MONITORING CHANGES IN THE CATCH RATES AND ABUNDANCE OF JUVENILE GOLIATH GROUPER USING THE ENP CREEL SURVEY, 1973-2009

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ABSTRACT

In early 2006, NOAA Fisheries removed goliath grouper from its list of species of concern. It cited a recent status report that showed a significant increase in the abundance of the U.S. population and suggested that goliath grouper are re-establishing themselves throughout their historic range. However, under the Magnuson-Stevens Conservation Act, the goliath grouper remains "overfished", and harvest is still illegal. The historical center of abundance of goliath grouper is the Ten Thousand Islands area of southwest Florida. Detailed catch and effort data are available from this region from 1973-2009. The data were collected by Everglades National Park (ENP) during voluntary dockside interviews of sport fishermen. Using this data, a standardized index of abundance was created for juvenile goliath grouper. The index shows a substantial decline in abundance of juveniles during the late 1970s and early 1980s. Since that time, a strong increase through 2007 and decline from 2008-2009 is evident, suggesting that strong year classes recently occurred in ENP, but that as these animals matured and left the juvenile habitat, they may not have been replaced with ongoing strong recruitment.

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INTRODUCTION

Goliath grouper, *Epinephelus itajara*, (formerly referred to as jewfish) occur in tropical areas of the western Atlantic Ocean, from Florida south to Brazil, including the Gulf of Mexico and the Caribbean Sea (Heemstra and Randall, 1993). They are the largest of the western north Atlantic groupers, reaching a size of 2.0 to 2.5 m TL (Heemstra and Randall, 1993) and 320 kg (Smith, 1971). Adults are typically found in shallow, inshore waters at depths less than 40 m (Sadovy and Eklund, 1999). They generally occupy limited home ranges near areas of refuge such as caves, shipwrecks, and rocky ledges (Nagelkerken, 1981). Goliath grouper are slow to mature and long-lived. Their reproductive ecology is poorly known, but they appear to mature at 5-7 years of age and 1.15 to 1.35 meters in length (Bullock et al., 1992). The maximum recorded age from an exploited population of goliath grouper is 37 years (Bullock et al., 1992).

Goliath grouper may be unusually susceptible to overfishing due to their unwary behavior, conspicuous size, apparent site specificity and relatively long life span. Inshore populations began to decline in the 1950s, likely due to fishing pressure (Sadovy and Eklund, 1999). During the late 1970s and 1980s, fishing effort on goliath increased rapidly, while subsequent catches decreased. By 1989, substantial reductions in the number and size of spawning aggregations were noted (DeMaria[1]; Sadovy and Eklund, 1999). These observations led to strict regulatory measures. In 1990, the Gulf of Mexico Fisheries Management Council (GMFMC) prohibited the landing of goliath grouper in Gulf of Mexico federal waters (GMFMC, 1990). Identical moratoria were enacted in 1990 by the South Atlantic Fisheries Management Council (SAFMC) and the State of Florida. In 1993, the Caribbean Fisheries Management Council (CFMC) and the territorial government of the U.S. Virgin Islands expanded the moratorium to federal and territorial waters of the U.S. Caribbean.

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In addition to the regulatory measures, NMFS identified goliath grouper as a candidate species under the Endangered Species Act (ESA) in June, 1991 (56 FR 26797). In 1996, the World Conservation Union (IUCN) recognized the species as "critically endangered" throughout its range and distribution, implying an extreme risk of extinction in the wild in the immediate future. In April 2004, NMFS established a list of "Species of Concern", defined as those species about which NMFS has some concerns regarding status and threats, but for which insufficient information is available to indicate a need to list the species under the ESA. At that time, citing a lack of sufficient information, NMFS transferred 25 species, including goliath grouper, from ESA candidate status to "Species of Concern".

In February 2006, NMFS produced a status report which provided a summary of information pertaining to the U.S. distinct population segment of goliath grouper (NMFS, 2006[2]). The purpose of this report was to examine the status of goliath grouper relative to inclusion criteria for the NMFS list of "Species of Concern". The report concluded that the U.S. population of goliath grouper had undergone significant increases in abundance since 1991, and had re-established itself throughout its historical range. The authors did express concern regarding the rate of mangrove habitat loss, but they did not believe that current habitat loss was affecting the species status. Therefore, they concluded that the inclusion of goliath grouper on the NMFS list of "Species of Concern" was no longer warranted (NMFS, 2006).

The most recent NMFS stock assessment of goliath grouper off Southern Florida was completed in January 2004, and reviewed by a panel of independent experts during January 27-30, 2004 (SEDAR6-AR1[3]). The assessment indicated that the 1990 harvest ban had reduced

[2] NMFS. 2006. Status report on the continental United Stated distinct population segment of the goliath grouper (*Epinephelus itajara).* January 12, 2006. 49 pp.
[3] SEDAR6-AR1. 2004. Kingsley, M.C.S., ed. 2004. The goliath grouper in Southern Florida: Assessment Review and Advisory Report. Southeast Data and Assessment Review. 25pp.

fishing pressure by about 83% (Porch et al., 2006). Regardless, due to illegal harvest and release mortality, the fishing mortality rate remained above the overfishing threshold ($F_{SPR50\%} \approx 0.05$) and the stock biomass remained overfished ($S/S_{SPR50\%} < 1$). If the population continued to undergo fishing mortality at the current rates, the authors estimated the probability of recovery within the next ten years at less than 40%.

In the absence of a reliable catch history during the moratorium, the stock assessment relied on indicators of abundance including two visual surveys: the personal observations of a professional spearfisher (DeMaria[4]) and a volunteer fish-monitoring program administered by the Reef Education and Environmental Foundation[5] (Porch and Eklund, 2004). In addition, the assessment used an earlier version of the Everglades National Park (ENP) creel survey index that had been standardized using data collected during 1972-1999 (Cass-Calay and Schmidt[6]). This index showed a decline in juvenile abundance from 1973 to 1987, followed by a strong recovery from 1993 to 1996. However, abundance during 1997-1999 was somewhat reduced from the time-series maximum that occurred in 1995. Sensitivity runs of the most recent stock assessment model (Porch et al., 2006) demonstrated that the results were sensitive to the inclusion of the ENP creel survey index.

This study describes an updated index of abundance constructed using ENP data collected during 1973-2009. It was developed to monitor and quantify the abundance of juvenile goliath grouper within ENP. This information will be useful for managers and stock assessment biologists tasked to evaluate the status of the U.S. population of goliath grouper.

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[4] DeMaria, D. 2004. Personal. observ. P.O. Box 420975, Summerland Key, FL 33042.
[5] Reef Environmental Education Foundation. www.reef.org.
[6] Cass-Calay, S.L. and T W. Schmidt. 2003. Standardized Catch Rates of Juvenile Goliath Grouper *Epinephelus itajara*, From the Everglades National Park Creel Survey, 1973-1999. National Marine Fisheries Service, Sustainable Fisheries Division Document No. SFD-2003-0016.

METHODS

Data Collection

The current center of abundance for U.S populations of goliath grouper is the Ten Thousand Islands area of southwestern Florida (Sadovy and Eklund, 1999). Here, extensive estuarine and swamp mangrove habitats exist, ideal for juvenile goliath grouper (Bullock and Smith, 1991; Koenig et al., 2008). The Ten Thousand Islands region is located near Chokoloskee and Everglades City, Florida, and is predominantly contained within the borders of Everglades National Park (ENP; Fig. 1).

ENP was established in 1947, and systematic collection of fisheries data began in 1958. Monitoring procedures are described in detail by Davis and Thue (1979) and Schmidt et al. (2002). During the first ten years (1958-1969) the program was conducted by the University of Miami's Institute of Marine Science, and evaluated only the sport fishery. Estimates of catch and catch per unit effort (CPUE) were recorded only for specific species (not including goliath grouper) landed by sport fishermen operating out of Flamingo. In 1972, the National Park Service expanded the monitoring program to include daily trip ticket reports from commercial permit holders, and park-wide monitoring of sport fishing and commercial catch and effort. At this time, the species list was expanded to include all species typically landed within ENP. Fish length measurements were collected as of 1974 and, in 1980, routine monitoring of the Chokoloskee-Everglades City boat ramps began. For goliath grouper, CPUE data is currently available from 1973-2009.

ENP data were provided by the National Park Service, South Florida Ecosystem Office[7]. Detailed descriptions of ENP data collection and recording formats include Higman (1967),

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Davis and Thue (1979) and Tilmant et al. (1986). To summarize, sport fishermen are interviewed by ENP personnel at the Flamingo and Chokoloskee-Everglades City boat ramps (Fig. 1) upon completion of their trip. Data routinely recorded includes trip origin, area fished (Fig. 1), number of fish kept and released by species, number of anglers, hours fished, species preference, angler residence, and type of fisherman (skilled, family, novice, sustenance). According to ENP documentation (Davis and Thue, 1979) the type of fishermen is defined as follows:

1) "Skilled" anglers show their experience by their knowledge of park waters, fishing experience, fishing rods rigged with appropriate lures or fishing in a specialized manner for a particular species.
2) The "family" designation is applied to groups of children and adults, or to groups of adults whose primary interest is other than fishing.
3) The "novice" fisherman has little experience fishing or little experience in the park.
4) The "sustenance" fisherman is primarily fishing for food and usually keeps everything caught.

When possible, fish length measurements are also obtained. These measurements are recorded in separate data files. Goliath grouper length measurements are available during the period 1974-2005 (n = 419).

It is important to emphasize that landings of goliath grouper have been prohibited in all U.S. Federal and State of Florida waters since 1990. Yet goliath grouper continue to be captured and released by sport fishermen. Since ENP records include fish kept and released, they can be used to develop a standardized abundance index. For each trip, we calculated catch per unit effort (CPUE) using Eq. 1.

$$CPUE = (\text{Number Kept} + \text{Number Released}) / 1000 \text{ angler hours} \quad (1)$$

Index Development

In order to develop a sufficiently balanced sample design, it was necessary to construct the following categorical variables (Table 1). The factor SKILL refers to the skill level of the fishing party. Two levels were considered, fishers identified as “skilled” by ENP, and “other” (fishers identified as “family”, “novice” or “sustenance” by ENP). This classification is supported by the following. Skilled fishers caught or released 8.0 goliath grouper per 1000 angler hours, while sustenance, family and novice fishers caught or released 2.4, 2.0 and 1.6 goliath per 1000 angler hours, respectively. In addition, skilled fishers caught or released a goliath (positive trip) on 4.9% of trips, while sustenance, family and novice fishers caught or released a goliath on 1.3%, 1.8% and 1.3% of trips, respectively. The factor SEASON was constructed from MONTH to create four periods generally reflective of water temperatures and rainfall in the shallow waters of ENP. Those periods were: December-February, March-May, June-August and September-November. The factor AREA used the ENP definitions which were intended to delimit different habitats (Fig. 1).

We used the delta lognormal model approach (Lo et al., 1992) to develop the standardized index of abundance. This method combines separate generalized linear modeling (GLM) analyses of the proportion of positive trips (PPT; trips that kept or released a goliath grouper / total trips) and the catch rates on positive trips to construct a single standardized CPUE index. Parameterization of each model was accomplished using a GLM procedure (GENMOD; Version 8.02 of the SAS System for Windows © 2000. SAS Institute Inc. Cary, NC, USA).

A forward stepwise regression procedure was used to determine the set of fixed factors and interaction terms that explained a significant portion of the observed variability. For both the binomial and lognormal components of the delta-lognormal model, deviance tables were constructed to determine the percentage of total reduction in deviance explained by the addition of each factor or interaction term (i.e. %Total reduction in deviance = 100*(reduction in residual deviance due to addition of factor/(residual deviance of null model – residual deviance of fully populated model)). Factors and interaction terms were selected for final analysis if: 1) the percent of deviance explained by adding the factor exceeded 5% and the χ^2 test was significant ($P \leq 0.05$). Fixed factors and interaction terms appear in the final models from highest to lowest explanatory power (highest to lowest % total deviance).

Once the set of fixed factors and interaction terms was identified, the influence of the YEAR*FACTOR interactions were examined. YEAR*FACTOR interaction terms were added to the mixed model as random effects if they explained at least 1% of the total deviance and the χ^2 and likelihood ratio tests (Littell et al., 1996) were significant ($P \leq 0.05$). The final delta-lognormal model was fit using the SAS macro GLIMMIX.

RESULTS

ENP records include more than 184,500 sport fishing trips within the park during the time series. Of these 6,630 observed a total of 13,607 goliath grouper. Length measurements are available for 419 goliath grouper landed within the park from 1974-2005 (Fig. 2). An unexpected peak occurs at 999 mm (n = 24) because ENP technicians record length only to 999 mm, therefore this represents a plus-group. The mean total length, excluding the plus-group, was 583 mm (SD±168 mm).

The length composition was examined for three time intervals, 1975-1979, 1980-1989 and 1990-2005. Unfortunately, measurements are too sparse after 1979 (n = 39) to permit strong statistical inference regarding changes in mean size over time. However, the available data does not support obvious changes in the size range of goliath grouper observed during the three time intervals.

The number of trips interviewed annually and the number of positive trips are summarized in Figures 3 and 4. In all areas of ENP, the proportion of positive trips declined from 1975-1990 (Fig. 5). In areas 3, 5 and 6, the decline was particularly notable. The nominal CPUE also declined in areas 3, 5 and 6 during 1975-1990 (Fig. 6). In other areas, nominal CPUE was generally low. The extreme value in 1978 in area 1 is based on only two trips that observed goliath. The proportion of positive trips and the nominal CPUE on positive trips began to increase throughout the park after 1990. In 2007, the proportion of positive trips and nominal CPUE were the highest ever recorded. Since then, the PPT and CPUE has generally declined (Figs 5-6).

The stepwise construction of the binomial model on proportion of positive trips is summarized in Table 2, and the construction of the lognormal model on catch rates of positive trips is described in Table 3. The mixed models, including YEAR*FACTOR interaction terms are shown in Table 4. Because the number of trips that caught goliath grouper in areas 1 and 2 was generally small, particularly in early years, these areas were combined for the purposes of index construction.

Factors that influenced the proportion of positive trips included year, area and season and skill. The proportion of positive trips was higher in areas 5 (7.5%) and 6 (4.1%) than in areas 3 (3.4%) and 4 (3.1%), and lowest in area 1&2 (0.9%). Goliath grouper were more likely to be observed in summer (4.7%) than in autumn (4%) or spring (3.3%), and they were least likely to be observed in winter (2.6%).

Factors that influenced catch rates (goliath landed or released / 1000 angler hours) on positive trips included year, skill and area and season. On average, catch rates on skilled fishing trips were 4.4 times as high as on other trips (8.0 versus 1.8). With regard to area, catch rates were higher in areas 5 (11.5) and 6 (7.3) than in areas 3 (4.5) and 4 (4.5). The lowest catch rates were observed in area 1&2 (1.3).

Various diagnostics were examined to evaluate the fit of each component of the delta-lognormal model, including distributions of residuals by factor, frequency histograms of the proportion of positive trips by model strata and QQ-plots of the deviation from the expected lognormal distribution. All diagnostic plots met our expectations, and supported an acceptable fit to the selected models (Appendix 1).

The delta-lognormal index shows a decline in the abundance of juvenile goliath grouper from 1976 to 1990. No index estimate was possible for the year 1974 because only one positive trip was reported. After the harvest moratorium in 1990, a significant increase in the abundance of juvenile goliath grouper is notable (Fig. 7). The uncertainty of the abundance index was quantified using 95% confidence intervals (Fig. 7) and coefficients of variation. The coefficients of variation ranged from 15% to 37%, and averaged 24% (Table 5). All index statistics including the proportion of positive trips, nominal CPUE, standardized CPUE and uncertainty estimates are summarized in Table 5.

DISCUSSION

The great majority (94%) of goliath grouper measured by ENP biologists were smaller than 1 m TL. According to Bullock et al. (1992), most goliath grouper reach sexual maturity at 1.15 to 1.35 m TL. These results confirm that most goliath grouper kept or released by sport fishermen in ENP are juveniles, and that ENP data are appropriate for the construction of an index of abundance for juvenile goliath grouper. This conclusion is further supported by Bullock and Smith (1991) who report that juvenile goliath grouper are predominately found in the estuarine and swamp mangrove habitats common in ENP.

Sport fishing trips that occurred in areas 5, 6 and 3 (Fig. 1) were more like to encounter goliath grouper, and had higher catch rates on positive trips. This result is not unexpected as these areas contain extensive estuarine and swamp mangrove habitats which are ideal for juvenile goliath grouper (Bullock and Smith, 1991; Koenig et al., 2008). Sport fishing trips in area 4 were less likely to observe goliath grouper and had lower catch rates on positive trips. These trips were likely to occur in Whitewater Bay, a habitat that is less ideal for juvenile goliath grouper. The lowest proportion of positive trips and catch rates on positive trips occurred in Florida Bay and its immediate surroundings (Area 2), suggesting that this may be a poor habitat for juvenile goliath grouper, which are known to prefer undercut banks and mangrove swamps.

The delta-lognormal index is quite similar to the nominal CPUE series and the annual trend in the proportion of positive trips. Each time-series indicates a substantial decline in abundance during the late 1970s and 1980s. During that time, rising demand for goliath grouper inflated selling prices, which led to a corresponding increase in landings and directed effort, particularly in the U.S. Gulf of Mexico (Sadovy and Eklund, 1999). Commercial landings of goliath grouper off the Florida Gulf Coast increased from 34,107 lbs in 1978 to 135,716 lbs in 1988, and then dramatically declined (Sadovy and Eklund, 1999). Index abundance estimates are uniformly low during the 1980s, consistent with reports of diminished populations at aggregation sites (DeMaria[8]).

Since the 1990 moratorium, which prohibited landing goliath grouper in U.S. Federal and State of Florida waters, abundance estimates suggest that populations of juvenile goliath grouper have increased appreciably within ENP. Particularly large numbers of juveniles are noted during 1995, 1996 and 2004-2007, suggesting that one or more strong year classes were present during those years. These results are consistent with additional indices described by Porch and Eklund (2004). They constructed indices for goliath grouper using visual survey data, and reported similar increases after 1990, with the highest abundances occurring after 1997. These indices have not been updated since publication. Since these surveys monitored the reef and wreck habitats typically occupied by adults, it is not inconsistent that maximal abundances occurred after 1997. A short delay is anticipated as juvenile fish mature, and later migrate to adult territory.

Since 2007, this study suggests that the abundance of juvenile goliath grouper has declined substantially. At this time, it is not clear if this decline is reflected in other data sources or studies. This result suggests that the large year classes that were present in ENP in the early 2000s have since diminished in abundance through mortality (e.g. cold kills, red tide events) or that the animals have matured and moved into adult habitat outside ENP, and that more recent year classes have not replaced these losses.

The results of this study suggest that the abundance of juvenile goliath grouper within ENP has increased considerably since the 1990 harvest moratorium. This conclusion is further supported by the research of Koenig et al., 2008. They determined the density of juvenile goliath grouper at selected sampling sites within ENP and the Ten Thousand Islands region, then

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estimated the total abundance of juveniles in the region by extrapolating their density across the total area of suitable habitat. They estimated that 71,000 juveniles were present within the analysis region. This number may underestimate the total abundance of juvenile goliath grouper if the range of appropriate habitat extends beyond ENP and the Ten Thousand Islands area. However, the number may be an overestimate if the habitat within the region is, on average, less suitable than the selected sampling sites.

It is unlikely that the ENP indices solely reflect trends in abundance. Goliath grouper appear to be hardy animals with low release mortality. Tagging studies in ENP have recaptured juvenile goliath grouper up to eight times without mortal injury (Schull[9]). As goliath grouper increase in abundance within ENP, it may be more likely that fishermen target certain sites known to be inhabited by a resident goliath grouper. If certain individuals are repeatedly targeted by fishermen, estimates of abundance would be inflated. It is not known how often this fishing behavior occurs, or whether the likelihood of this type of fishing has varied through time. Indices of abundance would only be affected if the likelihood has varied substantially and systematically though time. This could be an important topic for future research.

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Table 1. Description of factors.

Factor	**Levels**	**Description**
YEAR	36	1973, 1975-2009
SKILL	2	Skilled = "Skilled" Other = Novice + Sustenance + Family
AREA	5	See Fig. 1 (Areas 1&2 were combined)
SEASON	4	Winter = December-February Spring = March – May Summer = June – August Autumn = September - November

Table 2. Deviance table for the binomial model (1973-2009). Factors were added to the model if they accounted for at least 1% of the total reduction in deviance and were significant according to a χ^2 test ($P \leq 0.05$). Terms added are indicated in bold italics.

GENMOD (FIXED-FACTOR) OUTPUT

Binomial Model Factors - Proportion Positive	DF	DF	Residual Deviance	Reduction in Deviance	% of Total Deviance	Log Like	Chi Square	P
Null	1	184682	57148.8	-	-	-28574.4	-	-
Year	35	184647	50865.9	6282.9	***67.9***	-25432.9	6282.9	***<0.001***
Year + ***Area***	4	184643	49159.0	1706.8	***18.5***	-24579.5	1706.8	***<0.001***
Year + Area + ***Season***	3	184640	48801.9	357.1	***3.9***	-24401.0	357.1	***<0.001***
Year + Area + Season + ***Skill***	1	184639	48507.0	294.9	***3.2***	-24253.5	294.9	***<0.001***
Year + Area + Season + Skill + Area*Skill	4	184635	48435.7	71.3	0.8	-24217.9	71.3	<0.001
Year + Area + Season + Skill + Area*Skill + Season*Area	12	184623	48402.5	33.3	0.4	-24201.2	33.3	0.001
Year + Area + Season + Skill + Area*Skill + Season*Area + Season*Skill	3	184620	48399.8	2.6	0.0	-24199.9	2.6	0.451
Year + Area + Season + Skill + Area*Skill + Season*Area + Season*Skill + ***Year*Season***	105	184515	47950.5	449.3	***4.9***	-23975.3	449.3	***<0.001***
Year + Area + Season + Skill + Area*Skill + Season*Area + Season*Skill + Year*Season + Year*Skill	35	184480	47901.1	49.4	0.5	-23950.6	49.4	0.054

Final Model: PPT = Year + Area + Season + Skill + Year*Season

Table 3. Deviance table for the lognormal model (1973-2009). Factors were added to the model if they accounted for at least 1% of the total reduction in deviance and were significant according to a χ^2 test ($P \leq 0.05$). Terms added to the model are indicated in bold italics.

Lognormal Model Factors - CPUE

Lognormal Model Factors - CPUE	DF	DF	Residual Deviance	Reduction in Deviance	% of Total Deviance	Log Like	Chi Square	P
Null	1	6523	4055.0	-	-	-7706.0	-	-
Year	34	6489	3901.5	153.6	***47.0***	-7580.0	251.86	***<0.001***
Year + ***Skill***	1	6488	3870.2	31.3	***9.6***	-7553.8	52.55	***<0.001***
Year + Skill + ***Area***	4	6484	3845.0	25.2	***7.7***	-7532.5	42.62	***<0.001***
Year + Skill + Area + ***Season***	3	6481	3824.1	20.9	***6.4***	-7514.7	35.52	***<0.001***
Year + Skill + Area + Season + ***Area*Skill***	4	6477	3809.4	14.7	***4.5***	-7502.2	25.07	***<0.001***
Year + Skill + Area + Season + Area*Skill + Season*Skill	3	6474	3806.1	3.3	1.0	-7499.3	5.65	0.13
Year + Skill + Area + Season + Area*Skill + Season*Skill + Season*Area	12	6462	3799.5	6.6	2.0	-7493.7	11.34	0.5
Year + Skill + Area + Season + Area*Skill + Season*Skill + Season*Area + Year*Season	89	6373	3741.3	58.2	17.8	-7443.3	112.04	0.213
Year + Skill + Area + Season + Area*Skill + Season*Skill + Season*Area + Year*Season + Year*Skill	34	6339	3728.1	13.2	4.0	-7431.8	23.04	0.923

Final Model: log(CPUE) = Year + Skill + Area + Season + Area*Skill

Table 4. Analysis of mixed model formulations for the binomial model on the proportion of positive trips (1973-2009). The likelihood ratio test was used to test the difference in -2 REM log likelihood between two nested models. The final model is indicated with bold italics.

ANALYSIS OF MIXED MODEL FORMULATIONS

Proportion Positive	-2 REM Log likelihood	Akaike's Information Criterion	Schwartz's Bayesian Criterion	Likelihood Ratio Test	P	Scaled Deviance	Dispersion
Year + Area + Season + Skill	4022.0	4024.0	4029.3	-	-	1388.48	1.69
Year + Area + Season + Skill + Year*Season	**3955.6**	**3959.6**	**3965.5**	**66.4**	**<0.0001**	**1360.68**	**1.47**

Table 5. Abundance index statistics including nominal CPUE (goliath / 1000 angler hours), number of trips interviewed, proportion positive trips (PPT), standardized CPUE, upper and lower 95% confidence intervals and coefficients of variation (CV).

YEAR	Nominal CPUE	TRIPS	PPT	Rel Index	Lower 95% CI	Upper 95% CI	CV
1973	2.461	3861	0.02797	0.78819	0.49661	1.25098	0.23409
1974	0						
1975	2.485	4467	0.02373	0.40779	0.25116	0.66211	0.24593
1976	5.828	3552	0.05293	1.27542	0.85619	1.89994	0.20127
1977	4.801	4240	0.04363	0.86734	0.57974	1.2976	0.20348
1978	5.333	3649	0.04056	0.91079	0.59486	1.3945	0.21543
1979	3.27	2296	0.02831	0.61987	0.35953	1.06871	0.27748
1980	3.771	4161	0.02788	0.66362	0.42088	1.04637	0.23067
1981	1.907	5787	0.01572	0.38802	0.23817	0.63212	0.2477
1982	1.467	5440	0.00956	0.28677	0.15993	0.51418	0.29829
1983	1.148	6233	0.01027	0.26475	0.15251	0.45957	0.28109
1984	0.861	7808	0.00768	0.2301	0.13165	0.40218	0.28472
1985	0.615	6748	0.00519	0.14015	0.07111	0.2762	0.34921
1986	0.543	7765	0.00489	0.13479	0.0697	0.26066	0.33894
1987	0.459	6615	0.00454	0.10484	0.0512	0.21469	0.37019
1988	0.724	4123	0.00752	0.1398	0.06881	0.28401	0.36583
1989	1.567	3944	0.01851	0.30095	0.17773	0.50961	0.26798
1990	0.996	6422	0.00934	0.1558	0.08852	0.27424	0.28844
1991	1.006	5377	0.0093	0.17418	0.09567	0.31712	0.30645
1992	1.133	5816	0.01118	0.23787	0.13642	0.41477	0.28347
1993	1.75	6100	0.01623	0.25947	0.15983	0.42124	0.24588
1994	4.375	7076	0.03392	0.68509	0.46564	1.00796	0.19488
1995	7.29	5266	0.03988	1.07861	0.72533	1.60395	0.20037
1996	8.824	7084	0.04644	1.16931	0.81348	1.68078	0.18292
1997	4.895	7854	0.03119	0.71318	0.48385	1.05122	0.19582
1998	3.537	6238	0.0234	0.53169	0.34502	0.81936	0.21878
1999	3.811	5766	0.02359	0.55115	0.35574	0.8539	0.22156
2000	4.238	5540	0.0287	0.79369	0.52089	1.20937	0.21294
2001	4.755	5525	0.03566	0.71494	0.47851	1.06819	0.2028
2002	5.465	4588	0.04228	0.73732	0.49235	1.1042	0.204
2003	14.357	4177	0.08906	1.86283	1.31286	2.64319	0.17629
2004	14.158	4319	0.08984	1.97697	1.39912	2.79347	0.17416
2005	16.676	3352	0.10292	2.31596	1.63334	3.28388	0.17594
2006	28.377	3547	0.1497	3.54136	2.56247	4.8942	0.16283
2007	36.405	3807	0.19359	5.18082	3.84717	6.97679	0.14964
2008	27.521	3197	0.14232	3.5495	2.55093	4.93898	0.16631
2009	18.234	2943	0.0965	2.24707	1.56085	3.23499	0.18372

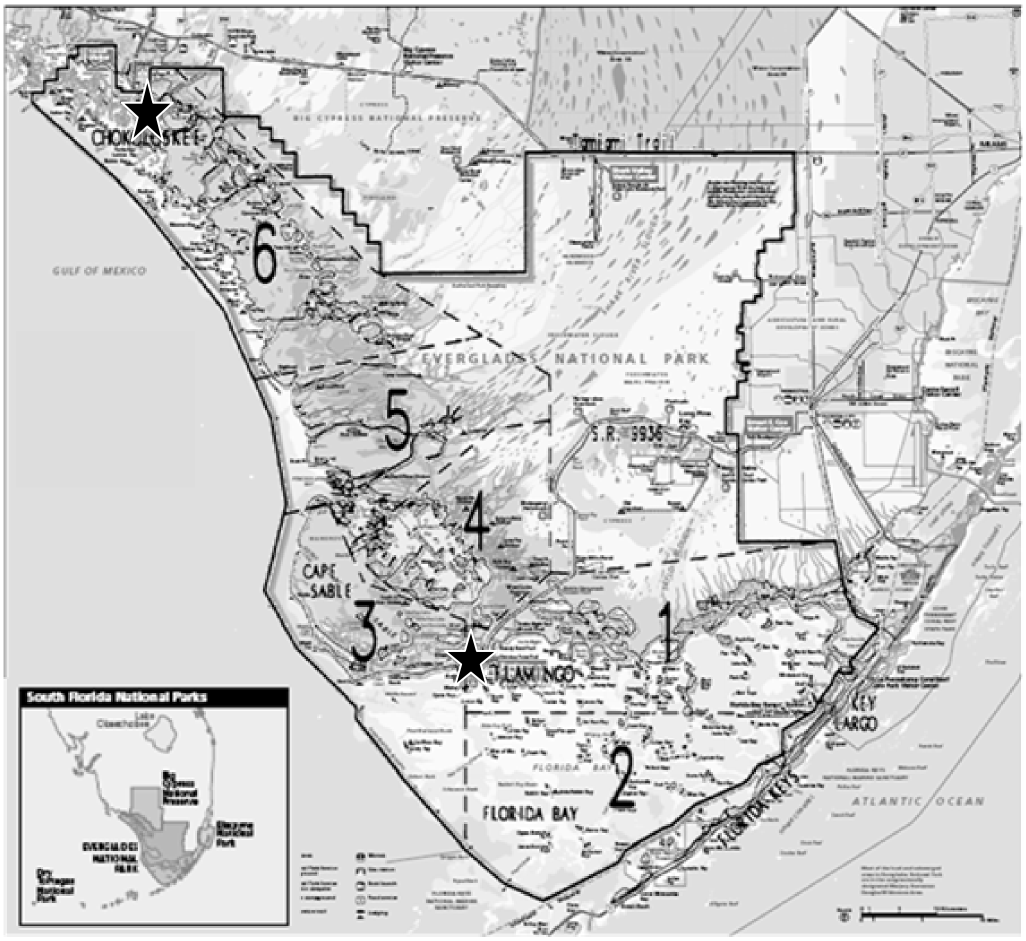

Figure 1. A map of Everglades National Park depicting the defined fishing areas (Schmidt et al., 2002). The Chokoloskee and Flamingo boat ramps are indicated with black stars. The Ten Thousand Islands area is located to the north and west of Chokoloskee, partially within Area 6.

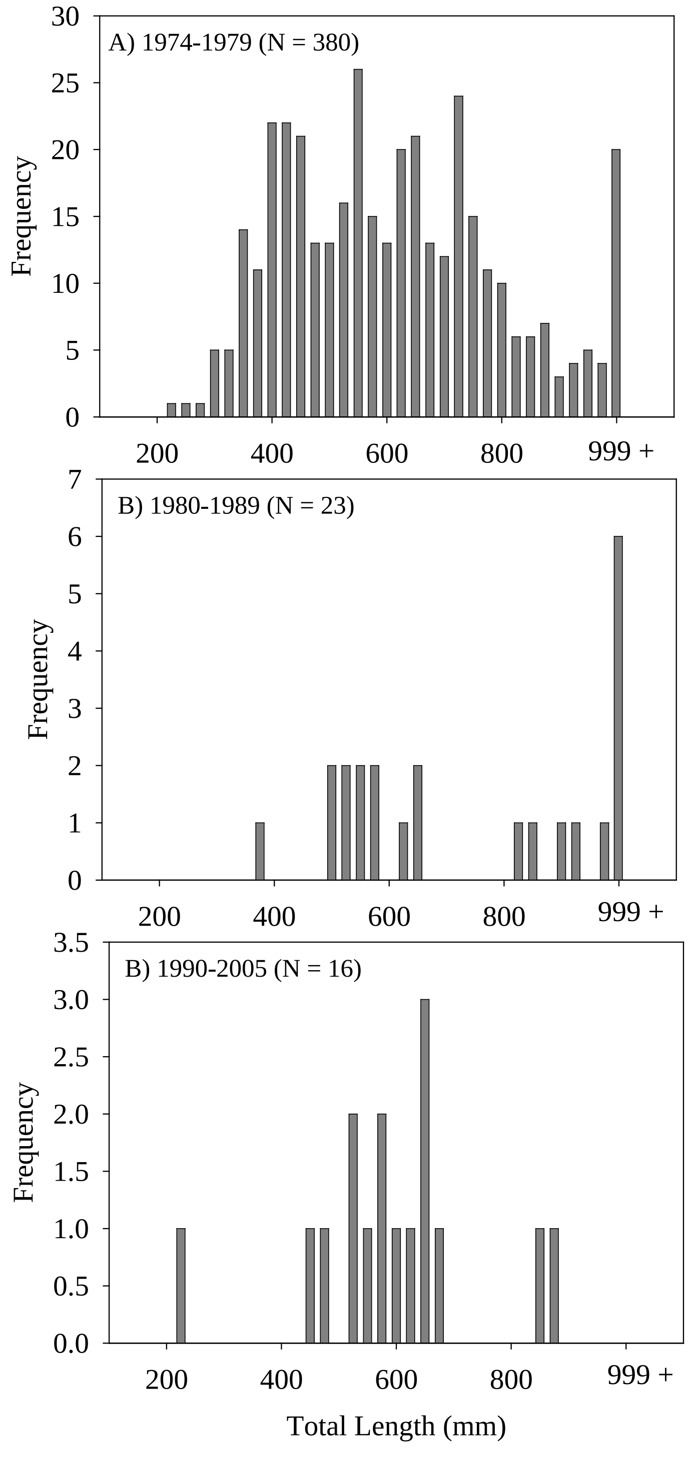

Figure 2. The length frequency of goliath grouper captured in ENP from A) 1974-1979 , B) 1980-1989 and C) 1990-2005.

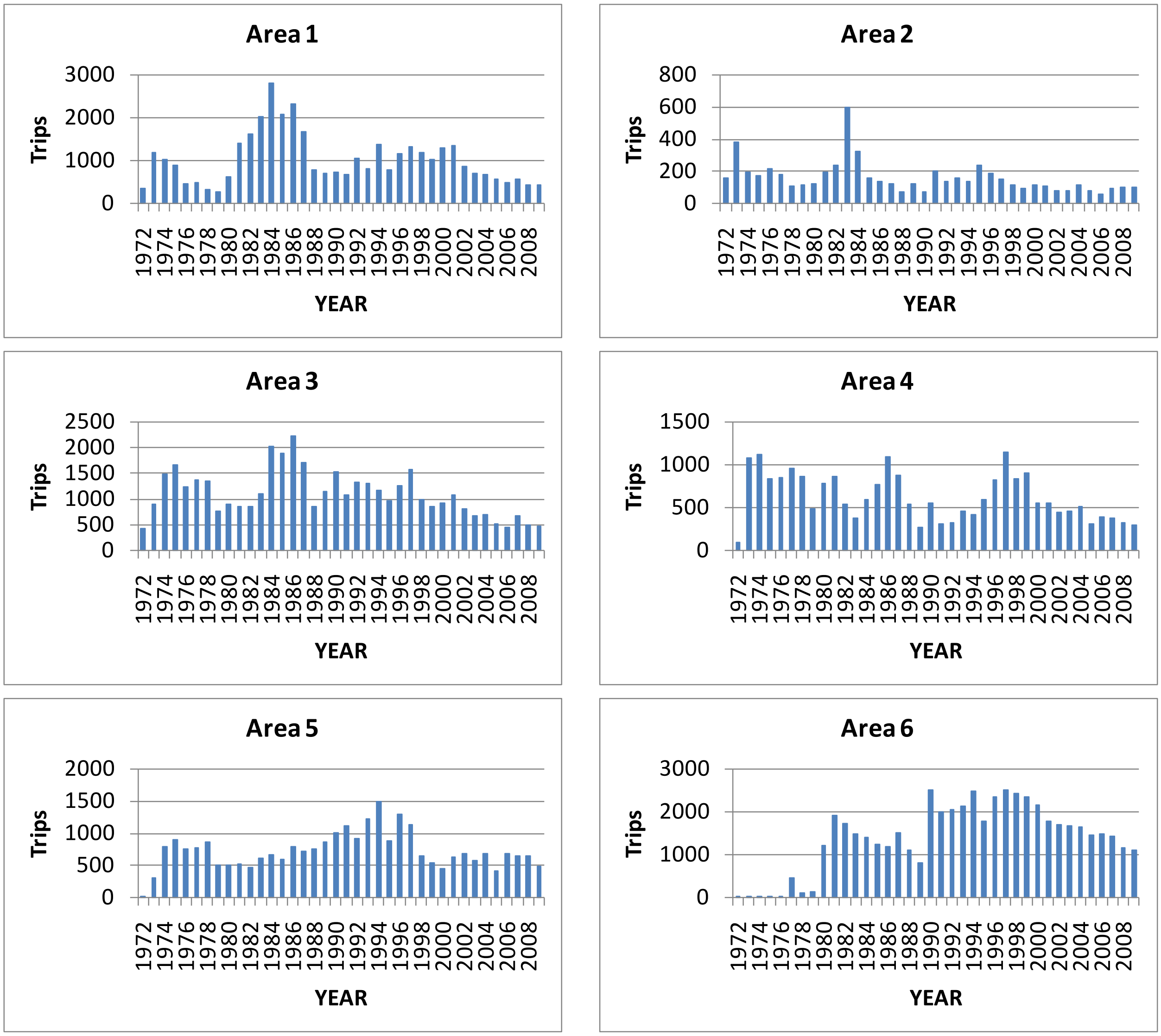

Figure 3. Annual trend in the number of trips in ENP, by area.

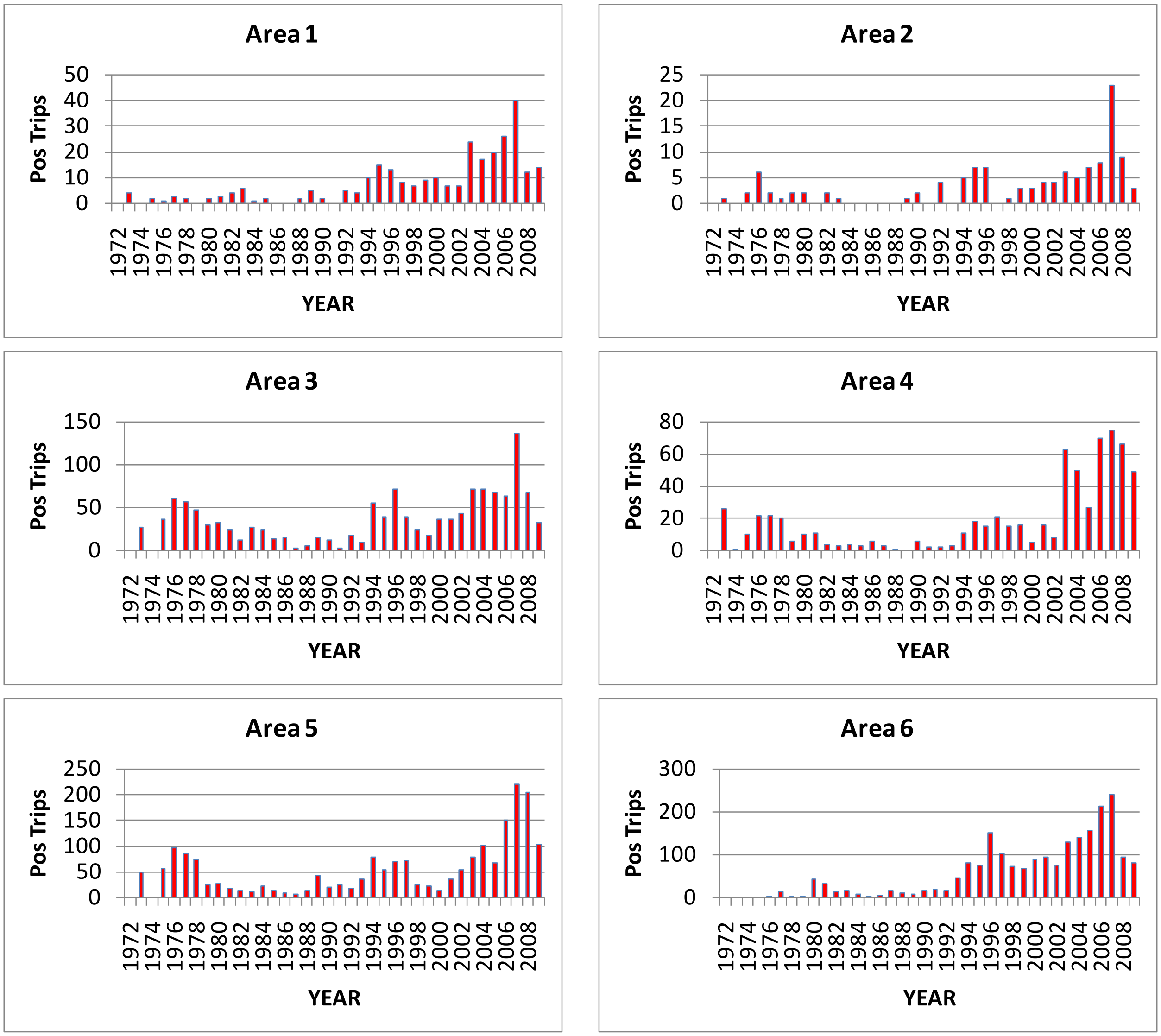

Figure 4. Annual trend in the number of positive trips in ENP, by area.

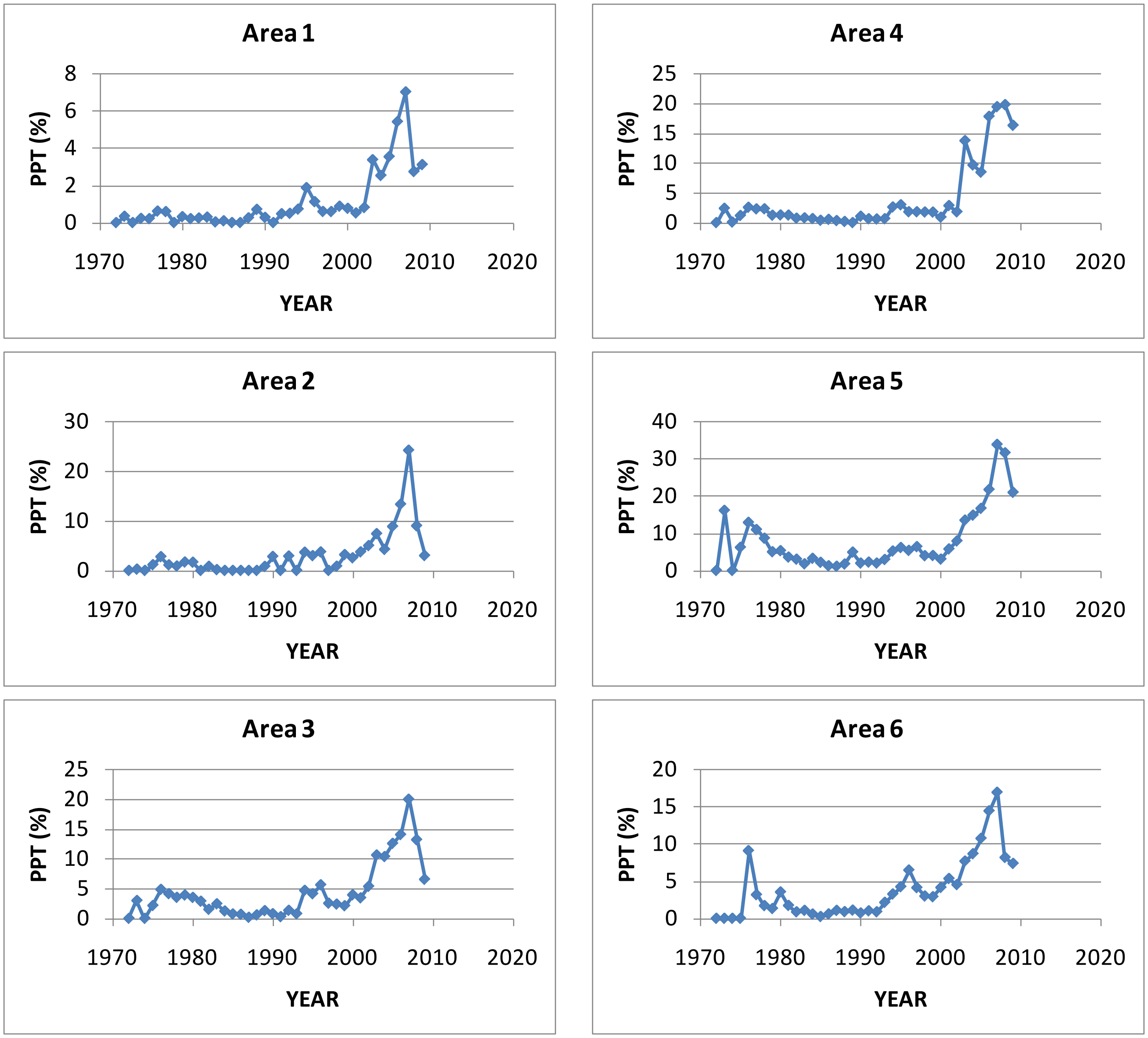

Figure 5. Annual trends proportion of positive trips by fishing area.

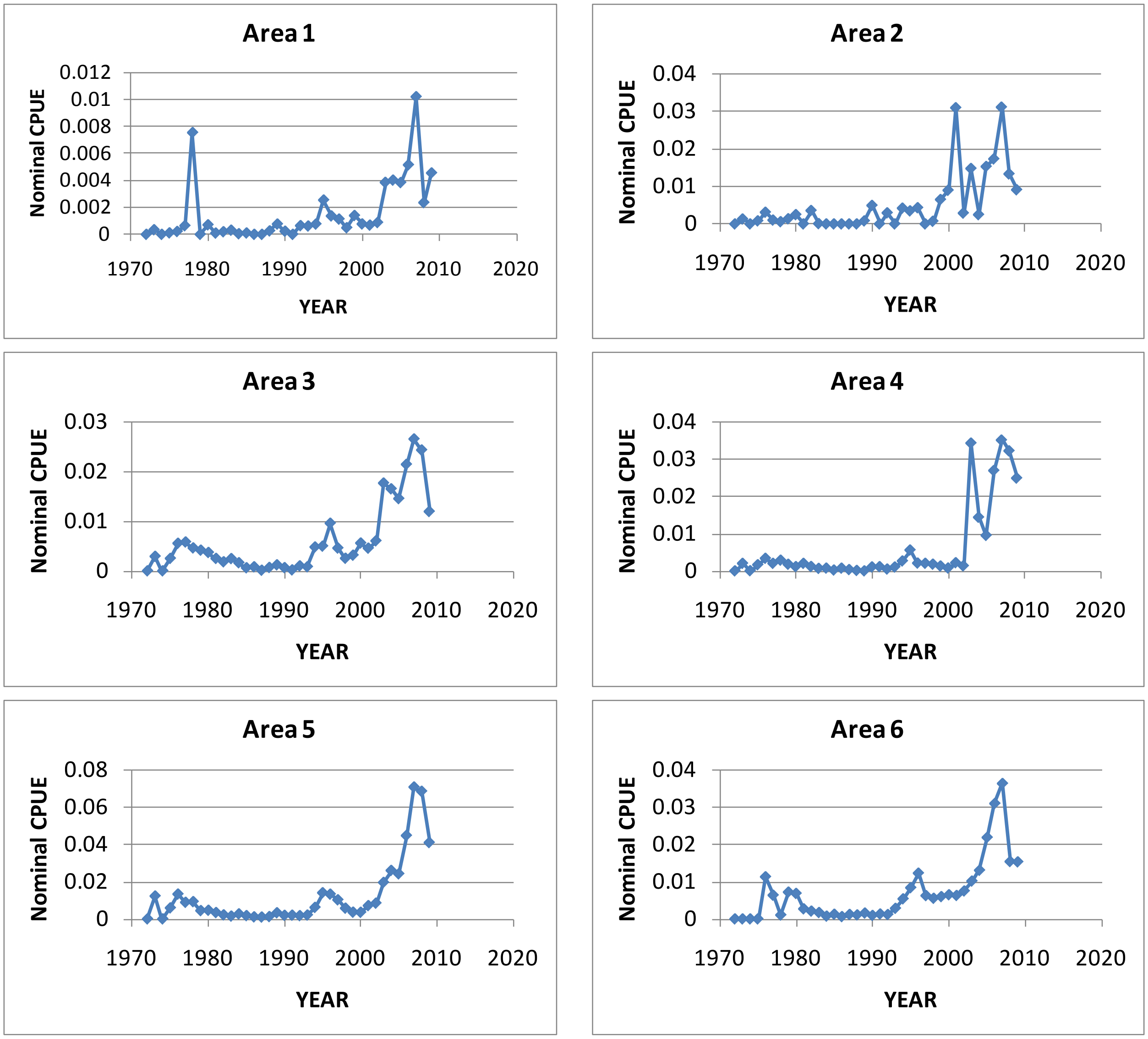

Figure 6. Annual trends in the nominal CPUE. Nominal CPUE is the average annual catch per unit effort before standardization.

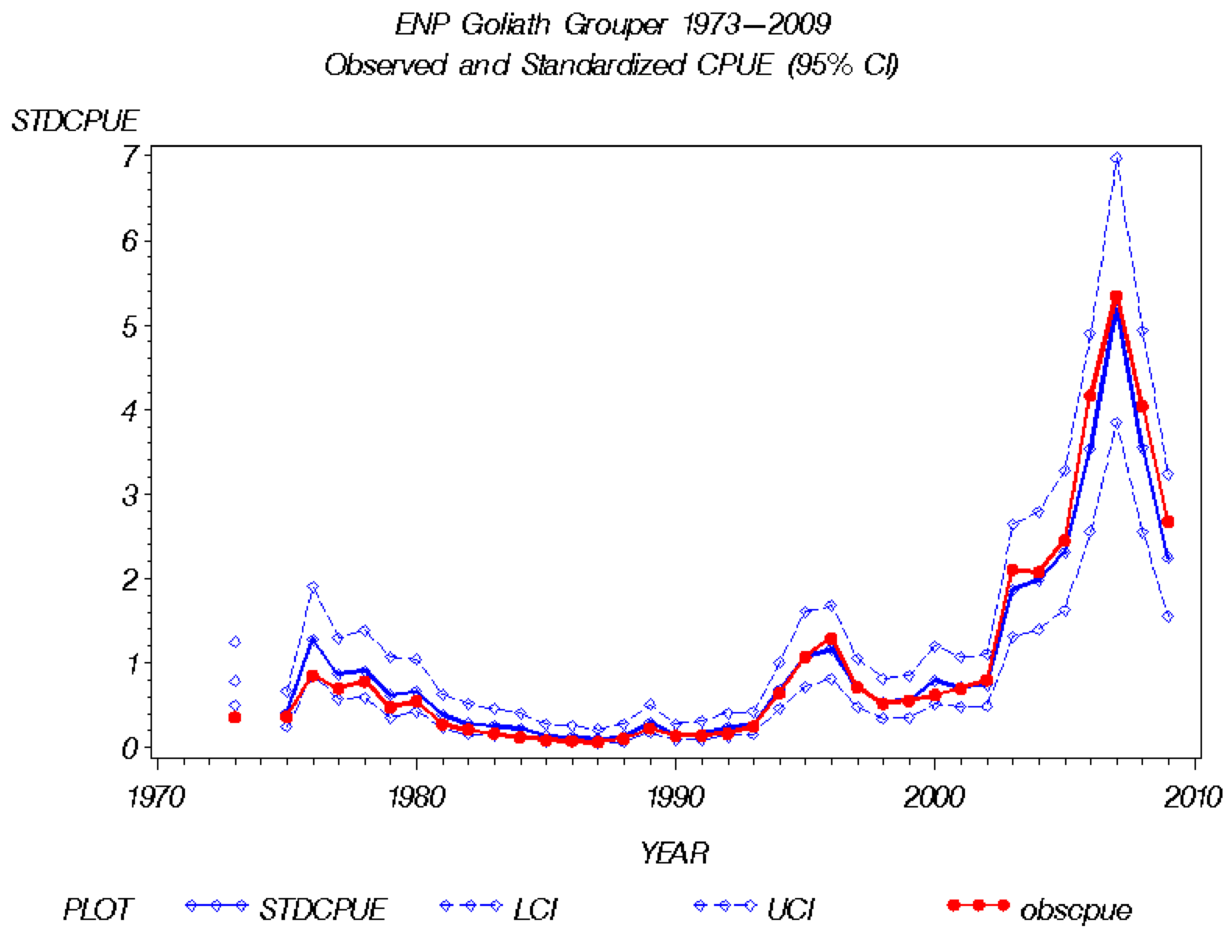

Figure 7. The nominal (red) and standardized catch per unit effort during 1973-2009 (solid red). Nominal CPUE is the average annual catch per unit effort before standardization. Both series have been scaled to their respective means. The dashed blue lines are the upper and lower 95% confidence limits for the standardized CPUE estimates.

APPENDIX 1:

Model Diagnostics.

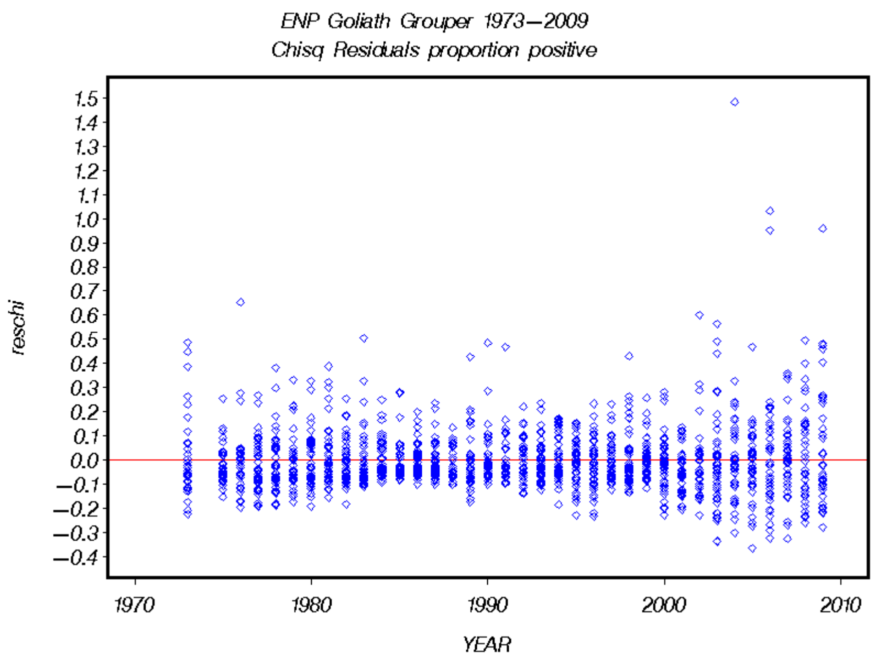

Figure A1. Chi-square residuals for the binomial model on proportion positive trips, by year.

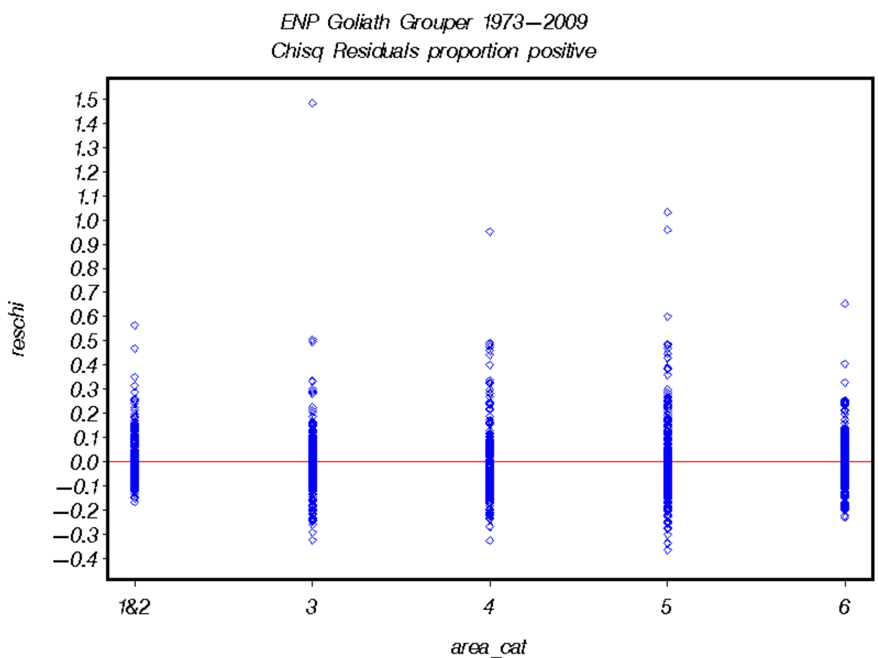

Figure A2. Chi-square residuals for the binomial model on proportion positive trips, by area.

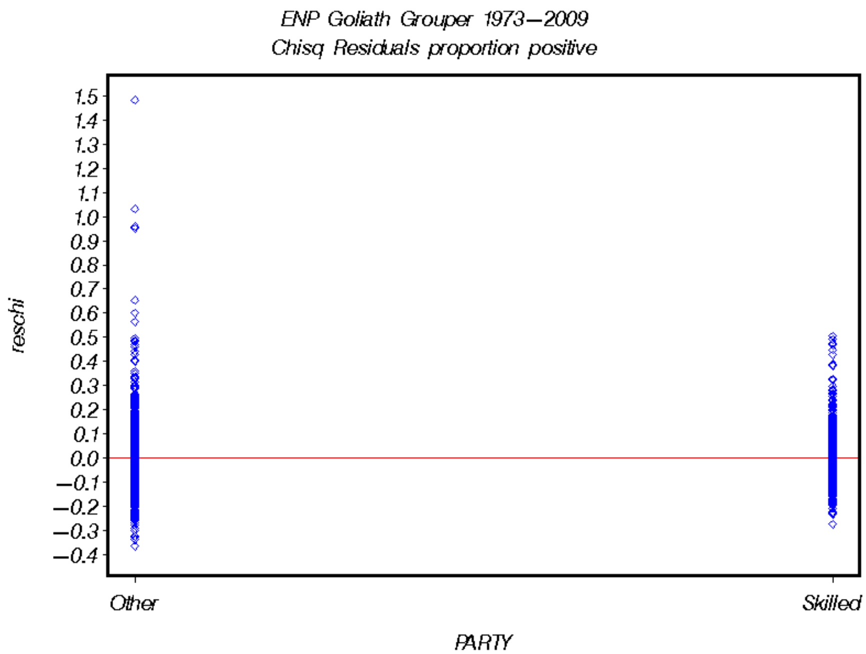

Figure A3. Chi-square residuals for the binomial model on proportion positive trips, by fisher skill level.

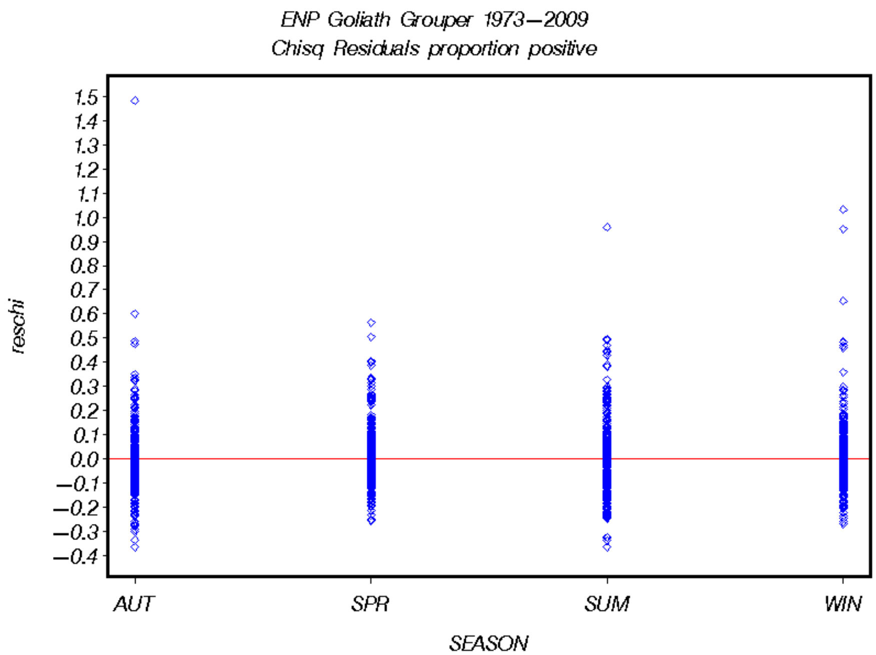

Figure A4. Chi-square residuals for the binomial model on proportion positive trips, by season.

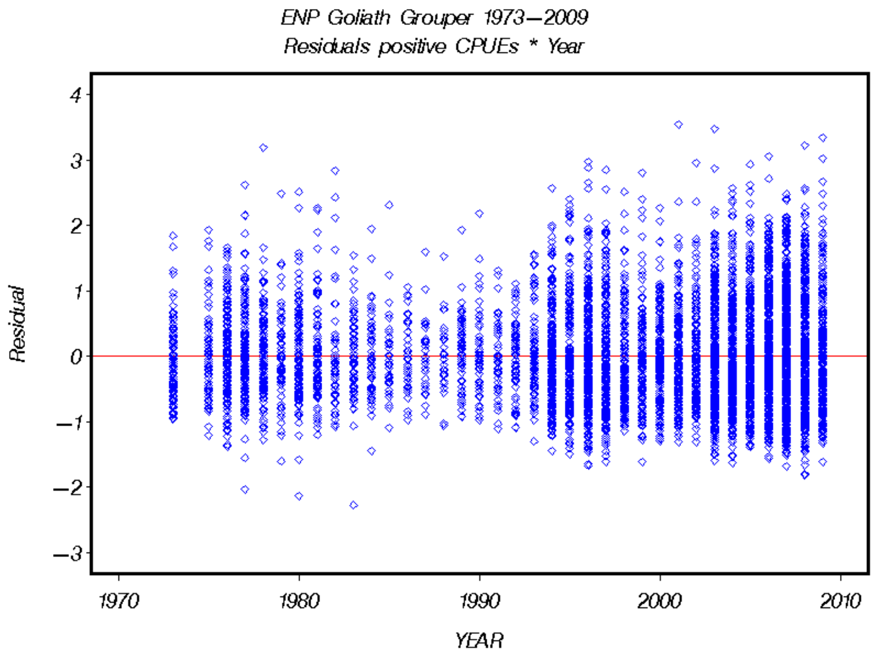

Figure A5. Residuals for the lognormal model on catch rates of positive trips, by year.

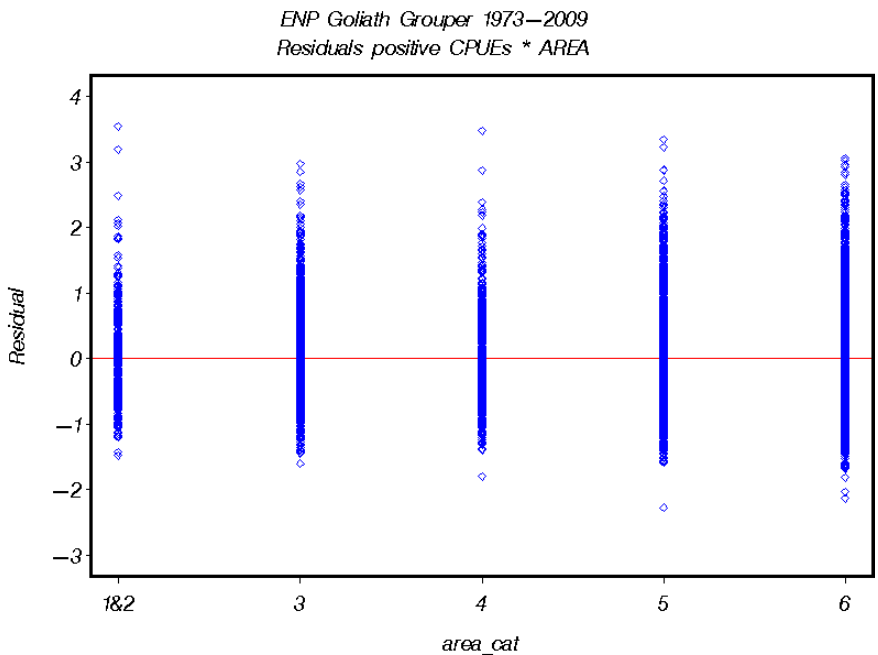

Figure A6. Residuals for the lognormal model on catch rates of positive trips, by area.

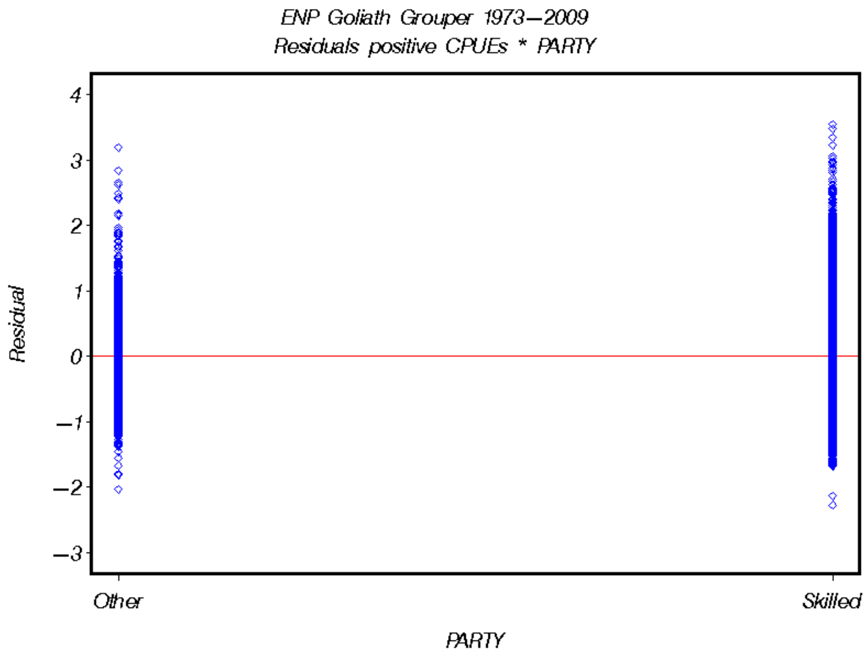

Figure A7. Residuals for the lognormal model on catch rates of positive trips, by fisher skill level.

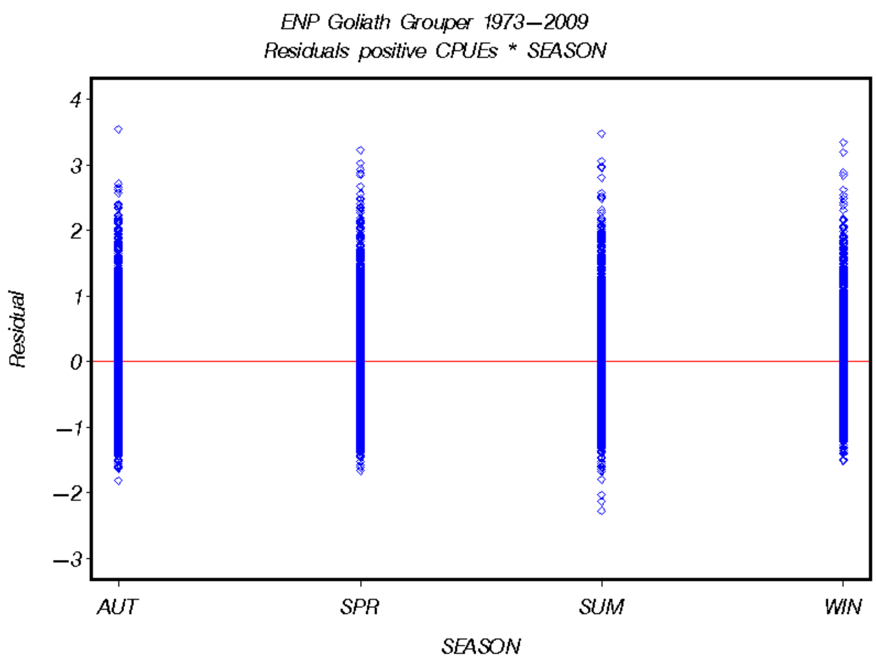

Figure A8. Residuals for the lognormal model on catch rates of positive trips, by season.

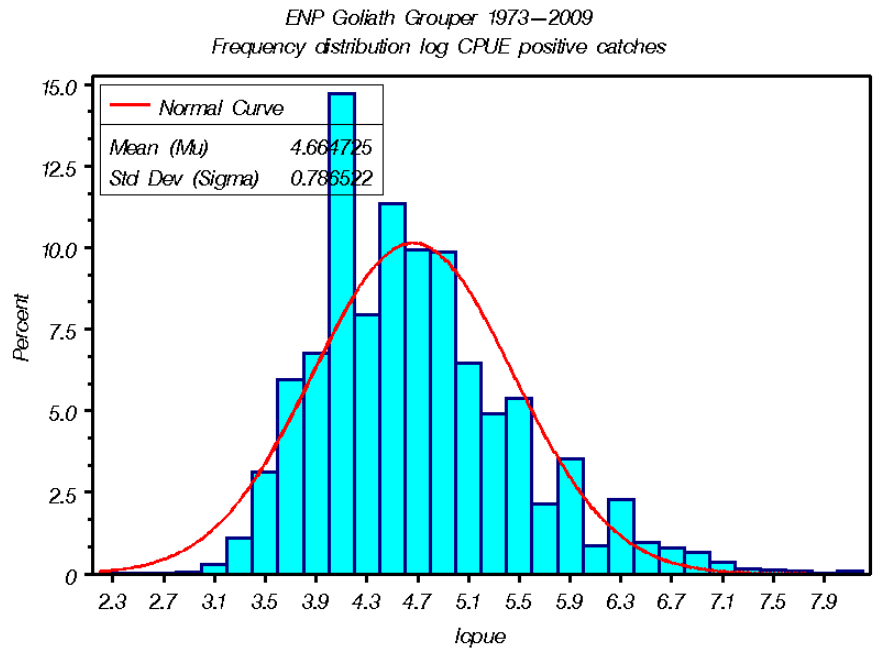

Figure A9. Frequency distribution of log (CPUE). The red line is the assumed normal distribution.

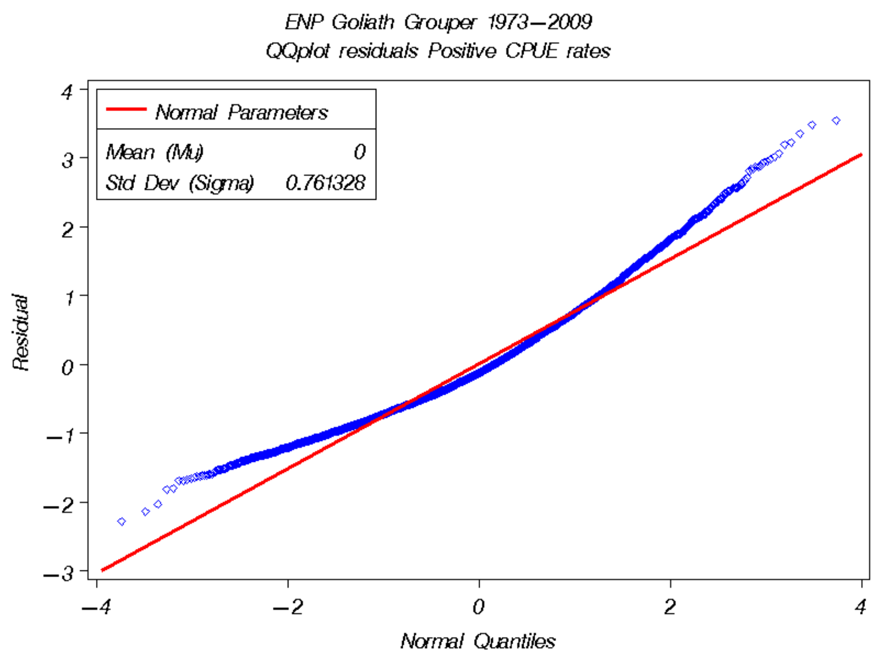

Figure A10. QQ-Plot of the fit to the lognormal model. The red line is the assumed normal distribution. There is some departure from the assumed distribution, particularly at the extremes.