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# SPATIAL ANALYSIS OF SWORDFISH LANDINGS AND CRYPTIC CATCH FROM THE U.S. LONGLINE FISHERY

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**SUMMARY**

U.S. longline fishermen who catch swordfish have been required to report the location of their sets and the number of swordfish kept and discarded since mid-year 1986. Locations of catch per unit effort, and locations of high catch per unit effort of discards are presented in this document. This analysis leads to methods of testing hypotheses about redirecting fishing effort within components of the U.S. fleet.

**RESUMÉ**

Les pêcheurs palangriers des Etats-Unis qui prennent de l'espadon ont été priés de signaler la localisation de leurs opérations et le nombre d'espadons gardés à bord et d'espadons remis à l'eau depuis le milieu de l'année 1986. Le présent document montre la localisation de la prise par unité d'effort, et de la capture élevée de rejets par unité d'effort. Cette analyse mène aux méthodes de vérification des hypothèses concernant la réorientation de l'effort dans certains éléments de la flottille américaine.

**RESUMEN**

Se ha solicitado a los pescadores norteamericanos de palangre para pez espada que informen sobre el lugar de sus lances y el número de pez espada retenido y descartado desde mediados de 1986. El lugar de captura por unidad de esfuerzo, y lugares de fuerte descarte de captura por unidad de esfuerzo se presentan en este documento. Este análisis conduce a métodos de ensayo de hipótesis acerca de la nueva dirección del esfuerzo de pesca dentro de los componentes de la flota de Estados Unidos.

## Introduction

Regulations, effective, June 1991, limited the U.S. pelagic longline landings of undersized swordfish (less than 25 kg whole weight, 125 cm lower jaw fork length) to 15% (by number) of the total swordfish landings. Landings of undersized swordfish have decreased since 1991. However, discarding of undersized fish increased (Cramer et al 1993, Cramer et al 1994) and the catching and discarding of these fish remains an issue. This paper presents summarizations of longline effort and swordfish catch per unit effort from 1987 to 1994 and analyses of the cost, in terms of landings, of reducing the catch of undersized swordfish.

## Methods

Logbook records were selected for this study which were not considered to be summary reports (reports which summed the catch of multiple sets) or reports of tended sets (sets where hooks were rebaited)and which reported at least 100 hooks set. Swordfish catch per unit effort (CPUE) is taken as:

$$CPUE = 1{,}000 * (swok + swod + swoa) / hooks$$

where swok is the number of swordfish kept (landed), swod is the number of swordfish discarded dead, swoa is the number of swordfish discarded alive and hooks is the number of hooks reported per set.

In order to look at changes in effort and CPUE between years, records were grouped by one degree (latitude and longitude) squares. Hooks were summed and CPUEs were averaged for each one degree square. Surfer software was used to produce effort (hooks) (Figure 1a-1h)and catch (CPUE)(Figure 2a-2h) maps for each year from 1987 to 1994. The size of the indicators at each one degree square was set proportionally to the total number of hooks set or the mean CPUE. Open squares were used to indicate areas where the CPUE was equal to zero.

Records from 1992 to 1994 were grouped by one degree square and quarter (Table 1) in order to identify areas and times with high rates of discarding of undersized swordfish. In this paper all discarded swordfish are assumed to be undersized. A discard ratio was calculated and CPUEs were averaged for each one degree square and quarter. The discard ratio is taken as:

$$Discard\ Ratio = (swod + swoa) / (swod + swoa + land)$$

where *swod* is number of swordfish discarded dead, swoa is the number of swordfish discarded alive and *land* is the sum of the numbers of swordfish, tuna and sharks kept.

To determine the cost of reducing the catch of undersized swordfish, in terms of the reduction in the numbers of fish landed, fishing effort was retroactively restricted by one degree square and quarter from 1992 to 1994 starting with the highest discard ratio.

Records, grouped by one degree square and quarter, were sorted in descending order by the discard ratio. Records were removed in order starting with the highest discard ratio. The percentage of the discards removed and the percentage of total landed fish (swordfish kept + tuna kept + sharks kept) removed were calculated (Hall, 1994).

## Results and Discussion:

Some pattern changes are apparent in reported U.S. pelagic longline effort(Figures 1a-1h)(Table 2). From 1987 to 1989 new fishing areas were explored. During this time fishing effort increased in the southern Gulf of Mexico, the Venezuelan Basin (eastern Caribbean) and off the Northeastern coast of South America. After 1990 longline effort shifted to and became more concentrated in swordfish spawning areas such as the Yukatan Channel, the Windward Passage, the Anegada Passage (east of Puerto Rico), and northeast of the Lesser Antilles (Arocha and Lee 1995). And in recent years the density of hooks set increased along the Atlantic coast of the United States.

The decrease in effort in the Venezuelan Basin is thought to be an effect of regulations limiting landings of undersized swordfish. This area is possibly a nursery area for swordfish and a high proportion of swordfish caught in this area are undersized (Arocha personal communication).

Overall swordfish CPUE (Figures 2a-2h)(Table 3) has decreased since 1991. The highest CPUEs for swordfish since 1991 were found primarily along the Florida Escarpment in the Gulf of Mexico, the southeast coast of the U.S., spawning areas in and northeast of the Caribbean, and the Grand Banks.

The graphs in figure 3 show the relationship between swordfish discards and landings as the one degree square/quarter records are removed. Reduction in the percentage swordfish discarded were plotted against reductions in the percentage total landings (swordfish kept, tuna kept and sharks kept). Reductions in the percentage swordfish discarded were also plotted against reductions in the percentage of swordfish landings (a subset of the total landings)(Figure 3).

When fishing was retroactively restricted starting with the one degree square/quarter record with the highest discard ratio in each year (1992 to 1994), a reduction in swordfish discards of 50% corresponded to a reduction in total landings of only 10% and a reduction in swordfish landings of approximately 30% (Figure 3). This, of course, was a theoretical exercise which had the combined advantages of both precise knowledge of where and when the highest discard ratios occurred and the ability to restrict fishing in areas as small as a one degree square. Actual restrictions would have to apply to areas larger than a one degree square and times could be longer or shorter than one quarter. Success of such a scheme would be dependent on the ability to predict where and when undersized swordfish were likely to be caught.

One degree squares with discard ratios equal to or above 50% were plotted on maps for each year and quarter from 1992 to 1994 (Figures 4-6). The size of the indicators on these maps is proportional to the number of swordfish discarded in each one degree square (Table 5).

The one degree square/quarters where reported discard rates were at or above 50% are shown in figures 4, 5 and 6. One degree square/quarters where reported discard rates were at or above 50% accounted for only 8% of the swordfish discarded in 1992. In 1993, 27%, and in 1994, 37%, of discarded swordfish were caught in sets reporting a discard rate of at least 50%. In 1993 and 1994 both the number of one degree square/quarter records having discard ratios at or above 50% and the number of swordfish reported discarded at these sites, indicated by the size of the circles (Table 5), increased.

A growing percentage of swordfish discards are being caught in one degree square/quarters where 50% or more of the catch of a longline set must frequently be discarded. These one degree square/quarters appear to be concentrated and fairly consistent between years.

## References Cited


Arocha, F., D. Lee. Maturity at size, reproductive seasonality, spawning frequency, fecundity and sex ratio in swordfish from the northwest Atlantic. ICCAT Working Document SCRS/95/103

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Hall, M. A. 1994. A classification of bycatch problems and some approaches to their solutions. In T. J. Pitcher and R. Chuenpagdee, eds. Bycatches in fisheries and their impact on the ecosystem. Fisheries Centre Research Reports, 1994, Vol 2 Nr. 1, pp. 65-74

Surfer for Windows. Golden Software Inc. 809 14th Street, Golden, Colorado


TABLE 1: QUARTERS USED IN THESE ANALYSES BEGIN AND END ON THE CALENDER DAYS INDICATED IN THIS TABLE.

| QUARTER | BEGINNING | ENDING |
|---|---|---|
| 1 | JANUARY 1 | MARCH 31 |
| 2 | APRIL 1 | JUNE 30 |
| 3 | JULY 1 | SEPTEMBER 30 |
| 4 | OCTOBER 1 | DECEMBER 31 |

TABLE 2: RANGE OF HOOKS REPORTED FOR DATA GROUPED BY ONE DEGREE SQUARES WITHIN YEARS.

| YEAR | MINIMUM | MEDIAN | MAXIMUM. |
|---|---|---|---|
| 1987 | 200 | 2,540 | 200,677 |
| 1988 | 120 | 3,138 | 195,920 |
| 1989 | 130 | 2,393 | 258,034 |
| 1990 | 132 | 2,400 | 229,610 |
| 1991 | 180 | 3,450 | 206,737 |
| 1992 | 200 | 2,548 | 285,384 |
| 1993 | 240 | 3,100 | 319,466 |
| 1994 | 150 | 3,220 | 388,738 |

TABLE 3: RANGE OF CPUE REPORTED FOR DATA GROUPED BY ONE DEGREE SQUARES WITHIN YEARS.

| YEAR | MINIMUM | MEDIAN | MAXIMUM |
|---|---|---|---|
| 1987 | 0.38 | 21 | 112 |
| 1988 | 0.47 | 23 | 100 |
| 1989 | 0.16 | 23 | 128 |
| 1990 | 0.05 | 20 | 92 |
| 1991 | 0.16 | 16 | 137 |
| 1992 | 0.25 | 11 | 106 |
| 1993 | 0.03 | 11 | 61 |
| 1994 | 0.12 | 11 | 85 |

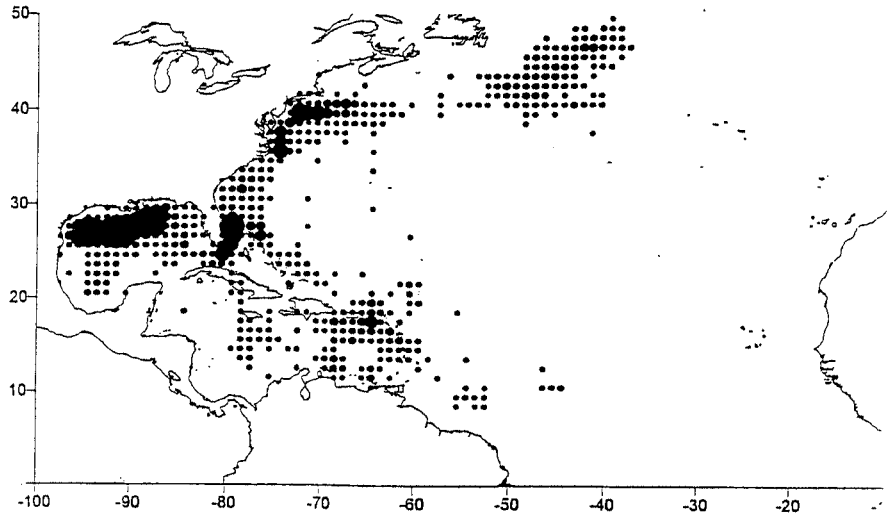
TABLE 4: PERCENTAGE OF SWORDFISH DISCARDS, TOTAL LANDINGS(SWORDFISH, TUNA AND SHARKS), AND SWORDFISH LANDINGS REMAINING AFTER LOCATION/QUARTER RECORDS WITH DISCARD RATIOS EQUAL TO OR GREATER THAN 50% ARE REMOVED.

| YEAR | SWORDFISH DISCARDS | TOTAL LANDINGS | SWORDFISH LANDINGS |
|---|---|---|---|
| 1992 | 8 | 1 | 2 |
| 1993 | 27 | 3 | 8 |
| 1994 | 37 | 4 | 11 |

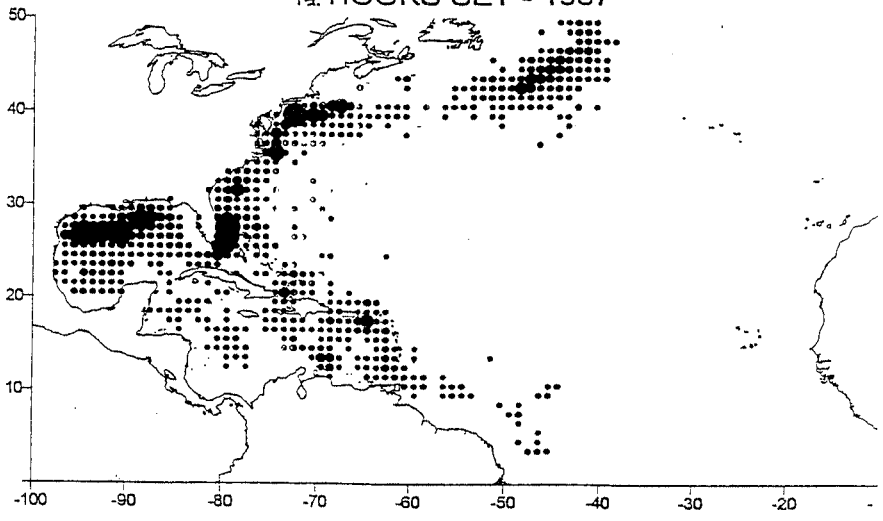
TABLE 5: RANGE OF NUMBER OF DISCARDS REPORTED IN ONE DEGREE SQUARES FOR ONE DEGREE SQUARES AND QUARTERS WHERE DISCARD RATIOS WERE 50% OR HIGHER.

| YEAR | MINIMUM | MAXIMUM |
|---|---|---|
| 1992 | 1 | 459 |
| 1993 | 2 | 1,199 |
| 1994 | 1 | 1,484 |

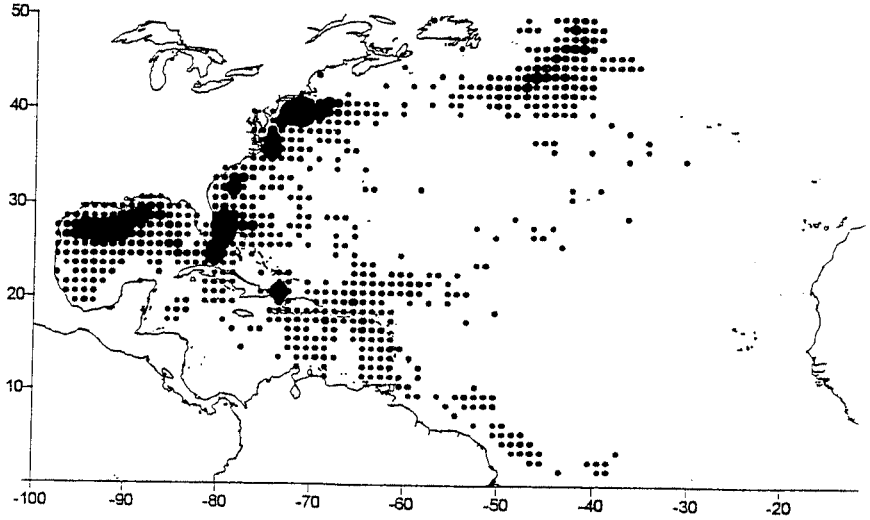
Figures 1a - 1h. U. S. longline effort by one degree squares
Circle size is in proportion to number of hooks



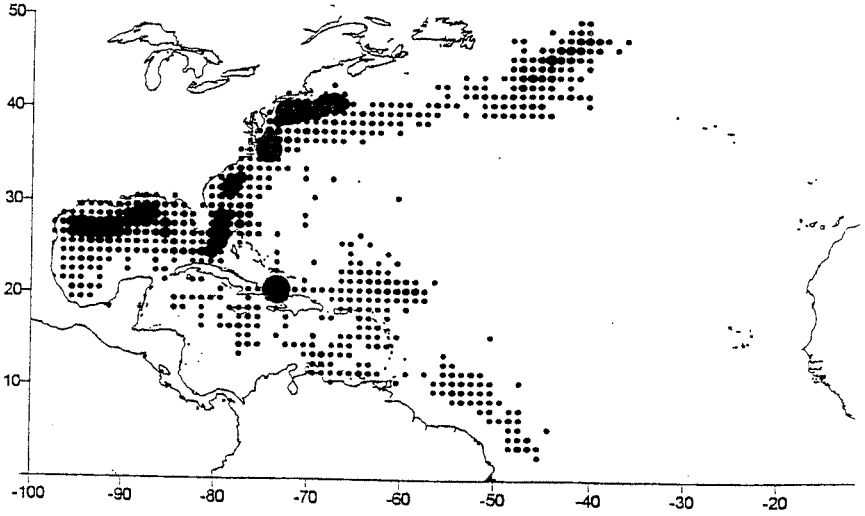

1a. HOOKS SET - 1987



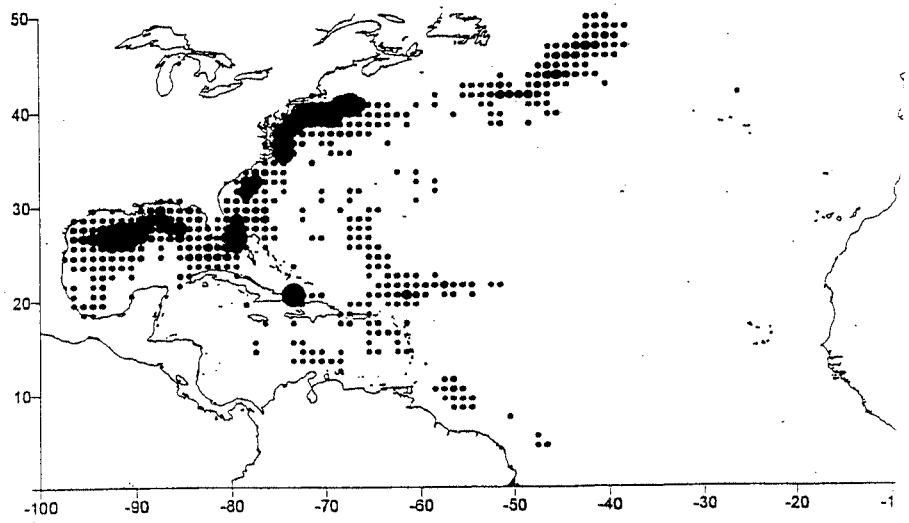

1b. HOOKS SET - 1988



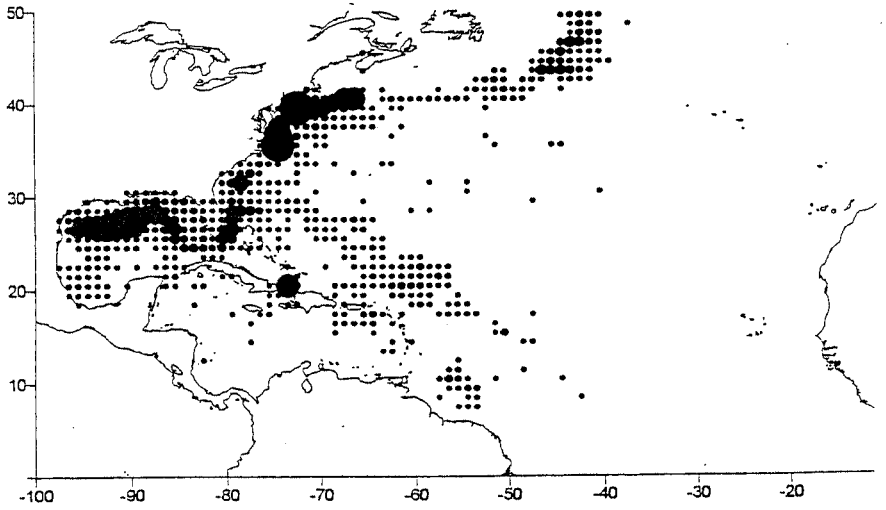

1c. HOOKS SET - 1989



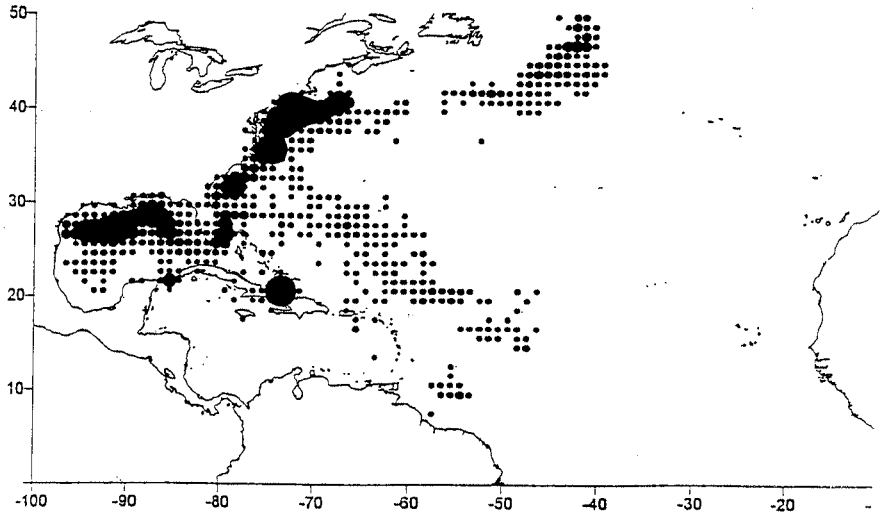

1d. HOOKS SET - 1990



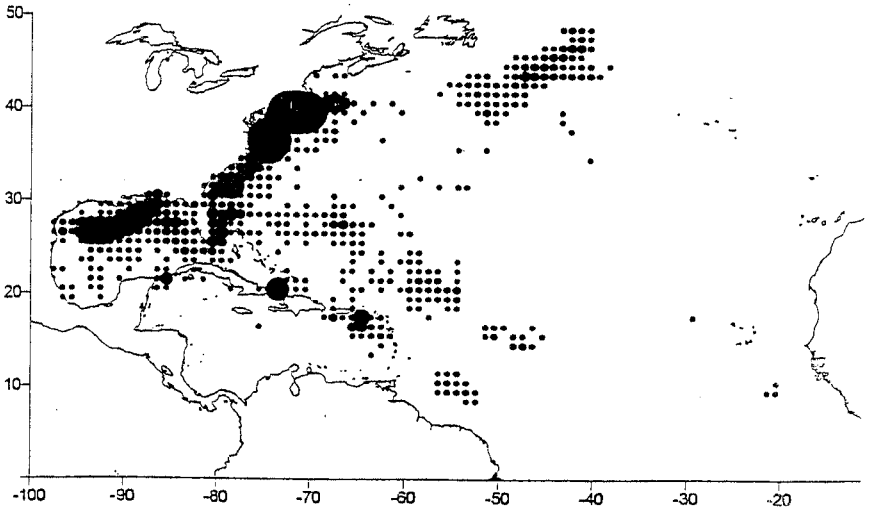

1e. HOOKS SET - 1991




1f. HOOKS SET - 1992




1g. HOOKS SET - 1993




1h. HOOKS SET - 1994

Figures 2a - 2h. U. S. longline CPUE by one degree squares
Circles are in proportion to CPUE.

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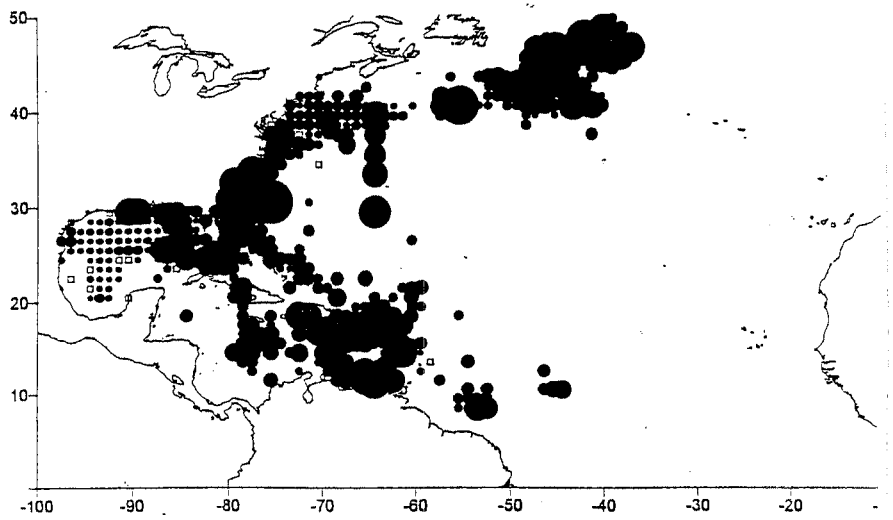
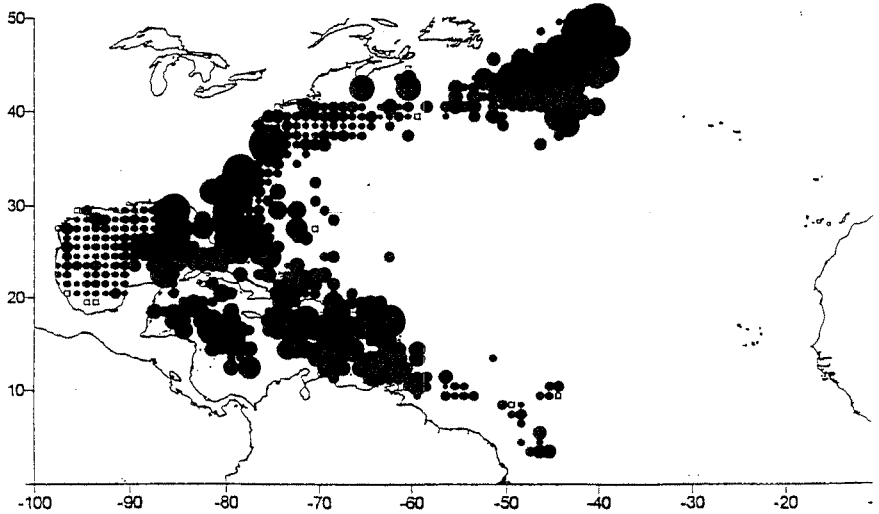
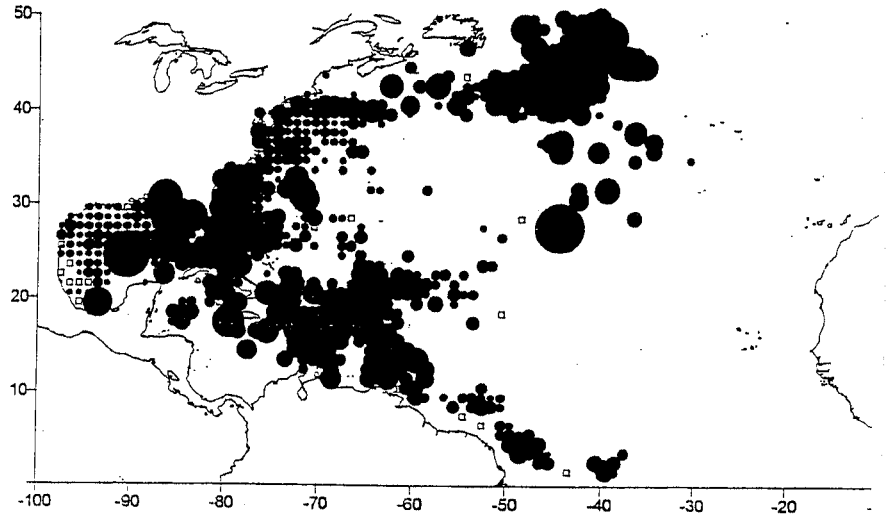


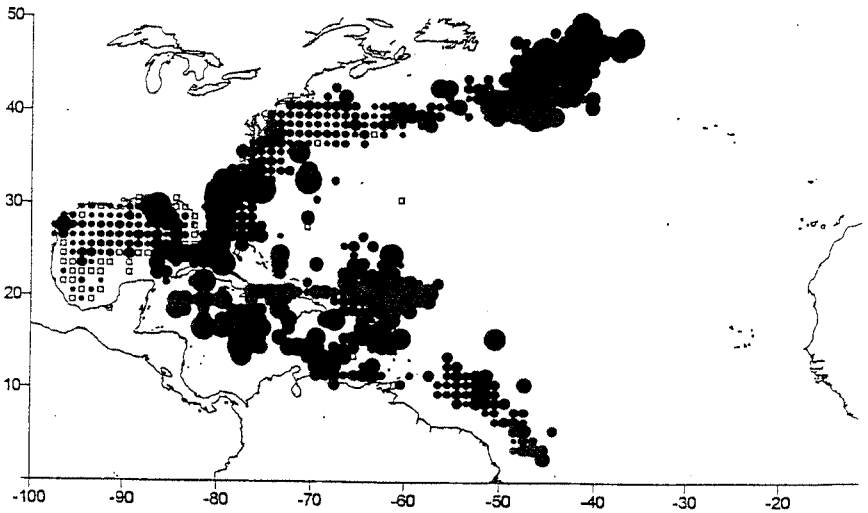

2a. SWORDFISH CPUE - 1987



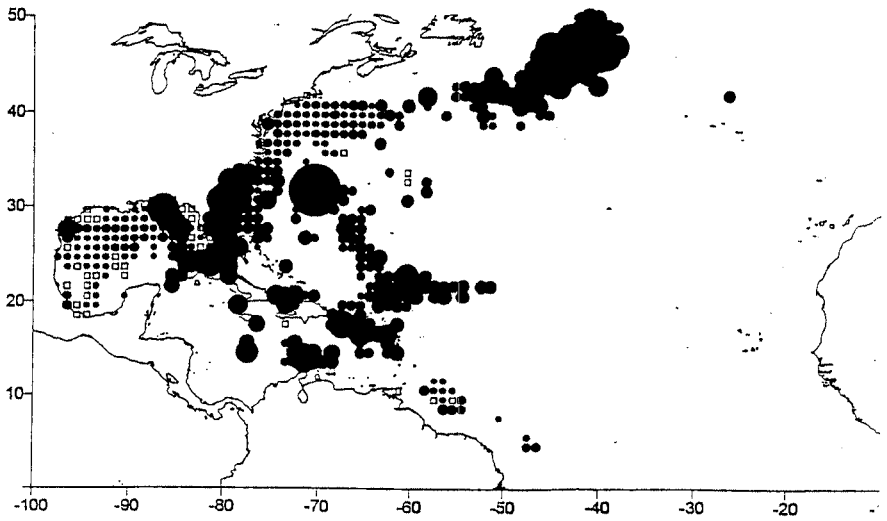

2b. SWORDFISH CPUE - 1988



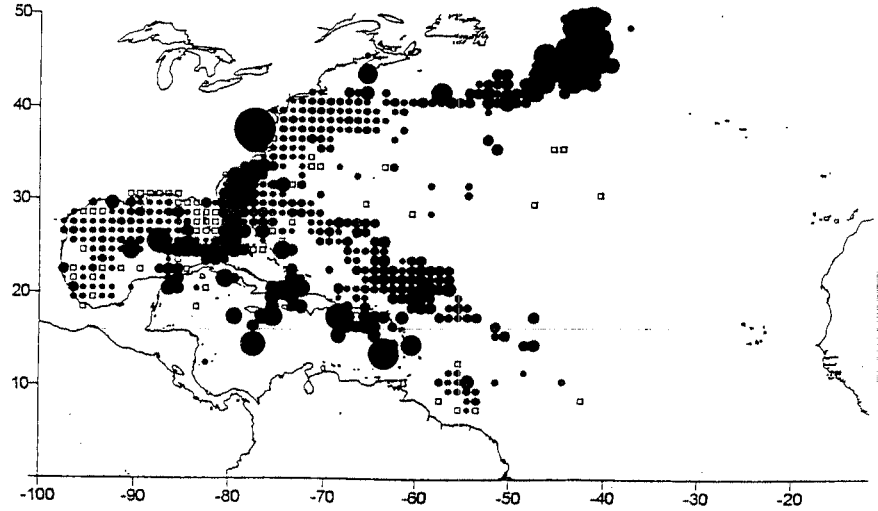

2c. SWORDFISH CPUE - 1989



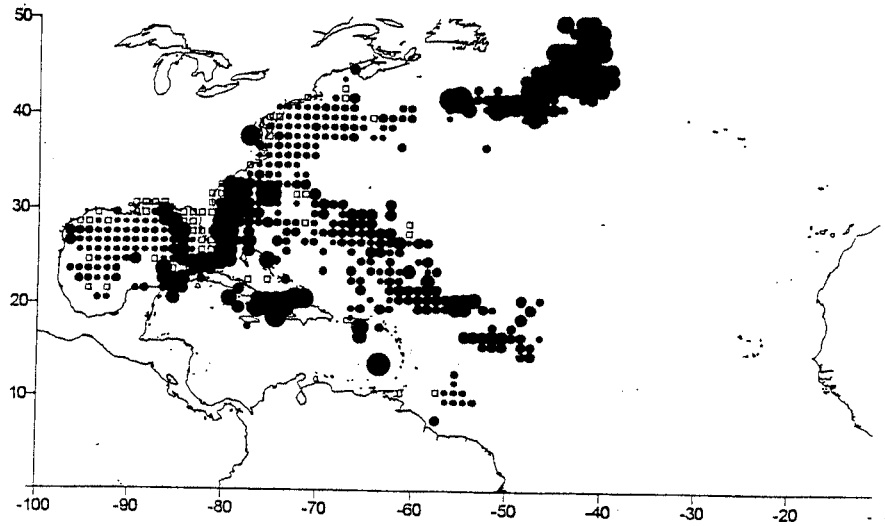

2d. SWORDFISH CPUE - 1990



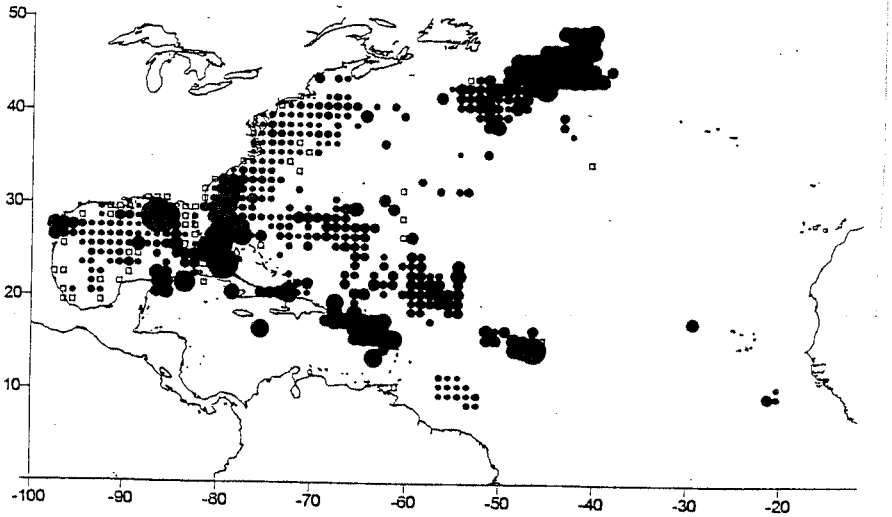

2e. SWORDFISH CPUE - 1991




2f. SWORDFISH CPUE - 1992




2g. SWORDFISH CPUE - 1993




2h. SWORDFISH CPUE -1994

Figure 3. The cost, in terms of total landings and of swordfish landings, of reducing swordfish discards.

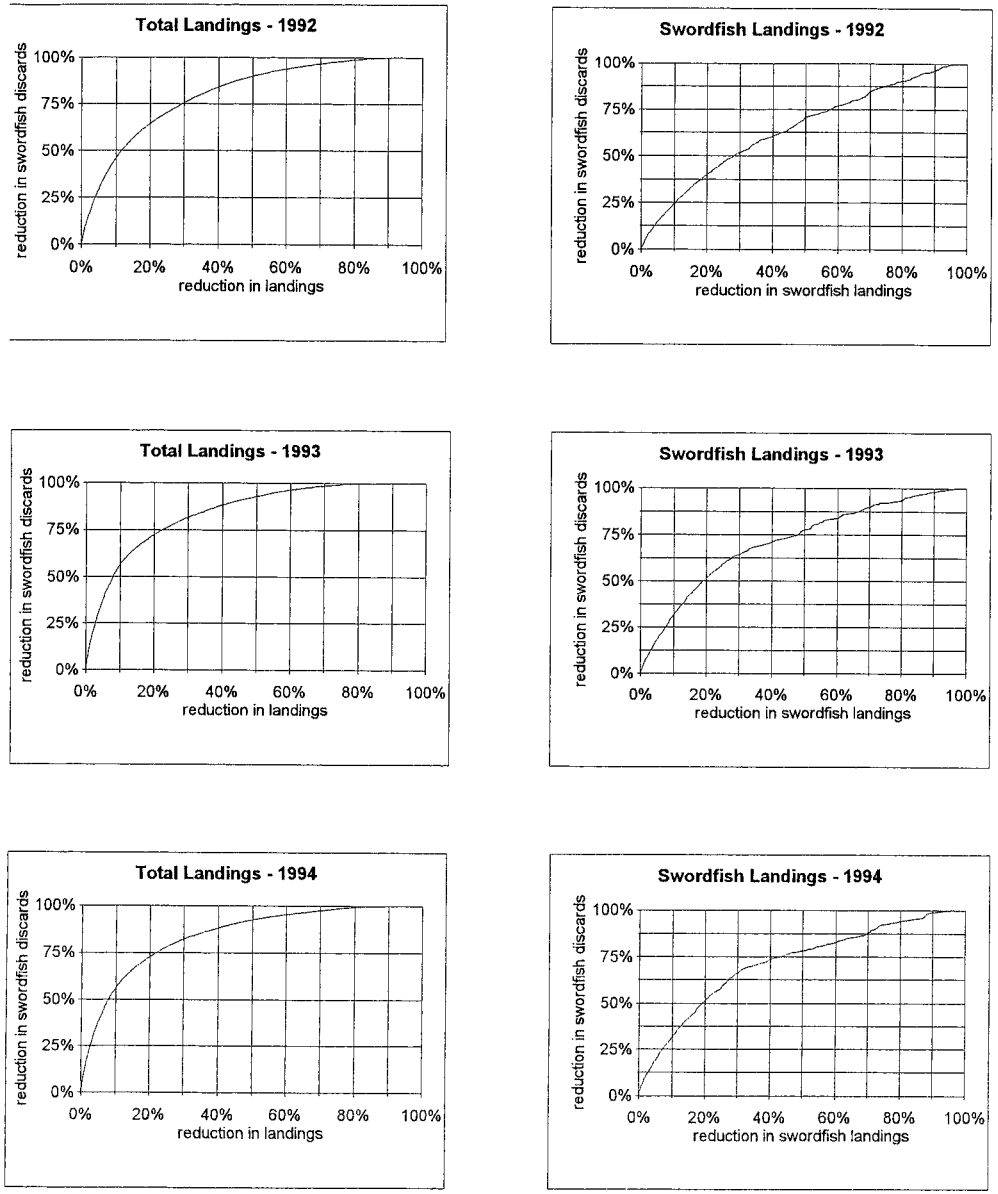



Figure 4. U. S. longline locations where the number of swordfish discarded was equal to or greater than the number of fish landed in each one degree square and quarter of 1992. Circles are proportional to the number of swordfish discarded.

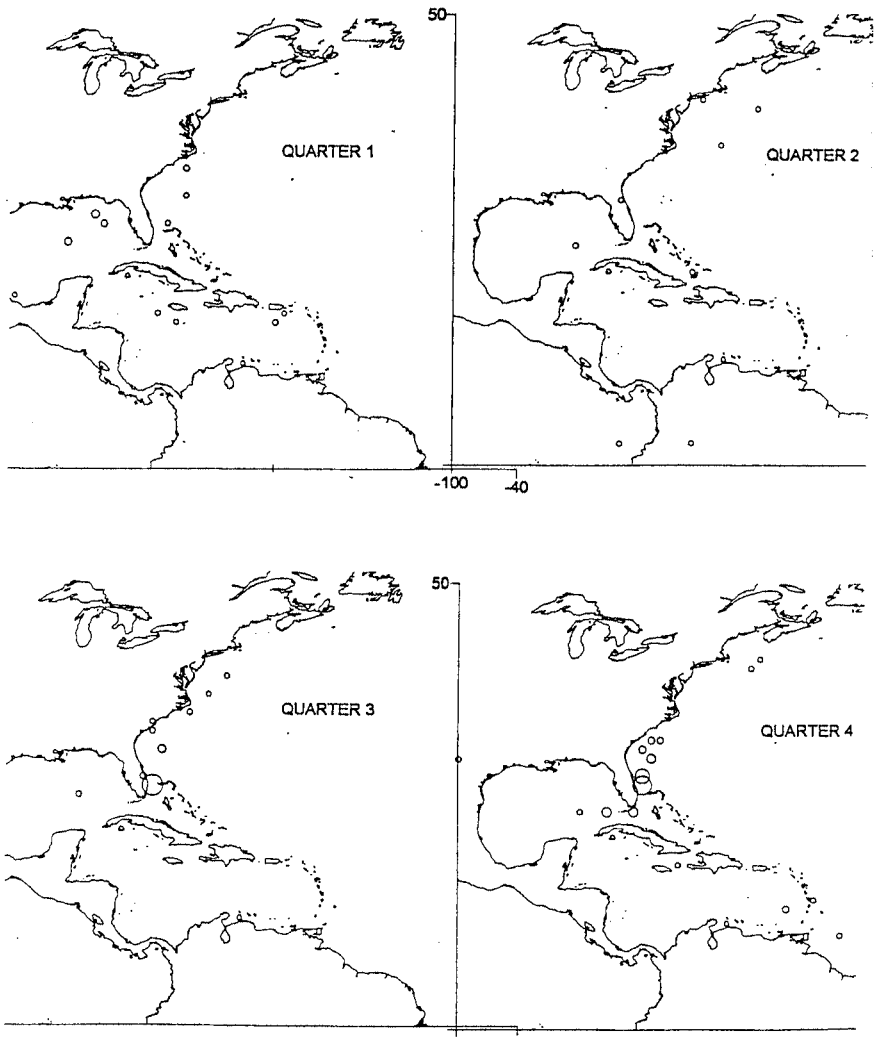


Figure 5. U. S. longline locations where the number of swordfish discarded was equal to or greater than the number of fish landed in each one degree square and quarter of 1993. Circles are proportional to the number of swordfish discarded.

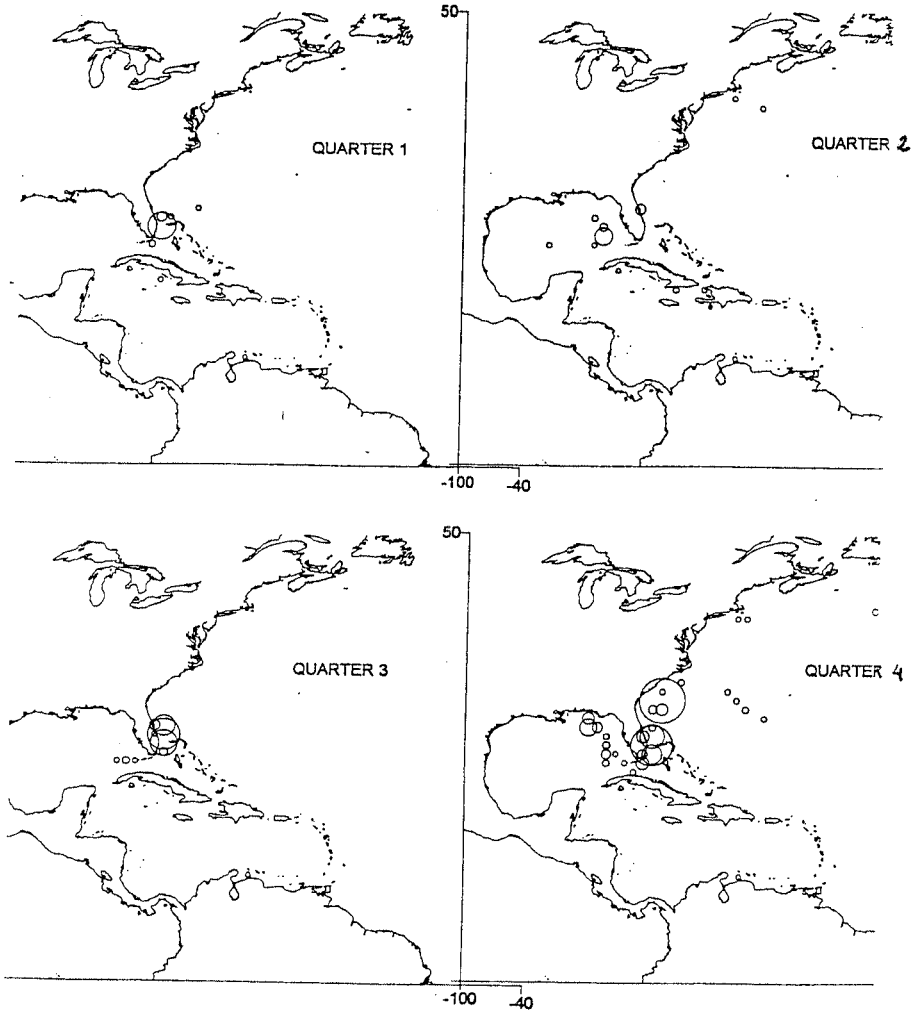



Figure 6. U. S. longline locations where the number of swordfish discarded was equal to or greater than the number of fish landed in each one degree square and quarter in 1994. Circles are proportional to the number of swordfish discarded.