Catch Rates of Greater Amberjack Caught in the Handline Fishery
in the Gulf of Mexico in 1990-1998

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Indices of abundance of Gulf of Mexico greater amberjack, *Seriola dumerili*, were developed from log books reports by commercial fishing vessels for possible use in an assessment of the status of the resource.

Materials and Methods

Data were obtained from the Gulf of Mexico Logbook data base. The data base contains of reports of catch and effort by trip for vessels with permits to fish in a number of fisheries managed by the Gulf of Mexico and South Atlantic Fishery Management Councils. The Gulf of Mexico reef fish log book program was initiated in 1990 with a 20% sample of vessels permitted for fish in the reef fish fishery with addresses in Florida (where the complimentary trip ticket program was in place) and a 100% sample of permitted vessels from other states bordering the Gulf of Mexico. Beginning in 1993 the sampling was increased to require reports from all vessels permitted in the reef fish fishery. Since then mandatory log book reports from vessels fishing the shark, king mackerel and spanish mackerel fisheries have been incorporated into that data base.

The data extracted from the logbook data base included information on vessel identifier, trip identifier, landing date, landing state and county, fishing gear, fishing area(s), number of crew, number of days at sea, several types of information on fishing effort which are gear specific (for handline: number of lines fished, number of hooks per line and estimated total fishing time), species caught and the whole weight (when the landed catch is reported in gutted weight, a standard conversion is used to transform it to whole weight) of the landed catch for each species. A record contained the information for a species caught by a gear fished; thus there generally were multiple records per trip with one record for each species landed. If multiple gears were reported fished, all of the catch for a species was assigned in the data base to one of the gears. One or more fishing areas were recorded for each trip; in the Gulf of Mexico fishing area was usually recorded as the NMFS statistical areas (also known as the NMFS shrimp statistical grids).

Only fishing trips reported to have used one fishing gear and to have fished in one area were retained for analysis. Trips were checked to determine whether part of the trip also was reported from Atlantic fishing areas in the South Atlantic Reeffish Logbook data based (data from all such trips were eliminated because they were from multiple areas). Only trips assigned to statistical grids 2-21 were retained. Area 1 was excluded because McClellan and Cummings (1997) concluded that fish from that area should be considered part of the Atlantic management unit, while areas greater than 21 were excluded because they were outside of U.S. waters and they had low levels of observed effort.

The selection of gears to analyze from the logbook data base was made based on the numbers of trips reported per year, the proportion of trips with reported greater amberjack catches and the proportion of the total yield that was greater amberjack.

To reduce the number of strata used for analysis general regions and seasons were defined through examination of the geographic distribution of effort and the pattern of catch rates by month. Nearly all records had fishing location recorded as NMFS grid number; though a few used the Atlantic reeffish logbook location codes for 1^o squares. To examine the distribution of the data graphically, the grids were assigned a latitude and longitude, though it is recognized that many grids cover more than 1^o x 1^o and that effort from outside of a grid is assigned to a grid within the same longitudinal or latitudinal band. For the seasonal definitions tabulations and regression tree analysis (Venables and Ripley 1977) of (1) proportion positive and (2) average catch rates by month and by number of hooks per line was used.

Because information was not available on the target of fishing effort, other factors were investigated to try to distinguish effort targeted at Gulf of Mexico greater amberjack and effort targeted at other species. Both numbers of hooks per line and the proportion of grater amberjack in the total yield of a trip were examined, though it should be noted that the Methods Working Group of ICCAT's (International Commission for the Conservation of Atlantic Tunas) Standing Committee on Research and Statistics recently noted that using fishing effort indicators of targeting was preferable to using catch composition information because catch composition can result in misleading conclusions (ICCAT MS).

The measure of fishing effort to use in calculating catch rates was determined through general linear model analysis of pounds per unit of effort as calculated for several possible effort measures (pounds/day fishing, pounds/day at sea, pounds/line, pounds/hook, etc) using only data from trips on which greater amberjack was reported. A lognormal error structure was assumed. Three independent variables (year, region and season) and no interactions were included. The unit of effort associated with the model with the highest coefficient of determination (R^2)was selected.

General linear models with fixed and random factors were used for catch rate standardization. For the analysis of trips not targeting greater amberjack (non-targeted) the Lo approach (Lo et al.1992) which assumes a delta-lognormal error structure was used.. That method employs separate analyses of the proportions of positive trips and of the catch rates on trips which caught greater amberjack, and combines the results of the separate analyses to derive the index. A binomial error assumption was used for the proportion positive analyses, and a lognormal error assumption was used for the analyses of positive trips (Ortiz et al 1999, Turner et al 1999, Cummings et al 1999). The dependent variable in the proportion positive analyses was success which indicated whether greater amberjack were caught or not. The data for the targeted trips only consisted of trips which caught greater amberjack, so a lognormal error assumption was used and the index of abundance was derived from the retransformed least squares means.

Standardization models were first developed with all factors treated as fixed effects and all two way interactions among those factors, and then additional analyses with fixed and random effects were conducted (Ortiz et al 1999, Turner et al 1999, Ortiz et al. 2000, Ortiz and Scott MS). If a year interaction was significant in the fixed effects analyses, it was subsequently examined for significance in the random effects analysis. If a factor such as region was included in random effects interaction with year (year*region) then all other interactions with that factor (such as region*season) were considered and tested as random effects.

Variables considered for inclusion in the standardization were year, season, region and hooks per line. Whether to include a factor in a fixed effects model was determined both by statistical significance of the deviance caused by adding that factor to the model given the degrees of freedom for the effect and by overall contribution of that factor to the maximum amount of deviance which was explained by the most complex model. A factor had to be statistically significant with a probability of 0.05 or less, and it had to explain at least 5% of the maximum amount of deviance.

For analysis the basic data set was restricted so that there would be at least 5 observations of each level of a factor in each level of the other factors in the analysis. This was done to try to create a more balanced design to try to minimize the effects of isolated observations. This was only done for the proportion positive data set; the positive catch rate data could have had fewer that 5 observations per cell.

Data were limited to the period (since 22 April 1990) when size limits were 36"FL for commercial vessels; therefore all observations from January through April 1990 were eliminated. Starting in 1998, commercial landing of greater amberjack was prohibited in the Gulf of Mexico during March-May; therefore all effort observations from those months in 1998 were eliminated.

Results

Handline fishing trips were roughly 75% of all trips recorded in the data retained for analysis (Table 1). Gulf of Mexico greater amberjack were caught on about 20% of the trips in most years (Table 2) and represented roughly 5% of the total handline yield in most years (Table 3). Greater amberjack were caught on about 20% of the longline trips, but they were generally less than 1% of the total longline yield. Greater amberjack were generally very small proportions of the trips by other two fishing methods examined (traps and troll) and represented small fractions of the total yield of those gears. Because of the large amount of data for handlines, the relatively higher predominance of greater amberjack in the fishery and the amount of time available, it was decided to analyze only handline trip data.

The number of hooks per handline was found to range from 1 to more than 40 (Figure 1). Conversations with people familiar with the fishery suggested that 1-2 hooks was typical of targeting groupers, 10-15 hooks per line might indicate targeting red snapper and 20+ hooks might indicate targeting vermillion snapper. Figure 1 shows that fishing occurred with numbers of hooks outside of those ranges, so four strata of hooks between lines were established: 1-2, 3-9, 10-19 and 20-40. About half of the trips reported 1-2 hooks per line, about 18% reported 3-9 hooks per line, about 16% reported 10-19 hooks per line and about 12% reported 20-40 hooks per line.

Examination of the geographic distribution of trips showed that effort with 1-2 hooks occurred throughout the Gulf of Mexico, but was primarily concentrated in the eastern Gulf while the 3-9 hook trips were more evenly distributed though fewer in number (Table 4). In contrast the trips with10-19 and 20-40 did not occur off central and southern Florida. The proportion of trips with greater amberjack was generally higher for trips with 10-19 and 20-40 hooks per line especially in the northeast Gulf while the average weight per trip (all trips combined) was generally lower for those trips (Tables 5 and 6). It was therefore decided to attempt analyses for trips with 1-9 hooks and 10-40 hooks assuming that they represented different types of handline fishing; within those ranges of hooks per line the finer stratification (1-2, 3-9, 10-19 and 20-40 hooks per line) was retained and if possible included in analyses.

Five regions were defined based on the geographic distribution of effort. They were southwest Florida (statistical grids 2-3), central west Florida (grids 4-5), northwest Florida-Alabama with some off Mississippi (grids 6-11), Louisiana (grids12-16), and west Louisiana and Texas (grids 17-21).

Nominal catch rates by region are shown in Figures 2-4 for the various targeting and hook per line configurations considered for analysis.

Regression tree analyses of handline trips (all levels of hooks per line combined) did not reveal strong and consistent patterns in monthly catch rates on successful trips or proportion positive, though there was some indication of higher catch rates in the summer months. Monthly patterns in proportion positive and average pounds of greater amberjack per trip were reviewed from trips with 1-9 and 10-40 hooks per line (Figures 5-8). The 1-9 hook per line trips once again did not reveal strong patterns, but the 10-40 hook per line trips showed higher catch rates on successful trips during June-August. Therefore four seasons of three months each were established with the first being January-March.

Targeting

To obtain multiple time series of data in which fishing occurred in as consistent a manner as possible, an attempt was made to separate clearly targeted catch and effort data from catch and effort data in which greater amberjack may have been a true bycatch. The concern was that fishermen might switch targets within a trip, but the effort associated with each target could not be distinguished. If Gulf of Mexico greater amberjack catch rates differed among different targets and the fishermen varied the amount of fishing for each target over time, then catch rate time series derived from such multi-targeted data might be influenced by the changes in fishing rather than solely by the changes in greater amberjack abundance.

Three data sets were defined - one targeted at amberjack and two data sets considered not targeting Gulf of Mexico greater amberjack. Persons knowledgeable about the reef fish fishery indicated that low numbers of hooks per line would probably indicated targeting at larger fish such as groupers and greater amberjack. Targeted trips were defined by (1) restricting the data to trips with 1-9 hooks per line, (2) selecting vessels which had consistently targeted greater amberjack and (3) selecting all trips by those vessels in which greater amberjack accounted for 70% or more of the total yield. Vessels which consistently targeted greater amberjack were defined as having reported at least three trips on which greater amberjack represented at least 80% of the catch in each of three years. The 80% criteria for defining greater amberjack vessels was arbitrarily selected; a 90% criteria resulted in a reduction in the number of selected vessels from 10 to 6 (at 3 trips in at least 3 years). The 70% criteria for selecting trips by those vessels was selected based on the proportion of greater amberjack in landings of the selected vessels (Figure 9). These criteria resulted in selection of 10 vessels which made 318 trips during 1990-1998; more stringent restrictions resulted in fewer vessels and trips.

The two additional subsets of data were created which were thought to represent effort less likely to have been targeted at Gulf of Mexico greater amberjack. One consisted of trips with 10-40 hooks per line which apparently is typical of some gear used for targeting snappers. The second was for trips which reported 1-9 hooks per line and relatively low proportions of greater amberjack in the total yield. The proportion of greater amberjack in the total yield for a trip was examined for all vessels which were not considered to have targeted greater amberjack (Figure10). No clear indication of possibly targeted versus non-targeted effort was apparent in that data set nor in the data from trips with 10-40 hooks (Figure 11). Therefore an upper limit of 27.4% of amberjack in the catch was chosen for including in the data set of possibly non-targeted trips with 1-9 hooks; all trips by vessels defined as having targeted greater amberjack (on at least three trips in at least three years) were excluded from this data set.

Index: Targeted 1-2 hooks per line

The 318 trips by vessels which made at least 3 trips targeted at greater amberjack in at least 3 years were further reduced to 218 trips after restrictions to create a more balanced design by year, season, region and hooks per line. Analyzed data were from 1994-1998, the central west Florida and northwest Florida-Alabama regions, 1-2 hooks per line, and three seasons (Jan-Mar, Jul-Sept and Oct-Dec). All trips caught greater amberjack and analysis of yield per day was performed using year, region, season and associated interactions.

From the fixed effects analysis all main effects (year, region, season) and their two-way interactions were significant or involved in significant interactions and therefore were considered for further analysis in the mixed effects model were (Table 7). Among the fixed effects models examined, a maximum of 10% of the overall deviance was explained. The mixed effects analyses (Table 8) indicated no significant factors. The fixed model without the year interactions (year, region, season, region*season) was selected for standardization; it accounted for only about 2% of the total deviance. That the highly significant year interactions, especially the year*season interaction (Table 7) were not included in the model used to calculated the standardized catch rates suggests that this index may not reliably reflect the catch rate data. The standardized index had a very low coefficient of variation (Table 17) which was thought to be due primarily to the lack of significant random effects. The resulting index showed a stable pattern (Figure 12); confidence intervals were not plotted because they were so narrow.

Index: Non-targeted 1-9 hooks per line

After data restrictions there were 38,858 trips on which 1-9 hooks per line were fished by vessels which were not included in the targeted analysis. Roughly 75% of the trips reported 1-2 hooks per line and the remainder had 3-9 hooks. About 50% of the trips were off northwest Florida and Alabama, about 30% were reported from off central and southern Florida and the remainder occurred off Louisiana and Texas. Trips occurred in all seasons and years.

For the positive catch rates (catch rates on trips which caught greater amberjack) the fixed effects analysis indicated that all main effects or interactions with main effects were significant (Table 9). After elimination of non-significant effects the model which explained the largest amount of deviance accounted for only about 4% of the total deviance (Table 9, phase 2). The main effects, the region*season and the region*hooks-per-line interactions and all year interactions were considered for mixed model analyses. The mixed model analysis indicated significant random effects due to the year*season, year*hooks-per-line, region*season and region*hooks-per-line interactions (Table 10), and those effects were included in the model used to derive the index.

For the fixed effects analyses of the proportion of trips which caught greater amberjack, all main effects were retained as were the region*season and the region*hooks-per-line interactions and the year*region and year*hooks-per-line interactions (Table 11). The model which explained the highest amount of deviance only accounted for about 3% of the total. The mixed model analysis indicated that year*region, year*hooks-per-line and region*season were significant random effects (Table 12).

The standardized index indicated relatively low catch rates in 1990-1992, an increase to about 1995 and 1997-1998 catch rates slightly higher than in the early 1990's (Figure 13). The coefficient of variation about the standardized catch rates was about 0.3 (Table 17).

Index: 10-40 hooks per line

After restrictions there were 16,241 trips on which 10-40 hooks-per-line were reported. About 50% occurred in the west Louisiana and Texas region, about 30% occurred in the northwest

Florida and Alabama region and about 20% occurred in the Louisiana region. About 55% of the trips reported 10-19 hooks.

In the fixed effects analysis of catch rates on trips which caught greater amberjack all main effects and all two way interactions except season*hooks-per-line were considered significant (Table 13). The model which explained the most deviance accounted for only about 3% of the total deviation. The mixed model analysis of those effects indicated that the year*region, year*season and region*season interactions were significant random effects (Table 14).

In the analysis of the proportion of trips which caught greater amberjack, the fixed effects analysis indicated that hooks-per-line and its interactions did not have significant effect (Table 15), and that the remaining main effects and the region*season and year*season effects were significant. The model with those effects accounted for about 13% of the total deviance. The mixed model analysis indicated that those two interactions were significant random effects (Table16).

The mean standardized index showed the greatest changes in 1990-1999 (increase) and 1997-1998 (decrease), though the 1990 estimate had a very high coefficient of variation of 0.89 (Table 17). Between 1991 and 1997 the index varied without substantial trend (Figure 14). The coefficients of variation about the 1991-1998 estimates ranged from 0.45 to 0.55.

Discussion

Preferred Index

Prior to analysis it was hoped that the different hook configurations might correspond to different size ranges of Gulf of Mexico greater amberjack caught. There has not been sufficient time to re-extract size and effort observations to test that hypothesis. However the similarity of the patterns of the three indices and particularly the 1-9 and 10-40 hook-per-line indices suggests that the hypothesis may not be correct (Figure 15); the similarity does suggest that they may be providing information on similar groups or the same group of greater amberjack.

Given that the indices may correspond to the same group of fish, then one index from the fishery should be selected for use in assessment. None of the models fit the data well as indicated by the proportion of total variation explained by the best fixed effects models. The choice might be the index from non-targeted trips with 1-9 hooks per line. That index was based on the largest amount of data, covered the broadest geographical range and had lower coefficients of variation than the index from 10-40 hooks per line. The index from trips targeted at greater amberjack is not recommended because of low sample size, relatively limited geographic distribution, shorter time series and, importantly, the difficulties and inconsistencies in the model fits. The 10-40 hook per line index had the highest proportion of total deviance explained in the fixed effects analysis of proportion of trips catching greater amberjack, but the levels of deviance explained in the fixed effects analysis of catch rates on trips with greater amberjack were similar for both the 1-9 and 10-40 hook per line data sets. Additionally the 10-40 hook per line trips had substantially higher proportion of trips with greater amberjack than the presumed non-targeted trips with 1-9 hooks per line; however the much higher coefficients of variation about the index values and its more limited geographic distribution suggest that the 10-40 hook per line index might be less preferable than the 1-9 hook per line index.

The reeffish logbook reports record data in a crude manner in that changes in catch and effort within a trip can not be recorded in detail. The analysis of catch and effort on a trip basis assumes that all of the fishing occurred as recorded. Certainly some fishing trips use multiple gear configurations, such as different numbers of hooks per handline or bandit rig or fish in multiple areas. An attempt to restrict the data to trips which used only one kind of gear in one area was made. However the log does not permit recording catch and effort by multiple gear configurations within a gear type, such as different numbers of hooks per line. Perhaps more of a concern might be geographic changes of fishing effort even within a statistical grid. Vessels probably move among locations within a trip and catch rates probably differ between locations. If such changes have occurred in a similar manner throughout the time series analyzed then the standardized indices of abundance may not have been affected; however if such within trip shifts in fishing have changed with changing stock, market or regulatory conditions then the indices of abundance could have been affected. Detailed catch and effort data might provide greater capability of defining effort which could catch greater amberjack for use in developing indices of abundance.

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Table 1. Number of trips by year and gear in the reeffish logbook data base.

	handline	bottom longline	trap	trol l	other	Total
1990	1708	412	391	0	23	2534
1991	3638	833	566	0	82	5119
1992	3803	521	861	0	118	5303
1993	8797	1316	1235	157	194	11699
1994	9542	1727	1059	313	358	12999
1995	9407	1933	998	311	246	12895
1996	10069	2296	951	518	280	14114
1997	10743	2048	682	444	305	14222
1998	11196	1676	490	908	344	14614
total	68903	12762	7233	2651	1950	93499

Table 2. Proportion of trips with greater amberjack by year and gear in the reeffish logbook data base.

	handline	longline	trap	trol l
1990	0.21	0.19	0.03	0.00
1991	0.28	0.24	0.02	0.00
1992	0.17	0.21	0.01	0.00
1993	0.18	0.22	0.01	0.13
1994	0.19	0.20	0.01	0.11
1995	0.19	0.19	0.01	0.08
1996	0.19	0.16	0.03	0.04
1997	0.19	0.21	0.01	0.05
1998	0.12	0.17	0.01	0.02

Table 3. Proportion of total yield that was greater amberjack by year and gear in the reeffish logbook data base.

	handline	longline	trap	trol l
1990	0.059	0.005	0.001	0.000
1991	0.052	0.009	0.001	0.000
1992	0.049	0.007	0.001	0.000
1993	0.061	0.006	0.001	0.012
1994	0.056	0.007	0.002	0.004
1995	0.066	0.007	0.001	0.004
1996	0.074	0.005	0.001	0.030
1997	0.064	0.006	0.000	0.002
1998	0.040	0.006	0.000	0.007

Table 4. Number of handline trips by assumed latitude and longitude and number of hooks per line.

1-2 hooks per line

Latitude	Longitude 95	94	93	92	91	90	89	88	87	86	85	84	83
29							182	599	1011	1620	1928	4571	
28	113	130	652	221	213	216	1023					7072	
27												4151	
26	187												3087
25													861
24													4601

3-9 hooks per line

	95	94	93	92	91	90	89	88	87	86	85	84	83
29							195	361	985	669	880	1182	
28	452	373	495	132	153	296	860					1307	
27	234											599	
26	369												563
25													332
24													328

10-19 hooks per line

	95	94	93	92	91	90	89	88	87	86	85	84	83
29								509	846	434	183	107	
28	830	1100	1241	916	641	738	1172						
27	169												
26													
25													
24													

20-40 hooks per line

	95	94	93	92	91	90	89	88	87	86	85	84	83
29							112	504	1208	583	215		
28	396	433	1623	1105	371	363	356						
27	151												
26	275												
25													
24													

Table 5. Proportion of trips with greater amberjack by assumed latitude and longitude and number of hooks per line.

1-2 hooks per line

Latitude	Longitude 95	94	93	92	91	90	89	88	87	86	85	84	83
29							0.08	0.08	0.11	0.15	0.28	0.12	
28	0.09	0.23	0.04	0.14	0.31	0.22	0.09					0.09	
27												0.23	
26	0.21												0.06
25													0.09
24													0.11

3-9 hooks per line

	95	94	93	92	91	90	89	88	87	86	85	84	83
29							0.16	0.18	0.15	0.17	0.24	0.08	
28	0.19	0.17	0.12	0.27	0.27	0.21	0.11					0.10	
27	0.20											0.15	
26	0.17												0.10
25													0.14
24													0.14

10-19 hooks per line

	95	94	93	92	91	90	89	88	87	86	85	84	83
29								0.33	0.34	0.27	0.34	0.34	
28	0.16	0.22	0.23	0.20	0.30	0.19	0.15						
27	0.12												
26													
25													
24													

20-40 hooks per line

	95	94	93	92	91	90	89	88	87	86	85	84	83
29							0.07	0.35	0.42	0.33	0.31		
28	0.11	0.26	0.17	0.16	0.11	0.18	0.12						
27	0.10												
26	0.36												
25													
24													

Table 6. Average pounds of greater amberjack per trip by assumed latitude and longitude and number of hooks per line.

1-2 hooks per line

Latitude	Longitude 95	94	93	92	91	90	89	88	87	86	85	84	83
29							174	197	180	147	97	111	
28	128	70	189	303	310	310	137					111	
27												287	
26	305												160
25													189
24													103

3-9 hooks per line

	95	94	93	92	91	90	89	88	87	86	85	84	83
29							139	52	73	85	113	131	
28	84	51	68	120	236	123	100					116	
27	49											338	
26	139												255
25													47
24													53

10-19 hooks per line

	95	94	93	92	91	90	89	88	87	86	85	84	83
29								36	32	36	67	56	
28	52	53	61	81	73	51	80						
27	49												
26													
25													
24													

20-40 hooks per line

	95	94	93	92	91	90	89	88	87	86	85	84	83
29							38	40	72	55	65		
28	57	31	30	102	44	120	47						
27	51												
26	118												
25													
24													

Table 7. Fixed effects analysis of targeted effort with 1-2 hooks per handline.

postive catch rate model	d.f. for added factor	deviance	change in deviance	maximum model deviance	% of total deviance explained	% total model deviance	*p*	chi sq
null		34219553						
year	4	34045934	173619			4.92%	< 0.001	0.0000
year region	1	33989776	56159			1.59%	< 0.001	0.0000
year season	2	33550656	495278			14.04%	< 0.001	0.0000
year season region	2	33440268	110388			3.13%	< 0.001	0.0000
year region season region*season	2	32926902	513367			14.55%	< 0.001	0.0000
year region season region*season year*region	4	32728553	198348			5.62%	< 0.001	0.0000
year region season region*season year*season	4	30692197	2234704			63.35%	< 0.001	0.0000
				3527355.8	10.31%			

Table 8. Random effects analysis of targeted effort with 1-2 hooks per handline.

postive catch rate model	-2 REM Log likelihood	Akaike's Information Criterion	Schwartz's Bayesian Criterion	Likelihood Ratio	*p*
year region season	515.987	-258.993	-260.667		
year region season *year*region*	515.987	-259.993	-263.340	0.0000	1.0000
year region season *year*season*	514.974	-259.487	-262.834	1.0132	0.3141
year region season *year*region year*season*	514.974	-260.487	-265.507	0.0000	1.0000
year region season *year*region1year*season region*season*	513.491	-260.746	-267.440	1.4822	0.2234

Table 9. Fixed effects analysis of positive catch rates on presumed non-targeted handline trips on which 1-9 hooks per line were fished. Initial examination.

postive catch rate model	d.f. for added factor	deviance	change in deviance	maximum model deviance	% of total deviance explained	% total model deviance	*p*	chi sq
phase 1								
drop added factors in highlighted models								
null		7064638						
year	8	6983140	81498.3			20.16%	< 0.001	0
year region	4	6861152	121988.0			30.18%	< 0.001	0
year season	3	6967080	16059.8			3.97%	< 0.001	0
year hkprline	1	6982383	757.1			0.19%	< 0.001	1E-166
year region season	3	6849097	12054.9			2.98%	< 0.001	0
year region hkprline	1	6860452	700.3			0.17%	< 0.001	3E-154
year season hkprline	1	6966566	513.9			0.13%	< 0.001	9E-114
year region season hkprline	1	6847914	1183.4			0.29%	< 0.001	2E-259
year region season hkprline reg*seas	12	6801678	46235.8			11.44%	< 0.001	0
year region season hkprline reg*hpl	4	6815075	32838.6			8.12%	< 0.001	0
year region season hkprline seas*hpl	3	6835804	12109.6			3.00%	< 0.001	0
year region season hkprline reg*seas reg*hpl	4	6768913	32765.1			8.11%	< 0.001	0
year region season hkprline reg*seas seas*hpl	3	6778041	23637.0			5.85%	< 0.001	0
year region season hkprline reg*hpl seas*hpl	3	6803066	12008.6			2.97%	< 0.001	0
year region season hkprline reg*seas reg*hpl seas*hpl	3	6751207	17705.5			4.38%	< 0.001	0
year region season hkprline reg*seas reg*hpl seas*hpl yr*reg	32	6681646	69561.4			17.21%	< 0.001	0
year region season hkprline reg*seas reg*hpl seas*hpl yr*seas	23	6660416	90791.0			22.46%	< 0.001	0
year region season hkprline reg*seas reg*hpl seas*hpl yr*hpl	8	6731217	19989.8			4.95%	< 0.001	0
				404221.9	5.72%			

Table 9. Continued. Models selected for further examination with mixed model analyses are highlighted.

postive catch rate model	**d.f. for added factor**	**deviance**	**change in deviance**	**maximum model deviance**	**% of total deviance explained**	**% total model deviance**	***p***	**chi sq**
phase 2								
models selected for mixed model tests are highlighted								
null		7064638						
year	8	6983140	81498.3			26.50%	< 0.001	0
year region	4	6861152	121988.0			39.66%	< 0.001	0
year season	3	6967080	16059.8			5.22%	< 0.001	0
year hkprline	1	6982383	757.1			0.25%	< 0.001	1E-166
year region season	3	6849097	12054.9			3.92%	< 0.001	0
year region hkprline	1	6860452	700.3			0.23%	< 0.001	3E-154
year season hkprline	1	6966566	513.9			0.17%	< 0.001	9E-114
year region season hkprline	1	6847914	1183.4			0.38%	< 0.001	2E-259
year region season hkprline reg*seas	12	6801678	46235.8			15.03%	< 0.001	0
year region season hkprline reg*hpl	4	6815075	32838.6			10.68%	< 0.001	0
year region season hkprline reg*seas reg*hpl	4	6768913	32765.1			10.65%	< 0.001	0
year region season hkprline reg*seas reg*hpl yr*reg	32	6697786	71126.8			23.13%	< 0.001	0
year region season hkprline reg*seas reg*hpl yr*seas	23	6675592	93320.7			30.34%	< 0.001	0
year region season hkprline reg*seas reg*hpl yr*hpl	8	6747578	21334.8			6.94%	< 0.001	0
				307547.9	4.35%			

Table 10. Mixed model analysis of positive catch rates on presumed non-targeted handline trips on which 1-9 hooks per line were fished. Random effects are *italics*; likelihood ratio statistics generally test the significance of the added interaction term.

postive catch rate model	-2 REM Log likelihood	Akaike's Information Criterion	Schwartz's Bayesian Criterion	Likelihood Ratio	*p*
phase 1					
drop added effect in highlighed models					
year region season hkprline	10091.733	-5046.866	-5049.925		
year region season hkprline *yr*reg*	10088.263	-5046.131	-5052.249	3.4703	0.062
year region season hkprline *yr*seas*	10087.945	-5045.972	-5052.090	3.7883	0.052
year region season hkprline *yr*hpl*	10083.035	-5043.518	-5049.635	8.6977	0.003
year region season hkprline *yr*seas yr*reg*	10084.308	-5045.154	-5054.330	3.6367	0.057
year region season hkprline *yr*hpl yr*reg*	10081.039	-5043.519	-5052.695	1.9962	0.158
year region season hkprline *yr*hpl yr*seas*	10078.587	-5042.294	-5051.470	4.4479	0.035
year region season hkprline *yr*reg yr*seas yr*hpl*	10076.515	-5042.258	-5054.492	2.0720	0.150
year region season hkprline *yr*reg yr*seas yr*hpl reg*seas*	10066.820	-5038.410	-5053.703	9.6950	0.002
year region season hkprline *yr*reg yr*seas yr*hpl reg*hpl*	10069.788	-5039.894	-5055.187	6.7275	0.009
year region season hkprline *yr*reg yr*seas yr*hpl reg*seas reg*hpl*	10061.208	-5036.604	-5054.956	5.6120	0.018
phase 2					
final model is highlighted					
year region season hkprline	10091.733	-5046.866	-5049.925		
year region season hkprline *yr*seas*	10087.945	-5045.972	-5052.090	3.788	0.052
year region season hkprline *yr*hpl*	10083.035	-5043.518	-5049.635	8.698	0.003
year region season hkprline *yr*hpl yr*seas*	10078.587	-5042.294	-5051.470	4.448	0.035
year region season hkprline *yr*seas yr*hpl reg*seas*	10068.170	-5038.085	-5050.320	10.418	0.001
year region season hkprline *yr*seas yr*hpl reg*hpl*	10071.952	-5039.976	-5052.211	6.635	0.010
year region season hkprline *yr*seas yr*hpl reg*seas reg*hpl*	10062.741	-5036.371	-5051.664	5.428	0.020

Table 11. Fixed effects analysis of proportion of positive trips on presumed non-targeted handline trips on which 1-9 hooks per line were fished. Seas*hpl not to be included in models to be tested with mixed model analysis.

highlighted models to be examined with mixed models
seas*hpl not to be included

proportion postive model	d.f. for added factor	deviance	change in deviance	maximum model deviance	% of total deviance explained	% total model deviance	*p*	chi sq
null		23049.8						
year	8	23010.1	39.69			5.93%	< 0.001	3.7E-06
year region	4	22912.3	97.80			14.63%	< 0.001	2.9E-20
year season	3	22990.1	19.98			2.99%	< 0.001	0.00017
year hkprline	1	22917.5	92.65			13.86%	< 0.001	6.2E-22
year region season	3	22890.9	21.39			3.20%	< 0.001	8.7E-05
year region hkprline	1	22854.8	57.49			8.60%	< 0.001	3.4E-14
year season hkprline	1	22897.2	92.93			13.90%	< 0.001	5.4E-22
year region season hkprline	1	22833.8	57.16			8.55%	< 0.001	4E-14
year region season hkprline reg*seas	12	22552.4	281.35			42.07%	< 0.001	3.8E-53
year region season hkprline reg*hpl	4	22805.4	28.38			4.24%	< 0.001	1E-05
year region season hkprline seas*hpl	3	22741.6	92.15			13.78%	< 0.001	7.6E-20
year region season hkprline reg*seas reg*hpl	4	22513.4	38.98			5.83%	< 0.001	7E-08
year region season hkprline reg*seas seas*hpl	3	22521.5	30.86			4.62%	< 0.001	9.1E-07
year region season hkprline reg*hpl seas*hpl	3	22684.4	57.17			8.55%	< 0.001	2.4E-12
year region season hkprline reg*seas reg*hpl seas*hpl	3	22480.5	32.96			4.93%	< 0.001	3.3E-07
year region season hkprline reg*seas reg*hpl seas*hpl yr*reg	32	22381.1	99.39			14.86%	< 0.001	7.9E-09
year region season hkprline reg*seas reg*hpl seas*hpl yr*seas	23	22390.3	90.13			13.48%	< 0.001	6.8E-10
year region season hkprline reg*seas reg*hpl seas*hpl yr*hpl	8	22459.2	21.24			3.18%	0.00654	0.00654
				668.72	2.90%			

Table 12. Mixed model analysis of proportion positive of presumed non-targeted handline trips on which 1-9 hooks per line were fished. Random effects terms are in *italics.* The highlighted model without the yr*seas term was considered final.

postive catch rate model	**-2 REM Log likelihood**	**Akaike's Information Criterion**	**Schwartz's Bayesian Criterion**	**Likelihood Ratio**	***p***
year region season hkprline	1121.637	-561.818	-563.718		
year region season hkprline *yr*reg*	969.365	-486.683	-490.482	152.272	0.000
year region season hkprline *yr*seas*	969.163	-486.581	-490.380	152.474	0.000
year region season hkprline *yr*seas yr*reg*	966.446	-486.223	-491.922	2.717	0.099
year region season hkprline *yr*reg yr*seas reg*seas*	860.744	-434.372	-441.970	105.702	0.000
year region season hkprline *yr*reg yr*seas reg*hpl*	963.943	-485.972	-493.570	2.502	0.114
year region season hkprline *yr*reg yr*seas reg*seas reg*hpl*	860.039	-435.020	-444.517	0.705	0.401

Table 13. Fixed effects analysis of catch rates on trips which caught greater amberjack and which reported using 10-40 hooks-per-line. Hignlighted models without the season*hooks-per-line interaction were selected for further analysis with mixed models.

postive catch rate model **highlighted models to be examined with mixed models** **seas*hpl not to be included**	**d.f. for added factor**	**deviance**	**change in deviance**	**maximum model deviance**	**% of total deviance explained**	**% total model deviance**	***p***	**chi sq**
null		8377.59						
year	8	8347.98	29.61			11.66%	< 0.001	0.000
year region	2	8329.29	18.69			7.36%	< 0.001	0.000
year season	3	8332.02	15.96			6.28%	0.001	0.001
year hkprline	1	8343.25	4.72			1.86%	0.030	0.030
year region season	3	8306.20	23.09			9.10%	< 0.001	0.000
year region hkprline	1	8319.86	9.43			3.71%	0.002	0.002
year season hkprline	1	8328.47	3.55			1.40%	0.060	0.060
year region season hkprline	1	8297.49	8.71			3.43%	0.003	0.003
year region season hkprline reg*seas	6	8240.15	57.34			22.58%	< 0.001	0.000
year region season hkprline reg*hpl	2	8285.77	11.72			4.62%	0.003	0.003
year region season hkprline seas*hpl	3	8280.61	16.88			6.65%	< 0.001	0.001
year region season hkprline reg*seas reg*hpl	2	8224.66	15.48			6.10%	< 0.001	0.000
year region season hkprline reg*seas seas*hpl	3	8226.56	13.59			5.35%	0.004	0.004
year region season hkprline reg*hpl seas*hpl	3	8262.09	23.68			9.32%	< 0.001	0.000
year region season hkprline reg*seas reg*hpl seas*hpl	3	8214.78	9.89			3.89%	0.020	0.020
year region season hkprline reg*seas reg*hpl seas*hpl yr*reg	16	8123.68	91.10			35.88%	< 0.001	0.000
year region season hkprline reg*seas reg*hpl seas*hpl yr*seas	23	8143.17	71.61			28.20%	< 0.001	0.000
year region season hkprline reg*seas reg*hpl seas*hpl yr*hpl	8	8196.37	18.41			7.25%	0.018	0.018
				253.91	3.03%			

Table 14. Mixed model analysis of catch rates on trips which caught greater amberjack and which reported 10-40 hooks-per-line.

postive catch rate model **highlighted model to be used for index** **yr*hpl not to be included**	**-2 REM Log likelihood**	**Akaike's Information Criterion**	**Schwartz's Bayesian Criterion**	**Likelihood Ratio**	***p***
year region season hkprline	12781.4	-6391.7	-6394.9		
year region season hkprline *yr*reg*	12759.3	-6381.6	-6387.9	22.158	0.000
year region season hkprline *yr*seas*	12767.7	-6385.8	-6392.1	13.763	0.000
year region season hkprline *yr*hpl*	12781.3	-6392.7	-6399.0	0.126	0.723
year region season hkprline *yr*reg yr*seas*	12746.2	-6376.1	-6385.6	13.088	0.000
year region season hkprline *yr*reg yr*hpl*	12759.3	-6382.6	-6392.1	0.017	0.897
year region season hkprline *yr*seas yr*hpl*	12767.5	-6386.7	-6396.2	0.217	0.642
year region season hkprline *yr*reg yr*seas yr*hpl*	12746.1	-6377.1	-6389.7	0.058	0.810
year region season hkprline *yr*reg yr*seas yr*hpl reg*seas*	12688.8	-6349.4	-6365.2	57.312	0.000
year region season hkprline *yr*reg yr*seas yr*hpl reg*hpl*	12746.1	-6378.1	-6393.8	0.000	1.000
year region season hkprline *yr*reg yr*seas yr*hpl reg*seas reg*hpl*	12688.8	-6350.4	-6369.3	0.000	1.000

Table 15. Fixed factor analysis of proportion of trips which caught greater amberjack on trips which reported 10-40 hooks-per-line.

proportion postive model	d.f. for added factor	deviance	change in deviance	maximum model deviance	% of total deviance explained	% total model deviance	*p*	chi sq
phase 1: main effects								
drop highlighted models								
null		18245.4						
year	8	18089.1	156.3			6.53%	< 0.001	0.000
year region	2	17647.1	442.0			18.46%	< 0.001	0.000
year season	3	16669.0	1420.1			59.31%	< 0.001	0.000
year hkprline	1	18078.3	10.8			0.45%	0.001	0.001
year region season	3	16546.9	1100.2			45.95%	< 0.001	0.000
year region hkprline	1	17647.1	0.0			0.00%	0.969	0.969
year season hkprline	1	16664.6	4.4			0.18%	0.035	0.035
year region season hkprline	1	16546.8	0.1			0.00%	0.792	0.792
year region season hkprline reg*seas	6	16366.0	180.9			7.55%	< 0.001	0.000
year region season hkprline reg*hpl	2	16509.5	37.4			1.56%	< 0.001	0.000
year region season hkprline seas*hpl	3	16524.5	22.4			0.93%	< 0.001	0.000
year region season hkprline reg*seas reg*hpl	2	16328.1	37.9			1.58%	< 0.001	0.000
year region season hkprline reg*seas seas*hpl	3	16351.4	14.5			0.61%	0.002	0.002
year region season hkprline reg*hpl seas*hpl	3	16476.5	48.0			1.38%	< 0.001	0.000
year region season hkprline reg*seas reg*hpl seas*hpl	3	16310.9	17.1			0.72%	< 0.001	0.001
year region season hkprline reg*seas reg*hpl seas*hpl yr*reg	16	16231.1	79.8			3.33%	< 0.001	0.000
year region season hkprline reg*seas reg*hpl seas*hpl yr*seas	23	15851.1	459.9			19.21%	< 0.001	0.000
year region season hkprline reg*seas reg*hpl seas*hpl yr*hpl	8	16296.5	14.4			0.60%	0.072	0.072
				2394.4	13.12%			

Table 15. Continued. Final phase.

proportion postive model	d.f. for added factor	deviance	change in deviance	maximum model deviance	% of total deviance explained	% total model deviance	*p*	chi sq
phase 2: highlighted model selected for examination with mixed models								
null		18245.4						
year	8	18089.1	156.3			6.65%	< 0.001	0.000
year region	2	17647.1	442.0			18.81%	< 0.001	0.000
year season	3	16669.0	1420.1			60.43%	< 0.001	0.000
year season region	2	16546.9	122.1			5.20%	< 0.001	0.000
year region season reg*seas	6	16366.4	180.5			7.68%	< 0.001	0.000
year region season reg*seasl yr*reg	16	16282.0	84.4			3.59%	< 0.001	0.000
year region season reg*seas yr*seas	23	15895.3	471.1			20.04%	< 0.001	0.000
				2350.1	12.88%			

Table 16. Mixed model analysis of proportion of trips with greater amberjack on trips which reported using 10-40 hooks-per-line. Highlighted model selected for index standardization.

proportion positive model	-2 REM Log likelihood	Akaike's Information Criterion	Schwartz's Bayesian Criterion	Likelihood Ratio	*p*
year region season	272.01	-137.00	-138.26		
year region season *yr*seas*	262.43	-133.22	-135.73	9.578	0.002
year region season *yr*seas reg*seas*	244.18	-125.09	-128.85	18.255	0.000

Table 17. Standardized catch rates for Gulf of Mexico greater amberjack from handline reports in the reeffish log book data base.

	targeted 1-2 hooks per line			**non-targeted 1-9 hooks per line**			**10-40 hooks per line**		
	index	standard error	coefficient of variation	index	standard error	coefficient of variation	index	standard error	coefficient of variation
units	biomass			biomass			biomass		
1990				1.77	0.634	0.36	0.060	0.054	0.89
1991				2.05	0.598	0.29	0.145	0.069	0.47
1992				1.95	0.585	0.30	0.139	0.071	0.51
1993				2.66	0.734	0.28	0.164	0.079	0.48
1994	442		0.023	2.83	0.781	0.28	0.171	0.080	0.47
1995	472		0.022	3.14	0.870	0.28	0.139	0.075	0.54
1996	459		0.019	2.95	0.808	0.27	0.152	0.076	0.50
1997	411		0.021	2.32	0.644	0.28	0.191	0.086	0.45
1998	445		0.027	2.23	0.638	0.29	0.124	0.068	0.55

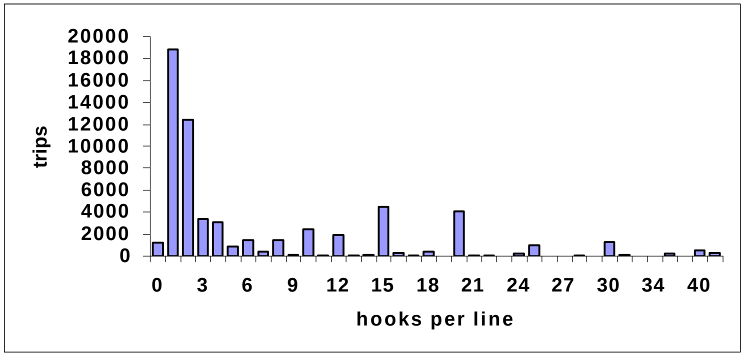

Figure 1. Number of hooks per line in the Gulf of Mexico handline fishery.

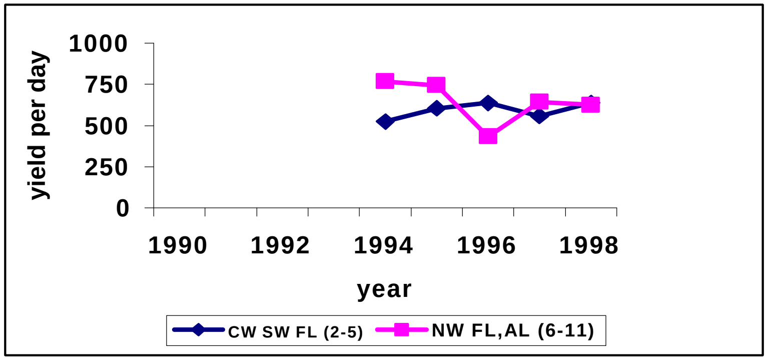

Figure 2. Nominal yield per day from targeted handline trips fishing 1-2 hooks per line by region.

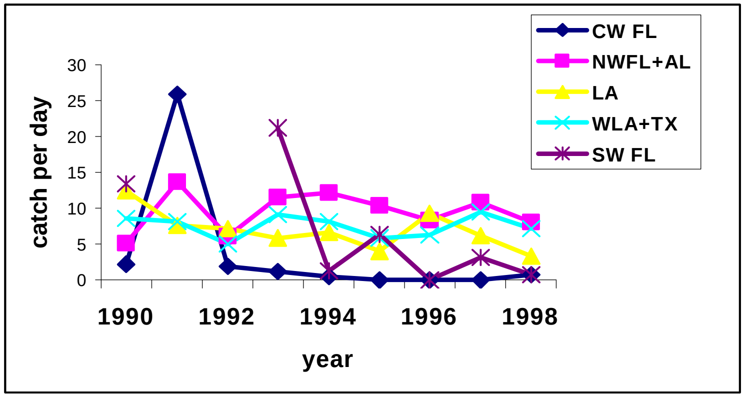

Figure 3. Nominal catch per day of greater amberjack from all trips with 1-9 hooks per line by non-targeting vessels.

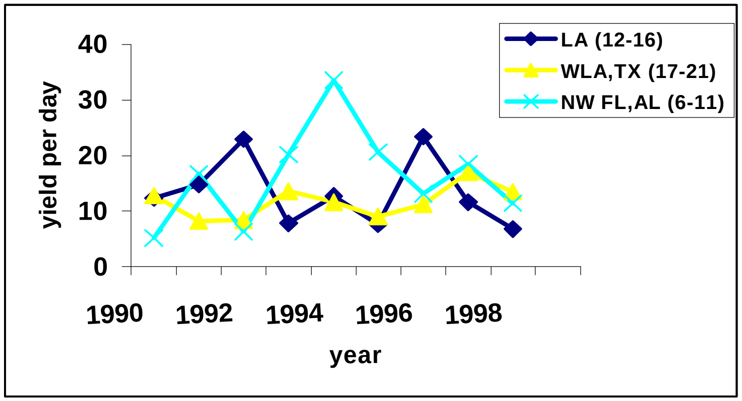

Figure 4. Nominal yield per day of greater amberjack from all trips fishing 10–40 hooks per line.

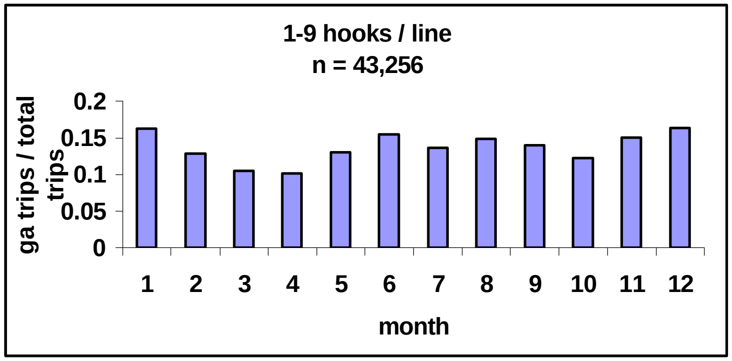

Figure 5. Proportion of trips with greater amberjack by month for trips with 1-9 hooks per line.

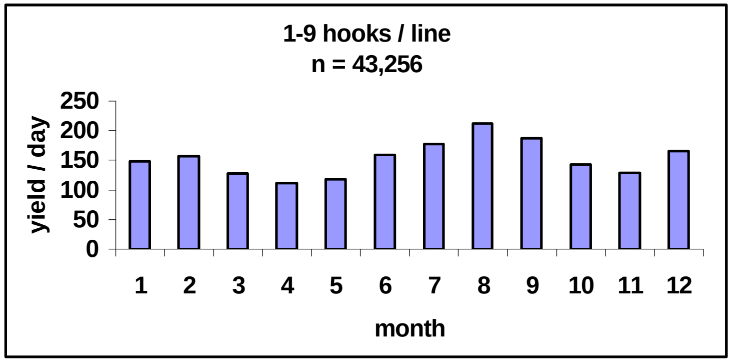

Figure 6. Greater amberjack pounds per day on trips with 1-9 hooks per line which caught greater amberjack.

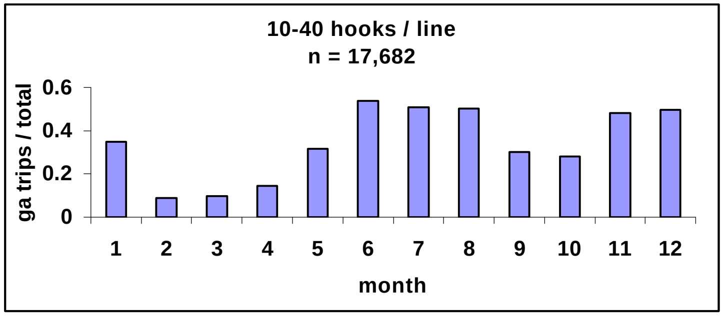

Figure 7. Proportion of trips with greater amberjack by month for trips with 10-40 hooks per line

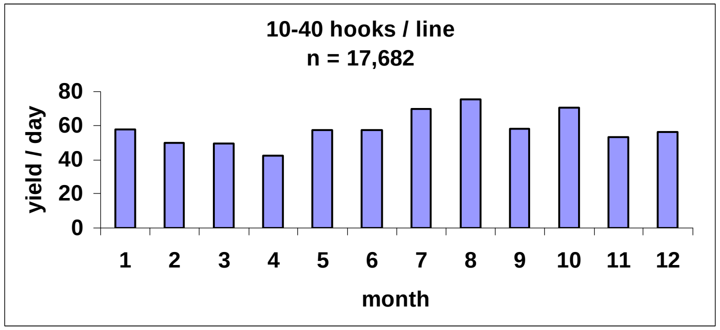

Figure 8. Greater amberjack pounds per day on trips with 10-40 hooks per line which caught greater amberjack.

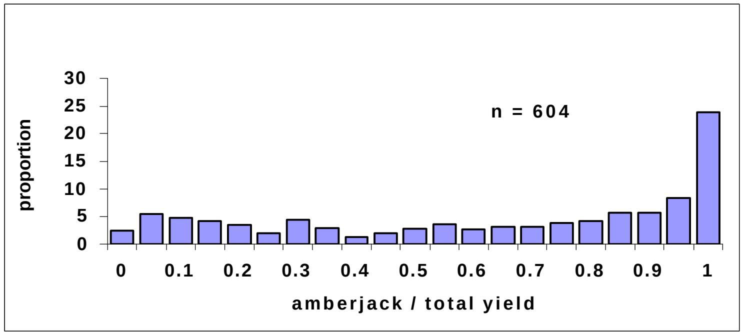

Figure 9. Fraction of greater amberjack in the total yield.of trips with 1-9 hooks per line by vessels which targeted greater amberjack in at least 3 years.

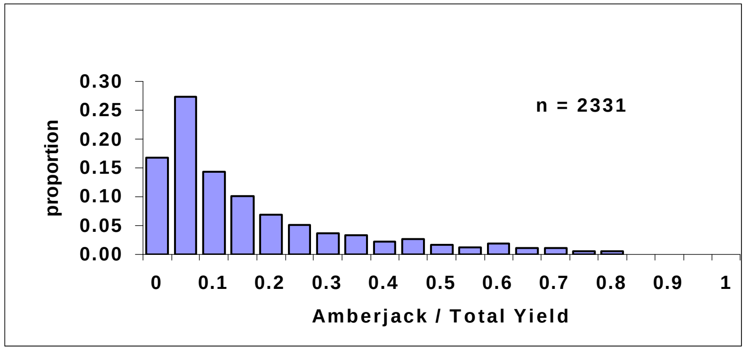

Figure 10. Fraction of greater amberjack in the total yield on trips which caught greater amberjack and reported 1-9 hooks per line by vessels not considered to have consistently targeted greater amberjack.

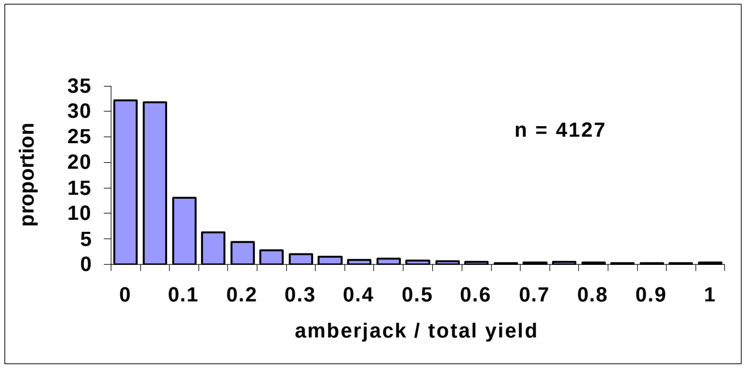

Figure 11. Fraction of greater amberjack in the total yield on trips which caught greater amberjack and reported 10-40 hooks per line.

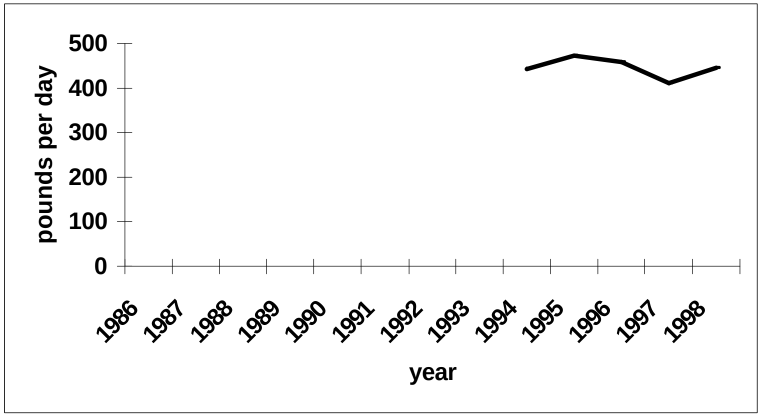

Figure 12. Standardized catch rate of greater amberjack from handline trips with 1-2 hooks per line.

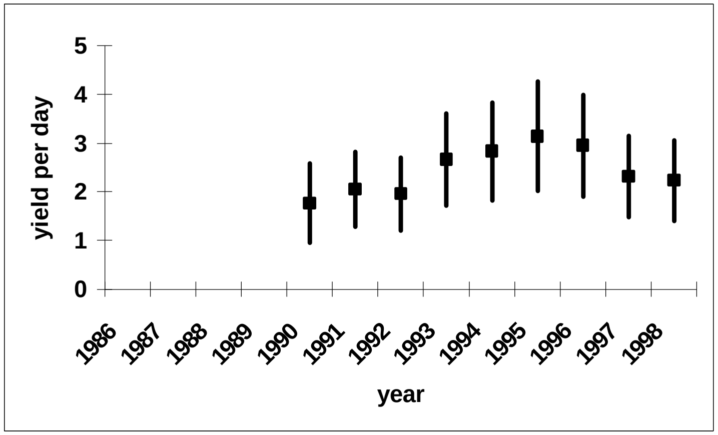

Figure 13. Standardized catch rate of greater amberjack on non-targeted handline trips with 1-9 hooks per line. 80% confidence intervals are shown.

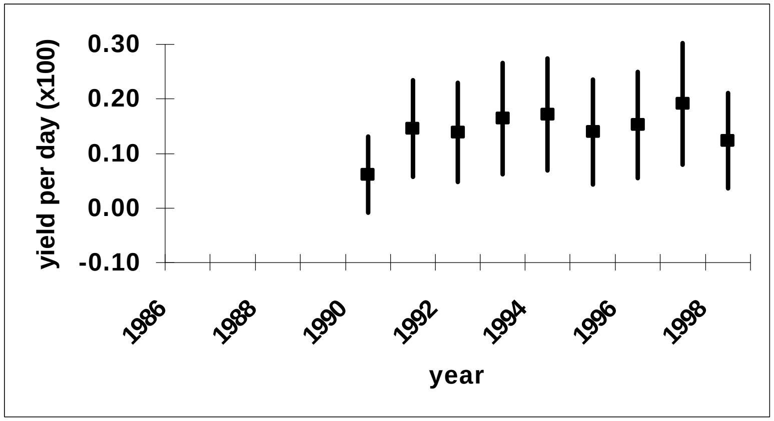

Figure 14. Standardized catch rate of greater amberjack on handline trips with 10-40 hooks-per-line. 80% confidence intervals are shown.

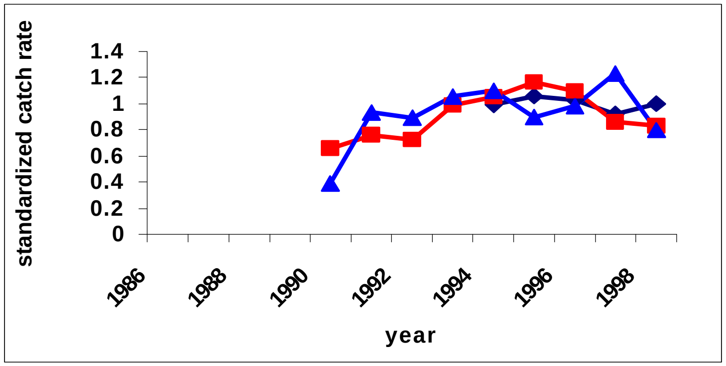

Figure 15. Comparison of standardized catch rates for greater amberjack caught by targeted handlines (diamonds), 1-9 hooks-per-line (squares) and 10-40 hooks per line (triangles).