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ATLANTIC SWORDFISH STOCK STRUCTURE DATA AND SUGGESTIONS FOR ITS INTERPRETATION

S. A. Berkeley
University of Miami

SUMMARY

Approximately 50 tagged swordfish have been recaptured. All fish were tagged and recaptured in the northwest Atlantic suggesting stock separation between this area and the north-east and south Atlantic areas. Declining CPUE in the north-west Atlantic and stable or increasing CPUE in the northeast and south Atlantic fisheries also suggest stock separation. Based on tag returns, mixing between the northwest and the northeast Atlantic population was estimated to be a maximum of 5.8%. Within the northwest Atlantic, morphometric differences between nearby areas, different catch rates and average sizes between adjacent areas and tag recaptures made near the point of release even after several years at large, suggest a more complex stock structure. Prior to initiating research to de-termine stock structure, criteria to define management units are needed. It is suggested that the precision or sensitivity of the fishery model relative to the percent stock mixing be used as a guideline.

RESUME

Environ 50 espadons marqués ont été repris. La recapture, comme le marquage, de tous ces poissons a eu lieu dans l'Atlantique nord-ouest, ce qui suggère l'existence d'une séparation entre ce secteur et ceux de l'Atlantique nord-est et de l'Atlantique sud. Le fait que la CPUE soit en baisse dans les pêcheries du nord-est et du sud signale également une séparation. Le degré d'échange entre les populations du nord-ouest et du nord-est atlantique a été estimé, à partir des retours de marques, à 5,8 % maximum. Dans l'Atlantique nord-ouest, les différences morphométriques entre zones proches, les différences concernant le taux de capture et la taille moyenne entre zones adjacentes, ainsi que les récupérations de marques effectuées à proximité du point de marquage même après plusieurs années, suggèrent une structure plus complexe du stock. Des critères pour définir les unités d'aménagement sont nécessaires avant d'entreprendre des recherches visant à définir la structure du stock. Il est suggéré que le degré de précision ou de sensibilité du modèle de la pêcherie concernant le taux d'échange des stocks pourrait servir de ligne directrice.

RESUMEN

Se recapturaron aproximadamente unos 50 ejemplares de pez espada. Todos habían sido marcados y recuperados en el Atlántico Noroeste, lo que sugiere una separación de stocks entre esta zona y las del Noroeste y Sur del Atlántico. La tendencia decreciente de la CPUE en el Atlántico Noroeste, y su estabilización o aumento en las pesquerías del Noroeste y Sur del Atlántico, indican asimismo una separación de stocks.

Basándose en las marcas devueltas, se calculó que la tasa de mezca entre las poblaciones del Atlántico Noroeste y Nordeste sería de un máximo de 5.8%.En el Atlántico Noroeste, las diferencias morfométricas entre zonas adyacentes, distintas tasas de captura y promedios de talla entre zonas contíguas, y recuperación de marcas cerca del punto donde fueron liberados los peces - incluso después de varios años en libertad - indican la existencia de una estructura de stock más compleja. Antes de dar comienzo a la investigación destinada a determinar la estructura del stock, se precisan criterios para definir unidades de ordenación. Se sugiere que,como pauta,se utilice la precisión o sensibilidad del modelo de pesquería relativo al porcentaje de mezcla de stock.

Introduction

The unit stock is both a biological as well as a management concept. Recent biochemical genetic studies on a variety of marine fishes have shown that genetically distinct sub-populations may exist even in the absence of apparent reproductive isolating mechanisms. Adults of several sub-populations may co-occur in a relatively discrete geographic area and yet maintain their genetic identity by spatial or temporal isolation during spawning. Alternatively, widely distributed species may have considerable gene flow and thus appear genetically homogeneous throughout their range. Between the two extremes of complete genetic and geographic isolation and total interbreeding and geographic overlap a continuum of possible degrees of mixing exist. Since the concept of stock structure addresses population differences below the sub-species level we might reasonably assume, a priori, that some genetic interchange must be occurring among population units for the species to maintain its singular taxonomic identity. If the occurrence of some degree of mixing among populations or stocks is the common situation in marine fishes, then stock structure will rarely be absolutely defined. The question for management then becomes, what percentage mixing must exist before population units are considered a single stock for management purposes, or conversely, how much separation is necessary to define populations as separate stock units. The identification of genetically distinct populations has generally been used to suggest management units (Iles and Sinclair, 1982; Wishard et al., 1980). Although ideally, the biological stock unit and the management unit should coincide, in actual application this may not be desirable. If populations exhibit the same growth and mortality rates, and are caught by a fishery in proportion to their abundance, then from a fishery standpoint, they may be managed as a unit stock. Conversely, a single interbreeding biological stock may best be managed as several "stocks" if its components (age classes or sexes) exhibit either different growth and/or mortality rates or if fishing mortality varies among age classes or sexes. If these age or sex classes are sufficiently separated spatially or temporally, then a single biological stock may be most effectively managed as if it were composed of a number of separate stocks

Swordfish Stock Structure

Wide ranging, non-schooling oceanic pelagic species such as the billfish, would seem unlikely to exhibit a highly complex stock structure. Swordfish, the most widely distributed of the billfish, occur worldwide from 45°N to 45°S latitude. Swordfish larvae have been found in all tropical seas where surface water temperatures were $\geq 24°C$ (Nishikawa and Ueyanagi, 1974; Matsumoto and Kazama, 1974). In the Atlantic, the apparent abundance of swordfish as estimated from Japanese longline catch records indicates a relatively uniform distribution with regard to both latitude and longitude (Wise and Davis, 1973). Despite this, evidence to date suggests that swordfish have a complex though poorly understood stock structure.

Evidence from tag recapture data suggests that at least the northwest Atlantic population is separate from the northeast and south Atlantic populations. As of 1981 a minimum of 40-50 swordfish tagged in the western North Atlantic had been recaptured (South Atlantic Fishery Management Council, 1981). All recaptures of fish tagged in the northwest Atlantic have come from the northwest Atlantic. The following assumptions were used to estimate maximum exchange rates:

1. 50 tag recaptures have been made
2. at least as many swordfish have been caught in the Northeast Atlantic as in the Northwest Atlantic.[1]
3. probability of a tag being returned is the same for all areas.
4. all tagged fish are northwest Atlantic swordfish.
5. tagged fish have been at large long enough to become distributed throughout their range

Then, for the observed recapture results to occur 5% of the time, the proportion of northwest Atlantic swordfish in the northeast Atlantic is .0582 (1.0:17.2). Since catches in the northeast Atlantic have been consistently greater than in the northwest Atlantic, a 5.8% mixing west to east represents a maximum figure, which is probably insufficient to assume a single management unit. Because only northwest Atlantic swordfish have been tagged, the mixing rate from east to west cannot be estimated.

Catch-per-unit-effort data from the Japanese longline fishery show three distinct seasonal concentrations of swordfish (Beardsley, 1977). One concentration is in or just outside the Mediterranean Sea from September through December. A second concentration is in the northwest Atlantic in July, September and October. A third concentration is located in the south Atlantic off the coast of Uruguay and Argentina from April through October. Beardsley (1977) concluded that the occurrence of these widely separated concentrations suggest the existence of three populations of swordfish in the Atlantic. Ripe females and larvae occur in the Straits of Messina in the Mediterranean from April through September and in the Caribbean and throughout the Florida Straits from January through October. (Beardsley, 1977). Arfelli and Amorim (1982) reported that spawning occurs mainly in January and February in the area off the Brazilian coast, 20^{o}–28^{o}S latitude, 39^{o}–47^{o}W longitude. In the western North Atlantic, Grall et al. (1981) reported the greatest abundance of larvae in November and February. These data tend to support the hypothesis that there are at least three Atlantic stocks of swordfish.

Further evidence for stock separation can be found in landing records. In the northwest Atlantic, reported U.S. and Canadian swordfish landings increased from <1800 mt in 1975–1977 to 6375 mt in 1979, then declined to 5420 mt in 1980 (Farber and Conser, 1982). Using Japanese longline catch data, they noted a decrease in abundance of swordfish in the northwest Atlantic area during 1978–1980. Berkeley and Irby (1982) also noted a decline in CPUE in the Straits of Florida fishery between 1979 and 1980. In the northeast Atlantic area there were no recent trends while the South Atlantic showed a steady increase reaching a 10 year high in 1980 (Farber and Conser, 1982).

While the available evidence suggests that northwest, northeast and south Atlantic swordfish comprise separate stocks, several populations may exist within these major areas. Twenty-two of 23 swordfish tagged on their summer feeding grounds off the Canadian maritime provinces were recaptured subsequently on the same feeding grounds even after several years at large (Beckett, 1974; Hurley and Iles, 1981). In addition, Beckett (1974) reported that morphometric data suggested some heterogeneity between fish on Georges Bank and those on the Grand Bank. Recently, with the expansion of the U.S. swordfish fishery along the entire U.S. east coast and Gulf of

[1] Between 1968 and 1979 reported total landings in the northeast Atlantic have varied between approximately 1.6 and 35.0 times those from the northwest Atlantic (ICCAT, 1981).

Mexico, long range recaptures have been made. Fish tagged in the Gulf of Mexico have been recaptured off the northeastern U.S. and Canada and vice versa suggesting additional spatial and temporal complexity in the population structure of this stock.

In the Canadian longline fishery begun in the 1960's average sizes and catch rates in 1° areas dropped markedly after several seasons of fishing while subsequent effort in previously unfished adjacent areas resulted in increased sizes and catch rates (Beckett, 1971). While none of this evidence is conclusive, it does appear that swordfish in the northwest Atlantic exhibit a complex stock structure. To further complicate management considerations, it has been well-documented that male and female swordfish have different growth, natural and fishing mortality rates, occur in different ratios latitudinally in the northwest Atlantic, and exhibit differential migrations by size or age and sex (Berkeley and Houde, 1981; Wilson and Dean, in press; Radtke and Hurley, in press; Palko et al., 1981). Thus, even within a single biological stock a number of management units may exist.

Discussion

While many questions remain unanswered, evidence suggests that swordfish exhibit all possible complications of stock structure: stock separation among widely divergent geographical areas, the possibility of multiple stocks within areas, and management units within stocks (size and sex specific population parameters).

For management purposes, two questions must be definitively answered: 1) Is the stock (or stocks) exploited by a particular fishery exploited by any other fishery(s)? and 2) Does a particular fishery exploit one stock or several? Tagging studies on swordfish have partially answered the first question, indicating that swordfish in the northwest Atlantic do not mix to an appreciable extent with northeast or South Atlantic populations. However, within the northwest Atlantic area, the stocks are exploited by several fisheries (U.S., Canada, Japan). Additional tagging studies elsewhere in the Atlantic would help determine if there is any mixing from other areas into the northwest Atlantic or between the northeast and south Atlantic. Biochemical studies, while often less definitive than tagging, are likely to yield results more quickly. Temporally synoptic samples from the most widely divergent geographic areas would seem the logical place to start. Analysis of size, age and sex frequency data from different fisheries can supply supporting evidence and can be initiated immediately.

If studies designed to answer the first question indicate a significant stock overlap among geographically divergent fisheries, then management as a single stock is indicated. If stock separation among areas is shown then the second question must be addressed. In the northwest Atlantic, tag returns have shown that at least some swordfish migrate over the latitudinal range of the fishery, from the Gulf of Mexico (~25°N latitude) to New England (~45°N latitude). This allows the possibility that the northwest Atlantic population may be a single stock but cannot establish it as such. Tagging is not likely to resolve this question because of the large number of fish needed to ensure sufficient recaptures. Because swordfish are highly migratory and move differentially by size and sex, stock structure may involve the dimension of time as well as space. To determine whether a fishery is operating on a single or multiple stock, tagging would have to be done in combinations of area and time. Recaptures should also be analyzed with regard to both parameters. The number of combinations of space and time in which fish must be tagged, complicated by differential movements by size and sex suggests that tagging is unlikely to answer this question. Biochemical studies may be most appropriate. Initially, samples should be taken at the same time in different areas by sex and size. If repeated several times over the fishing season and no meaningful differences can be detected, then the fishery is probably exploiting a single stock. If the results suggest different stocks, then a large number of samples will be necessary to account for all combinations of size, sex, area and time before stock structure can be delineated.

Many questions remain unresolved regarding stock structure of Atlantic swordfish. While it may be theoretically possible to determine swordfish stock structure with existing methodology, guidelines for the interpretation of the results should be established. Regardless of the techniques used, some degree of mixing or separation among populations is likely to be found. Once the degree of mixing is known, an objective criterion should be applied to decide whether management need consider the population as one stock or several. One possibility is to consider the sensitivity or precision of the fishery model being used for management. If the degree of change in population abundance necessary before the model can detect a change is greater than the percentage mixing, then management as a single stock would be appropriate. If the percentage mixing is great enough or the fishery model sensitive enough then the stocks can be managed separately. Whether this or another approach is used, the criteria to define stock units for management purposes should be decided before a major research effort is undertaken.

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