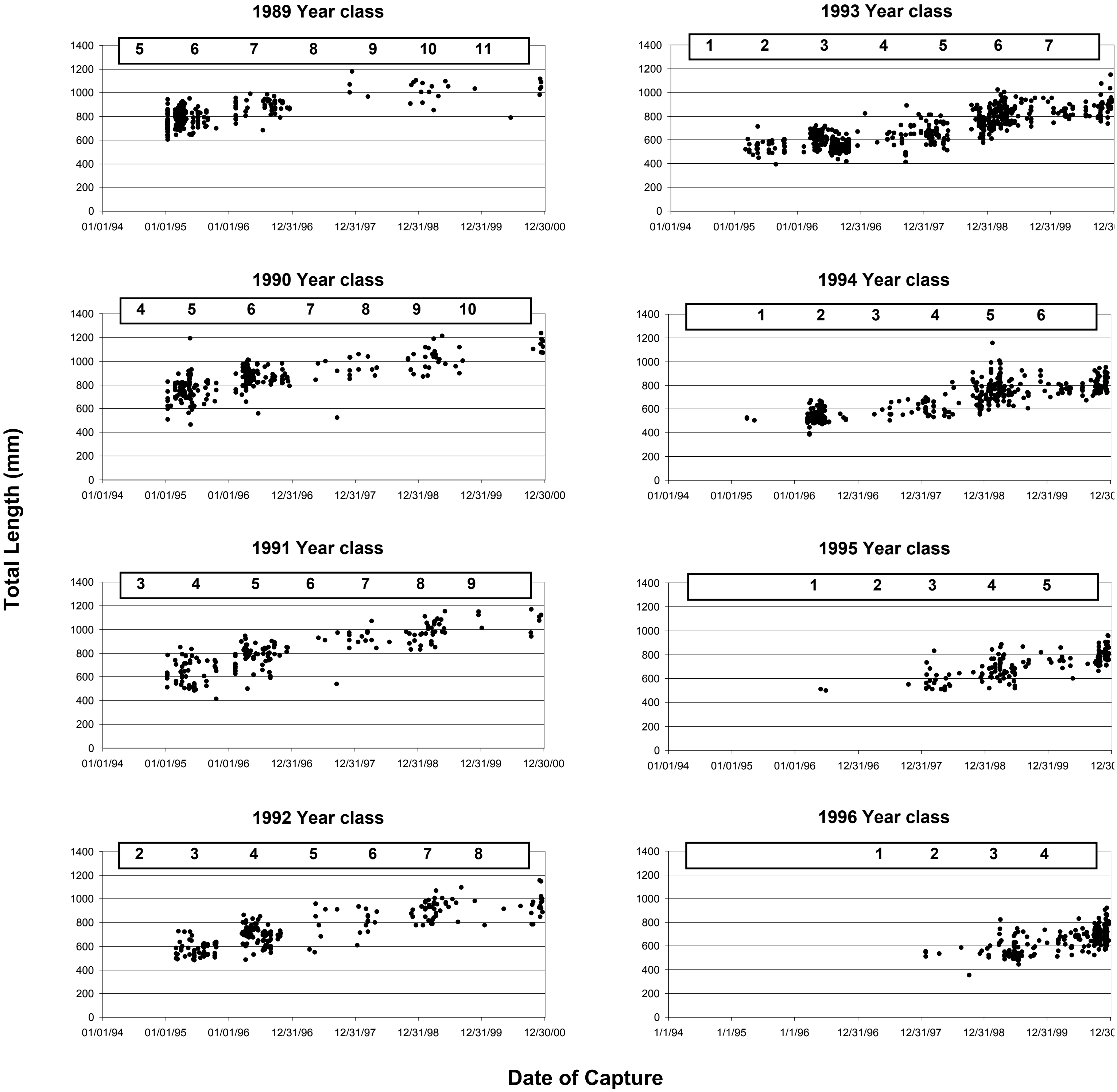

Figure 5. Longitudinal growth trajectories of size at capture date for individuals from each year class. The corresponding annual ages are shown at the of each graph and are advanced after January 1 of each year.

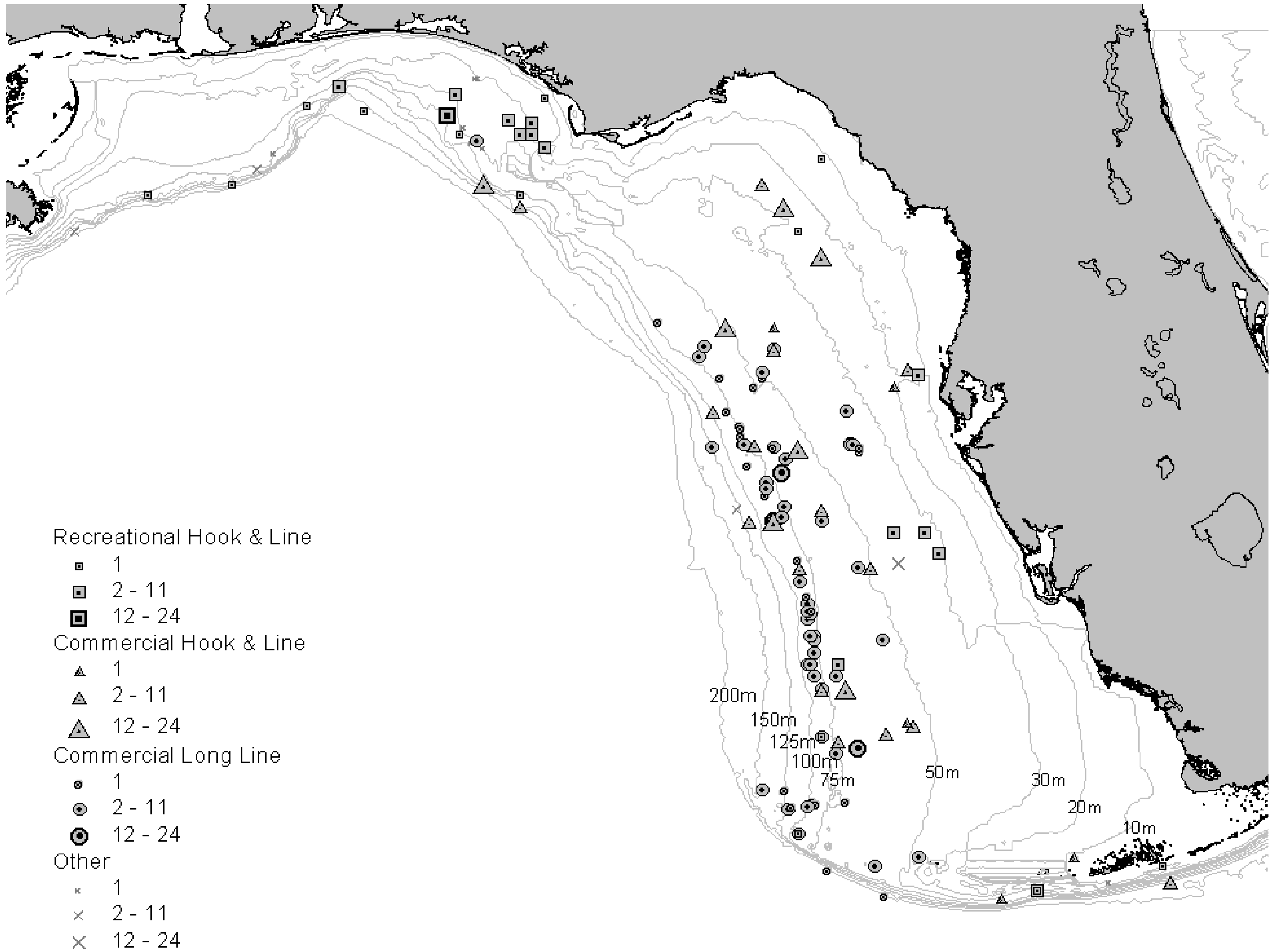

Figure 6. Capture locations for gag sampled 1998-1999. Captures made by commercial and recreational hook and line and long line gear are represented by different symbols and the relative number of gag samples from each location is Indicated by the symbol size. The “other” symbol represents scientific survey, spear, and trap gear types.

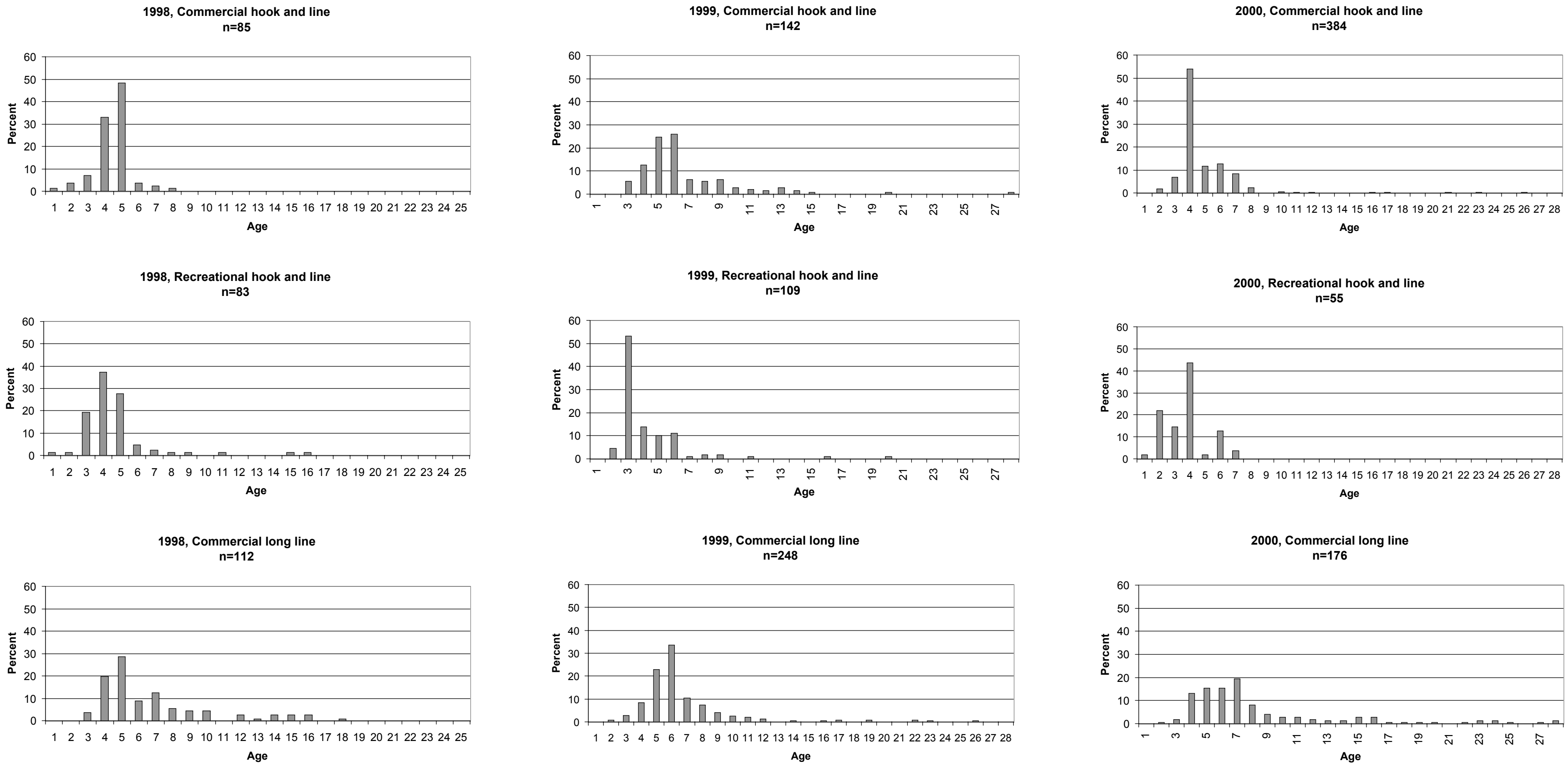

Figure 7. Age distribution of gag by principal fishing modes for years 1998-2000

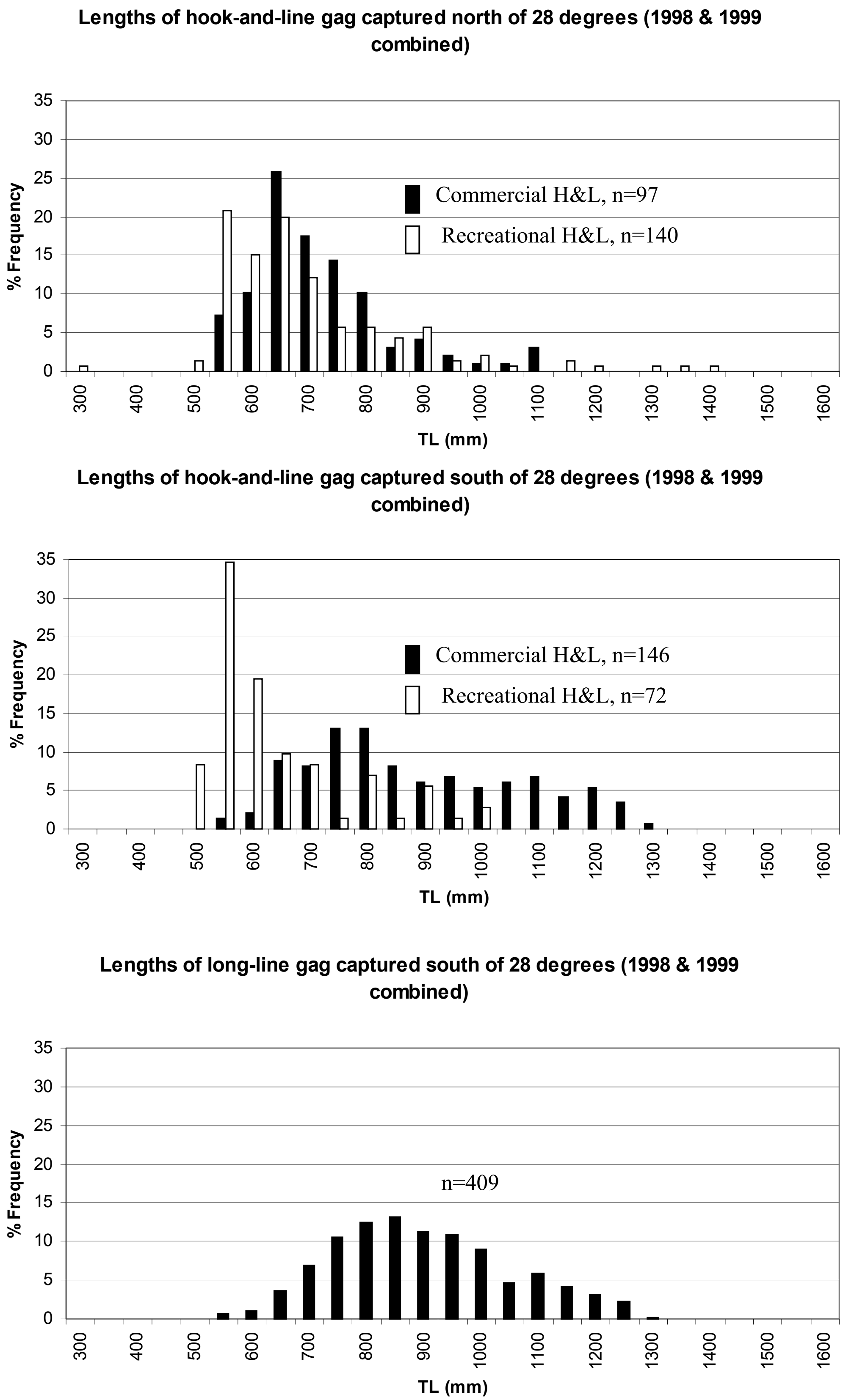

Figure 8. Length distributions by gear type, north and south of Tampa (28 Degrees N. latitude) for gag sampled for age during 1998 and 1999

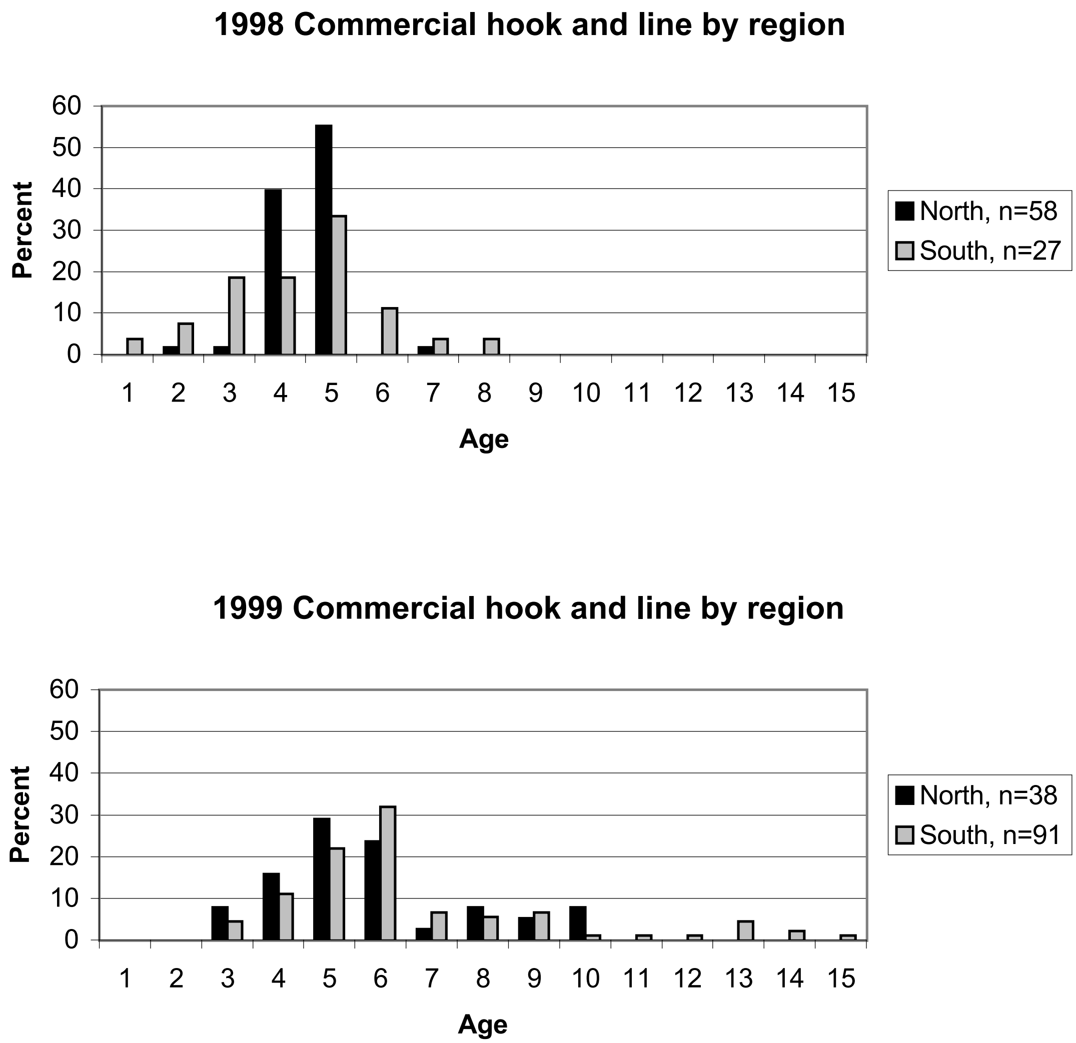

Figure 9. Age distribution of gag captured by commercial hook and line from locations north and south of Tampa (28 degrees N. latitude) for 1998 (top panel) and 1999 (bottom panel).