NOAA TECHNICAL MEMORANDUM

NMFS-SEFSC-359

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BY

W. N. Witzell

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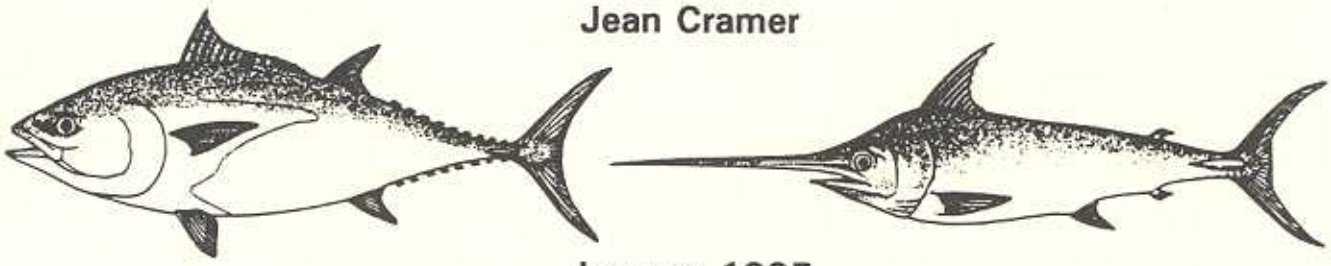

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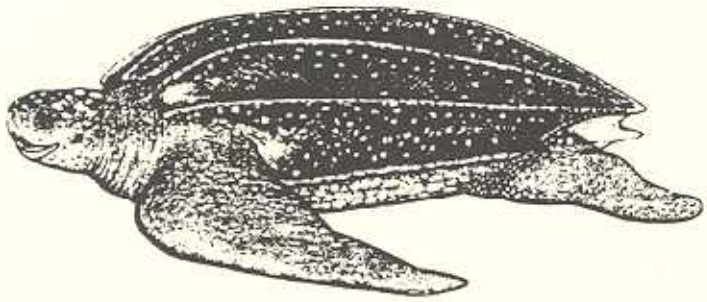

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U.S. DEPARTMENT OF COMMERCE
Ronald H. Brown, Secretary

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
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INTRODUCTION

Pelagic longlines consist of a mainline that is held horizontally at a set depth in the water column by floats with a series of baited hooks hanging vertically, typically targeting species are swordfish (*Xiphias gladius*) and tuna (*Thunnus* spp.). The gears are essentially the same for both except that swordfish fish at night, preferably during a full moon, using chemical light sticks 1-3m above the baited hooks and tuna vessels fish during the day without light sticks. The Japanese bluefin tuna fleet fished in the U.S. Gulf of Mexico and Atlantic waters from the late 1970'S to the mid-1980's (Lopez et al., 1979; Thompson, 1982; Reese, 1983), and then moved fishing operations off the U.S. mid-Atlantic coast. Since then, the U.S. pelagic longline fishery for tuna and swordfish has increased in effort and expanded geographically throughout the western North Atlantic Ocean. The U.S. North Atlantic longline fisheries have been previously described (Berkeley et al., 1981; Hoey, 1983; Hoey and Bertolino 1988; Hoey and Casey, 1988; Hoey et al. 1988; Yao, 1988; Podesta et al., 1993).

The longline fishery for large pelagic fish incidentally captures threatened and endangered sea turtles, these turtles either ingesting the baited hooks or becoming entangled and/or hooked externally. The incidental capture of sea turtles by pelagic longline vessels was first examined for the Atlantic and Gulf Japanese tuna fleet by Witzell (1984). Other researchers have reported turtles incidentally captured in various longline fisheries, but there has been an overall lack of detailed analysis: Atlantic (Witzell, 1984, 1994; Bolten et al., 1994); Mediterranean (De Metrio et al., 1983; De Metrio and Megalofonou, 1988; Caminas, 1988; Gramentz, 1989; Panou et al., 1991, 1992; Argano et al., 1992; Aguilar et al., (1992); Pacific (Nishemura, 1990; Balazs and Pooley, 1994). The data reported in these studies indicates sea turtle catch and mortality rates differ significantly between the various longline fisheries, and this is because fishing strategies change temporally and spatially depending on target species, and depending upon annual changes in sea turtle distribution and abundance.

Proper analysis and interpretation of by-catch data from these individual longline fisheries are necessary when formulating recovery and management strategies as mandated by the Endangered Species Act of 1973 and subsequent amendments. This report examines the reported and observed catch rates of sea turtles by the U.S. longline fleet in the western North Atlantic Ocean.

MATERIALS AND METHODS

The data used in this analysis are from the National Marine Fisheries Service (NMFS) Mandatory Pelagic Logbook Program and the Southeast Fisheries Science Center (SEFSC) and Northeast Fisheries Science Center Pelagic Observer Programs. The logbook program was initiated in 1991 and requires all U.S. Atlantic vessels landing swordfish to report daily catch and effort data (Cramer 1993, 1994), and sea turtle by-catch information was added in 1992. The Pelagic Observer Program (PLOP) was initiated by the NMFS Northeast Fisheries Science Center (NEFSC) and SEFSC in 1991 and 1992, respectively, and requires observers to be placed randomly on selected vessels. The observer program has collected catch and effort information on protected species since its inception, and the data from both (NEFSC and SEFSC) observer programs are combined for this analysis. The logbook and observer data sets were analyzed by geographic region (Figure 1).

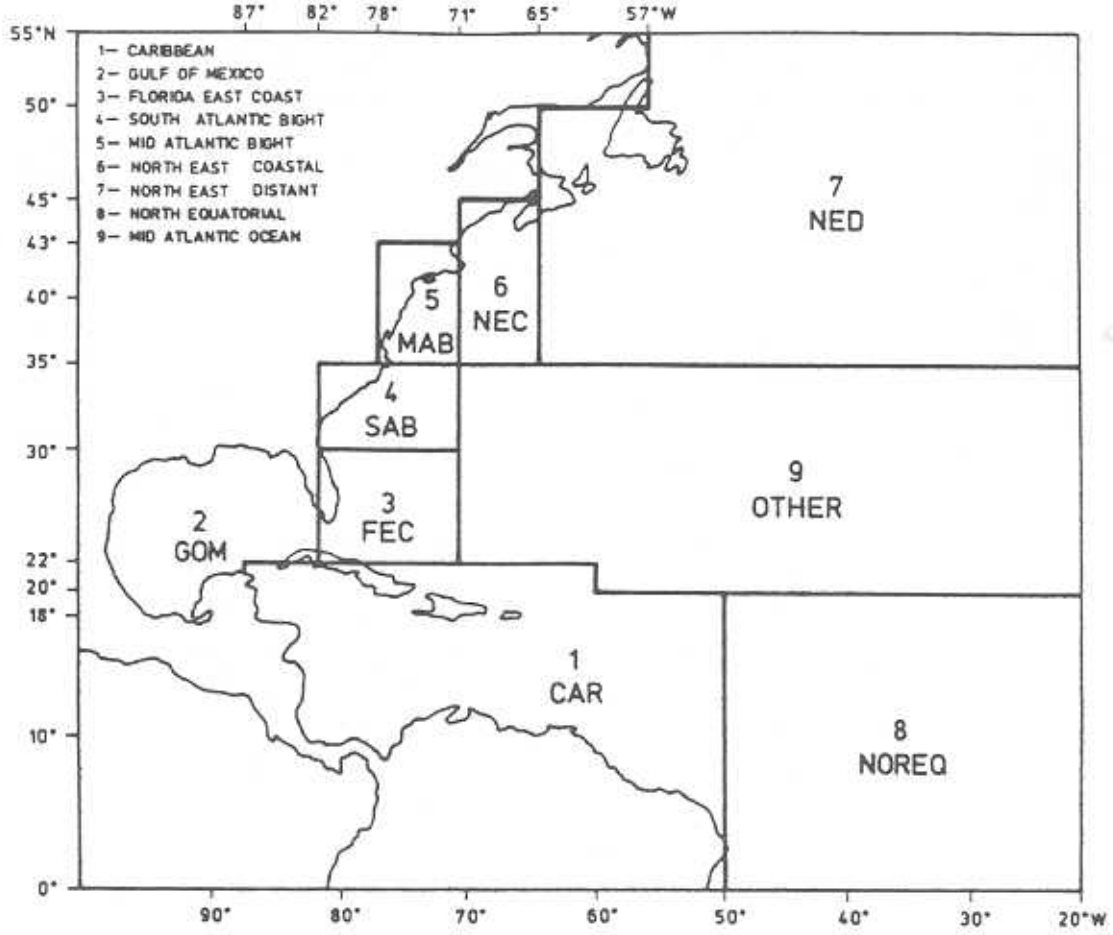

Figure 1. The fishing area definitions used to classify the U.S. Atlantic pelagic longline effort.

General linear model (GLM) techniques, based on the Poisson distribution error assumption, as proposed by Miyabe (SCRS/94/101) and Nakano (SCRS/94/141), were used estimate the number of interactions of turtles with U.S. longline gear. Wald 95% confidence intervals were estimated based on standard normal distributions (SAS Institute Inc.).

Estimated frequency of interactions of all turtles, leatherback turtles, and hard shelled turtles with the U.S. pelagic longline gear were based on Observer data (OBS). Mandatory self reported logbook data (LB) provided effort estimates in numbers of sets. Model variables included **area** (Caribbean (CAR), Gulf of Mexico (GOM), Florida East Coast (FEC), South Atlantic Bight (SAB), Mid Atlantic Bight (MAB), Northeast Coastal (NEC), and Northeast Distant (NED), **source** (OBS/LB), **light** sticks (present/absent), and **depth** of gear. The following model was used in all analyses.

Ln(turtles involved) = area source light depth

Estimates for leatherback turtles in the Gulf of Mexico were made separately from other areas because the model would not converge when all areas were included. Estimates for turtles killed were not made because there were too few data points to achieve and adequate fit.

Species identifications in the logbook and observer data were probably incorrect, and were subsequently edited to include only leatherback (*Dermochelys coriacea*) and loggerhead (*Caretta caretta*) turtles (Table 1). These two species commonly inhabit all waters currently fished by the U.S. pelagic longline fleet, and it is felt that the few hawksbill (*Eretmochelys imbricata*), green (*Chelonia mydas*), and Kemp's ridley (*Lepidochelys kempi*) sea turtles reported by observers and boat captains were probably incorrect because of unlikely distributions and feeding preferences. Photographic evidence also provided evidence of misidentifications regarding these three species. Large hawksbill and green turtles are tropical spongivores and sub-tropical herbivores, respectively, that would be unlikely to be found in the temperate pelagic longline environment, and therefore not likely to consume longline baits or become entangled in the branchlines (Witzell, 1983). Stranding (Teas, 1993) and aerial survey data (Shoop and Kenny, 1992) reflect the tropical nature of these species. Kemp's ridley turtles are small subtropical-temperate carnivores that feed on coastal crustaceans (Marquez, 1994). However, juvenile loggerheads, and an occasional Kemp's ridley, apparently travel the North Atlantic Gyre to the Azores and Canary islands (Bolten et al. 1994) and Europe (Brongersma, 1971, 1981), and it is possible, although unlikely, that specimens could occasionally be taken by U.S. longlines. Consequently, these few turtles originally identified as green, ridley, and hawksbill were combined and listed as loggerhead turtles for this analysis.

RESULTS

A total of 94 leatherback and 44 loggerhead turtle captures were reported by NMFS observers, and 598 leatherback and 243 loggerhead turtle captures were reported in the logbooks for 1992 and 1993 combined (Table 1). Of these turtles, only one leather back and two loggerheads were observed dead, and only one loggerhead was reported dead. This low mortality may be indicative of swordfish, yellowfin, and bigeye tuna longline gears that are lighter and set shallower than the heavy and deeper-set Japanese bluefin tuna gear (Witzell, 1984), and results in fewer drowned turtles.

Table 1. Sea turtle captures reported from the 1992 - 1993 NMFS logbook and observer programs from the western north Atlantic Ocean.

YEAR	SOURCE	NUMBER SETS	LEATHERBACK	LOGGERHEAD
1992	OBSERVER	329	28	18
1992	LOGBOOK	13,846	356	123
1993	OBSERVER	817	66	26
1993	LOGBOOK	14,357	242	116

Observer comments were reviewed to determine whether the turtles were entangled, hooked externally, or hooked in the mouth. Comments regarding 27 observed loggerheads revealed that 25 were hooked in the mouth and 2 were hooked externally. Of the 25 turtles hooked in the mouth, one was hooked twice and another was hooked three times, indicating that some hooked turtles can survive and continue to actively feed, at least for a while. Aguilar et al. (1992) also noted multiple recaptures of loggerheads in the western Mediterranean Sea by the Spanish swordfish fleet. Consequently, since these turtles may be captured more than once, the figures summarized in this report represent turtle captures, and not necessarily total turtles captured. Comments regarding 40 captured leatherbacks showed 2 were hooked in the mouth area, 17 were hooked externally, and 21 were entangled. Most of the 40 turtles were captured on branchlines, although 4 were captured on non-baited buoy lines. All of the turtles that were either hooked externally or entangled were related to the head and massive foreflipper area. It is apparent that loggerheads actively seek and consume baited hooks, whereas leatherbacks seemingly do not, partially confirming that leatherback turtles "probably will not take a baited hook, but are likely to become hooked in the flipper area or tangled in the branchline" (Witzell, 1984). However, it seems that leatherbacks will occasionally take a squid bait, as Skillman and Balazs (1992) also observed in the North Pacific Ocean, perhaps mistaking the squid for Scyphomedusidae. Interestingly, a leatherback entangled in a float line off the east coast Florida was observed on the surface feeding on a small swordfish, a large, tough-skinned, dense-muscled teleostean predator. This is the first report of a leatherback turtle consuming a large vertebrate.

Sea turtle catches and catch rates were examined, by geographic zone, from the logbook data (Table 2). These data were also categorized by the presence (swordfish set) or absence (tuna set) of light sticks. These chemical light sticks were introduced by recreational fishermen, and were quickly adopted by the commercial longliners. The highest catches and CPUE's for both leatherback and loggerhead turtles were from areas 5-7 (north of Cape Hatteras), and the highest CPUE's for both species were for vessels using light sticks. It was not surprising that the overall leatherback CPUE doubled with light sticks, since the turtles could easily mistake these glowing sticks for bioluminescent Schyozoa and become entangled in the lines (Skillman and Balazs, 1992). However, what was surprising was that the loggerhead CPUE was an order of magnitude higher with the lights sticks. Obviously these pelagic loggerhead turtles are strongly attracted to the lights suspended 30-60m below the surface, then find the baited hooks directly underneath. Area 5 (mid-Atlantic) also had a large catch of leatherbacks without light sticks, but with a relatively low CPUE), and is undoubtedly due to the extensive fishing effort in this area.

The results of the GLM are summarized in Table 3 and presented in detain in Appendices 1-3. The apparent differences between the reported incidental take (Table 1) and expanded take (Table 3) is possibly an artifact of an inadequate sample size of observed CPUE's used in the expansion model. Unfortunately, until a more appropriate expansion model is developed for these data, these expanded estimates of turtle captures should be interpreted with caution because of the high variances associated with each estimate. Additionally, fishermen are less inclined to remember discards (Cramer et al., 1994) and non-target species. These fishermen may also be reluctant to report encounters with protected species for fear of Federal regulation.

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Table 2. Sea turtle incidental CPUE from the combined 1992-92 pelagic logbooks, by geographic area, of longline sets with (Y) and without (N) light sticks.

Area	Light Sticks (Y/N)	Number Sets	Number Hooks	Leatherback	Leatherback CPUE (#/1,000 hks)	Loggerhead	Loggerhead CPUE (#/1,000 hks)
1	Y	2,374	1,052,180	34	0.0323	20	0.0190
1	N	202	112,492	2	0.0177	2	0.0177
2	Y	2,794	1,706,391	22	0.0128	11	0.0064
2	N	5,004	3,531,249	24	0.0067	5	0.0014
3	Y	4,534	1,305,686	8	0.0061	6	0.0045
3	N	172	53,418	1	0.0187	0	0.0000
4	Y	2,338	858,038	10	0.0116	7	0.0046
4	N	328	158,562	2	0.0126	2	0.0126
5	Y	1,224	777,531	92	0.1183	17	0.0218
5	N	3,969	2,424,384	132	0.0544	12	0.0049
6	Y	1,501	992,734	85	0.0856	55	0.0554
6	N	1,067	741,392	28	0.0377	11	0.0148
7	Y	2,254	1,600,378	148	0.0924	88	0.0549
7	N	128	71,197	1	0.0140	4	0.0561
8	Y	58	36,863	0	0.0000	0	0.0000
8	N	0	0	0	0.0000	0	0.0000
9	Y	599	361,571	9	0.0248	3	0.0082
9	N	51	27,107	0	0.0000	0	0.0000
1-9	Y	17,676	8,691,372	408	0.0469	207	0.0238
1-9	N	10,921	7,119,801	190	0.0279	36	0.0051

Table 3. Estimates and 95% confidence Intervals (CI) of Sea turtle interaction with U.S. pelagic longline gear.

Year	Species	Interaction Type	Estimate	Lower CI	Upper CI
1992	all	involved	1,282	977	1,841
1993	all	involved	1,557	1,089	2,276
1992	leatherback	involved	779	534	1,171
1993	leatherback	involved	994	669	1,530
1992	loggerhead	involved	505	327	820
1993	loggerhead	involved	567	363	926

Appendix 1: All Turtles Involved

Criteria For Assessing Goodness Of Fit

Criterion	DF	Value	Value/DF
Deviance	1129	581.0601	0.5147
Scaled Deviance	1129	1129.0000	1.0000
Pearson Chi-Square	1129	1310.8193	1.1610
Scaled Pearson X2	1129	2546.9225	2.2559
Log Likelihood	.	-749.9629	.

Analysis Of Parameter Estimates

Parameter		DF	Estimate	Std Err	ChiSquare	Pr>Chi
INTERCEPT		1	-0.6387	0.1660	14.8114	0.0001
AREA	1	1	-0.5098	0.3543	2.0698	0.1502
AREA	2	1	-1.3694	0.2374	33.2713	0.0000
AREA	3	1	-1.9324	0.3801	25.8463	0.0000
AREA	4	1	-1.5501	0.3406	20.7097	0.0000
AREA	5	1	-0.5076	0.1837	7.6342	0.0057
AREA	6	1	-0.3338	0.1972	2.8670	0.0904
AREA	7	0	0.0000	0.0000	.	.
LITE	no	1	-0.1836	0.1622	1.2807	0.2578
LITE	yes	0	0.0000	0.0000	.	.
SOURCE	OBS	0	0.0000	0.0000	.	.
SOURCE	SR	0	0.0000	0.0000	.	.
DEPTH		1	-0.0061	0.0016	13.9309	0.0002
SCALE		0	0.7174	0.0000	.	.

NOTE: The scale parameter was estimated by the square root of DEVIANCE/DOF.

LR Statistics For Type 3 Analysis

Source	NDF	DDF	F	Pr>F	ChiSquare	Pr>Chi
AREA	6	1129	13.3507	.0000	80.1040	0.0000
LITE	1	1129	1.2944	.2555	1.2944	0.2552
SOURCE	0	1129	.	.	0.0000	.
DEPTH	1	1129	24.0927	.0000	24.0927	0.0000

YEAR	SOURCE	SETS	PRED	LOWER	UPPER
1992	OBS	329	47.14	35.31	63.99
1992	SR	13575	1282.00	911.29	1841.35
1993	OBS	809	90.86	64.72	130.21
1993	SR	13933	1557.29	1088.93	2276.24

Appendix 2a: leatherback turtles Involved -
all areas except the Gulf of Mexico

Criteria For Assessing Goodness Of Fit

Criterion	DF	Value	Value/DF
Deviance	834	381.9312	0.4580
Scaled Deviance	834	834.0000	1.0000
Pearson Chi-Square	834	1004.8499	1.2049
Scaled Pearson X2	834	2194.2299	2.6310
Log Likelihood	.	-542.9023	.

Analysis Of Parameter Estimates

Parameter		DF	Estimate	Std Err	ChiSquare	Pr>Chi
INTERCEPT		1	-1.1398	0.2096	29.5563	0.0000
AREA	1	1	-1.1373	0.5709	3.9679	0.0464
AREA	3	1	-1.9759	0.5029	15.4383	0.0001
AREA	4	1	-1.1223	0.3679	9.3046	0.0023
AREA	5	1	0.0864	0.2093	0.1704	0.6797
AREA	6	1	0.0088	0.2281	0.0015	0.9691
AREA	7	0	0.0000	0.0000	.	.
LITE	no	1	-0.2938	0.1945	2.2825	0.1308
LITE	yes	0	0.0000	0.0000	.	.
SOURCE	OBS	0	0.0000	0.0000	.	.
SOURCE	SR	0	0.0000	0.0000	.	.
DEPTH		1	-0.0072	0.0021	12.4248	0.0004
SCALE		0	0.6767	0.0000	.	.

NOTE: The scale parameter was estimated by the square root of DEVIANCE/DOF.

LR Statistics For Type 3 Analysis

Source	NDF	DDF	F	Pr>F	ChiSquare	Pr>Chi
AREA	5	834	8.3899	.0000	41.9495	0.0000
LITE	1	834	2.3140	.1286	2.3140	0.1282
SOURCE	0	834	.	.	0.0000	.
DEPTH	1	834	23.7808	.0000	23.7808	0.0000

YEAR	SOURCE	SETS	PRED	LOWER	UPPER
1992	OBS	268	29.160	20.833	41.72
1992	SR	9654	778.627	534.297	1171.56
1993	OBS	574	52.840	36.286	79.81
1993	SR	10258	994.490	669.174	1529.95

Appendix 2b: leatherback turtles Involved -
Gulf of Mexico only

Criteria For Assessing Goodness Of Fit

Criterion	DF	Value	Value/DF
Deviance	293	79.1868	0.2703
Scaled Deviance	293	293.0000	1.0000
Pearson Chi-Square	293	333.3915	1.1379
Scaled Pearson X2	293	1233.5864	4.2102
Log Likelihood	.	-180.6425	.

Analysis Of Parameter Estimates

Parameter		DF	Estimate	Std Err	ChiSquare	Pr>Chi
INTERCEPT		1	-1.9111	0.4991	14.6610	0.0001
AREA	2	0	0.0000	0.0000	.	.
LITE	no	1	-0.6675	0.3391	3.8748	0.0490
LITE	yes	0	0.0000	0.0000	.	.
SOURCE	OBS	0	0.0000	0.0000	.	.
SOURCE	SR	0	0.0000	0.0000	.	.
DEPTH		1	-0.0070	0.0038	3.4536	0.0631
SCALE		0	0.5199	0.0000	.	.

NOTE: The scale parameter was estimated by the square root of DEVIANCE/DOF.
Normal Confidence Intervals For Parameters

LR Statistics For Type 3 Analysis

Source	NDF	DDF	F	Pr>F	ChiSquare	Pr>Chi
AREA	0	293	.	.	0.0000	.
LITE	1	293	4.0252	.0457	4.0252	0.0448
SOURCE	0	293	.	.	0.0000	.
DEPTH	1	293	3.9340	.0483	3.9340	0.0473

YEAR	SOURCE	SETS	PRED	LOWER	UPPER
1992	OBS	61	1.840	1.0374	3.339
1992	SR	3921	118.448	65.0206	225.497
1993	OBS	235	10.160	6.3633	16.533
1993	SR	3675	122.263	70.1638	222.878

Appendix 3: Loggerhead turtles Involved.

Criteria For Assessing Goodness Of Fit

Criterion	DF	Value	Value/DF
Deviance	1129	253.4462	0.2245
Scaled Deviance	1129	1129.0000	1.0000
Pearson Chi-Square	1129	1167.1280	1.0338
Scaled Pearson X2	1129	5199.0816	4.6050
Log Likelihood	.	-721.1190	.

Analysis Of Parameter Estimates

Parameter		DF	Estimate	Std Err	ChiSquare	Pr>Chi
INTERCEPT		1	-1.7100	0.1866	83.9954	0.0000
AREA	1	1	-0.3352	0.3415	0.9633	0.3264
AREA	2	1	-2.5833	0.3225	64.1811	0.0000
AREA	3	1	-1.9234	0.3656	27.6734	0.0000
AREA	4	1	-2.5073	0.4884	26.3562	0.0000
AREA	5	1	-2.5114	0.3162	63.0895	0.0000
AREA	6	1	-1.0447	0.2392	19.0810	0.0000
AREA	7	0	0.0000	0.0000	.	.
LITE	no	1	0.3513	0.2096	2.8083	0.0938
LITE	yes	0	0.0000	0.0000	.	.
SOURCE	OBS	0	0.0000	0.0000	.	.
SOURCE	SR	0	0.0000	0.0000	.	.
DEPTH		1	-0.0033	0.0019	3.1319	0.0768
SCALE		0	0.4738	0.0000	.	.

NOTE: The scale parameter was estimated by the square root of DEVIANCE/DOF.

LR Statistics For Type 3 Analysis

Source	NDF	DDF	F	Pr>F	ChiSquare	Pr>Chi
AREA	6	1129	29.6272	.0000	177.7631	0.0000
LITE	1	1129	2.7035	.1004	2.7035	0.1001
SOURCE	0	1129	.	.	0.0000	.
DEPTH	1	1129	4.5247	.0336	4.5247	0.0334

YEAR	SOURCE	SETS	PRED	LOWER	UPPER
1992	OBS	329	16.386	12.007	23.066
1992	SR	13575	386.778	261.854	594.830
1993	OBS	809	27.614	18.824	42.344
1993	SR	13933	444.354	293.054	703.413