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Stock Identity of Elasmobranchs in the North-east Atlantic in Relation to Assessment and Management

(Elasmobranch Fisheries – Oral)

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Abstract

Whilst biological stocks delineate species' populations which may be considered as self-perpetuating units, fisheries are monitored and regulated in areas which may or may not coincide with biological stock boundaries. Clearly, the assessment of the abundance of a stock and its response to exploitation should encompass that part of a species' range in which the effects of exploitation in a particular fishery or fisheries are recognisable. Such areas may be a management unit determined by the distribution of fisheries, but they should also include those parts of a particular species' population that have a high degree of biological integrity.

The natural variability and difficulty in measuring life-history and morphological characteristics at the population level suggest that these are not good indicators of stock separation for elasmobranchs. Information on population demography does, however, reveal the relationships between fisheries and resource, and indicates where sampling programmes for the collection of stock assessment data should take place. Tagging studies, in particular, can indicate a stock's main range and migrations, linked with a good description of the fisheries which share in its exploitation. The environmental parameters associated with the distribution of a species are also a useful guide to the likely boundaries of movement.

We show how biological and fishery information has been used to describe the stock identity for nine case study species in the DELASS project, from which informed decisions have been taken on the areas to be used for stock assessments.

INTRODUCTION

At present, the majority of fisheries in the North-east Atlantic are monitored and regulated in areas which are delineated by the International Council for the Exploration of the Sea (ICES). Though fish communities are unlikely to be restricted to any one area, the abundance of the more important commercial species, and their response to exploitation, are assessed within these areas, and thus management stocks are defined principally on a species-area basis. The concept of biological stocks, however, relies on the premise that fish populations are composed of intraspecific groups that have sufficient spatial and temporal integrity to warrant consideration as self-perpetuating units. It is apparent that several biological stocks of the same species may be exploited within each management area, and that stocks migrating through any particular area may have been exploited by fisheries operating in other areas. Stock assessments and fishery controls are considered to apply uniformly to species populations throughout each management area. It is therefore important that the population unit considered to be a stock responds largely independently to the effects of exploitation (Harden-Jones, 1968).

For fisheries management purposes, the stock unit is conventionally delineated by the extent to which the effects of exploitation in a particular fishery are recognisable through a species' population. Ideally, this management unit should also have a high degree of biological integrity, particularly when planning the collection of data to be used in stock assessments. Whilst there is also a need to ensure conservation of habitat, prevent the loss of genetic diversity and minimise the selective effects of fishing (Rymen, 1991), the priority for elasmobranch populations is that existing fisheries management strategies are improved within current constraints. Nevertheless, knowledge of the distribution, integrity and separation of marine resource stocks is fundamental to effective management in both the short term and more strategically. Since the funding for fisheries biology and management has been predominantly a reactive process, few commercially important elasmobranch species were subject to study before they began to be exploited. The major aim of this paper is to present a rationale for collecting and analysing information describing the identification and distribution of the stocks of commercially important elasmobranch species in relation to their assessment and management. We discuss the relative merits and disadvantages of the various techniques for elasmobranch fishes, and describe how different sources of information have been used to delineate stock assessment units for nine case study species in the European DELASS project.

METHODS OF STOCK IDENTIFICATION

Many approaches to the biogeographical identification of teleost stocks have been adopted for elasmobranch species; these include studies on the distribution and relative abundance of various life-history stages, marks and tags, both natural and artificial, meristics and morphometrics, parasites, population genetics and life-history parameters. The rationale behind each of the methods available for stock identification is detailed in references written by specialists in their respective disciplines, and summarised in Pawson and Jennings (1996).

(1) Distribution and Abundance

Data that describe the distribution and relative abundance of fish, and preferably for the various stages in their life-history, often provide the basic information that assists with the recognition and delineation of areas used by different stocks. For teleost species, eggs and larvae can be sorted from plankton samples to identify spawning areas and seasons, or to investigate their movement to nursery areas. There are relatively few studies aimed at describing the distribution of spawning or juvenile elasmobranchs fish, though data from trawl surveys may be used to indicate their geographical distribution and relative abundance. The nursery areas used by some species are easily identified because they are often located in accessible inshore areas and the juveniles are present at high densities. In contrast, the distribution of juvenile deep-water sharks is poorly known. Moreover, there are few studies that reliably indicate the relationships between nursery areas and the adult stocks to which the juveniles will subsequently recruit. Such relationships are frequently assumed simply on the basis of geographical location, even though recruitment from nursery areas to the adult stock is potentially the most dispersive phase in a species' life-history. These connections are a vital component of understanding stock integrity, and this information is increasingly relevant to fisheries management, because stocks are being fished more intensively and juvenile fish frequently form a major and relatively unpredictable proportion of the catch. Moreover, knowledge of the abundance of juvenile fish is often the best evidence of stock status (i.e. breeding success).

Landings data from the commercial fishery may provide a valuable indication of general population distribution and movements that could not be obtained on such an extensive basis by any other means. In order to obtain indices of relative abundance, however, it is desirable to standardise landings data from different areas by allowing for variations in fishing effort. In many cases, this is difficult or impossible to achieve, because any given species may be caught by a range of methods, in both directed and non-directed fisheries, and gear selectivity and efficiency is usually unknown. Additionally, size limits and landings quotas have encouraged fishermen to discard a proportion of the actual catch at sea, and this will not be recorded in official landings statistics, which frequently record certain groups of elasmobranchs (e.g. skates and rays, dogfishes and hounds, and deep-water sharks) as mixed species groups. Nevertheless, abundance indices can be successfully calculated for a few fishing methods, for example trawling, where landings may be expressed per hour of fishing, weighted by the power of the vessel or other factors which correct for catching power (**examples for spurdog, rays to be provided**).

Groundfish surveys are potentially valuable for the study of stock movements and distribution, because the fish captured can be identified to species level and catch rates are based on standardised sampling at known survey sites. Whilst the gear used may not represent the most efficient means of catching the species in question, the standardised approach may allow the relative abundance of a particular species in different areas to be estimated. Though abundance indices are often derived from surveys by different vessels at various times, and the interpretation of the results is complicated by several sources of variability, they can provide a good preliminary indication of the species' general distribution.

Stock identification is rarely the primary aim of studies describing fish distribution and relative abundance and, as a result, many are too infrequent or geographically imprecise to provide good evidence of stock separation. Additionally, they are not of direct use for the identification of individuals in areas where stocks mix. Nevertheless, the ICES Study Group on Elasmobranch Fishes has used the international bottom trawl survey CPUE as a means of studying the relationships between thornback rays (*Raja clavata*) in the North Sea and English Channel. (**Further details to be provided.)**. This hypothesis is supported by independent tagging studies.

(2) Natural marks - parasites

Fish may encounter parasites in specific geographic regions during their life. These may "mark" the fish, which then carry an identifiable natural tag indicating the habitat occupied previously. Thus, investigations of the parasite loading of fishes may provide information about their life-history, movements and stock identity.

The identification of parasites as natural tags offered several advantages over artificial tags. In particular, when fish have to be captured for tagging, it is possible to mark only a very small proportion of fish in the stock, and even smaller numbers of fish are recaptured. Parasites are found in delicate fish and those which inhabit deep water which, at present, cannot be marked effectively using artificial tags. Parasites are also cheaply sampled, as fish only need to be caught once, and can rapidly provide preliminary information to aid the design of expensive and complex population sampling and tagging studies.

To interpret the results of parasite studies, it is important to know parasite longevity in the host and the capacity of parasites to infect fish at different stages of their life-history. The infective stages should also have a discontinuous distribution in space and time (Lester, 1990). Subsequent examination of an infected fish would indicate the fishes' former habitats, and may allow it to be distinguished from other fish of the same species but different origins. Parasite studies have allowed the identification of fish from different stocks in areas where the stocks mix (**examples from A. Moore on Lesser spotted digfish; McVicar on cuckoo rays; J. Caira review, etc)**.

Whilst parasite studies may be validated using conventional tagging data, parasites also share some of the disadvantages associated with artificial tags. In particular, they will not permit stock boundaries to be recognised when sampling effort is low, or if the infection by a parasite is not uniform throughout a particular fish stock.

(3) Chemical contaminants.

Fishes that spend part of their life-history in chemically-contaminated water may absorb or ingest these chemicals. In subsequent years, the chemicals may remain in certain body tissues, and provide an indication of the former life-history of the fish. Whereas such sources are sometimes present in fluvial and estuarine environments, few such sources are available in the open marine environment, and such studies have not been applied to elasmobranchs.

(4) Artificial marks and Tags

Historically, one of the most frequently used approaches to the study of stock identity and migration involves marking fish. As with any other method of stock identification, successful interpretation of the results relies on a good knowledge of the sampling regime, both in catching fish for tagging and in recapturing marked fish. Hence, a practical knowledge of the distribution of the commercial/recreational fisheries effort is important.

A comprehensive review of marking methods is provided by Parker *et al*. (1991). The principal tagging methods adopted for studies of stock identification and migration in elasmobranchs have been those using serially-coded external tags, which have the greatest longevity and which allow the identification of individual fish. Many factors are known to affect the probability of tagged fish being recaptured and returned, including the method of capturing and handling fish, the choice of tag (Pawson *et al*., 1987), and the condition of the fish after tagging (Beverton and Bedford, 1963).

The majority of tagged marine fish are recaptured by commercial fishermen who are not trained to search for tags, but their efforts to find and report tagged fish may be encouraged by publicity and reward systems (Horsted, 1963). (**Elasmobranch examples to be provided)**

(5) Meristics and Morphometrics

The meristic characters that are most often used to distinguish teleost fish from different stocks are typically counts of serially repeated elements such as vertebrae, fin rays and gill rakers. Whilst the mean counts of meristic characters may be significantly different for samples from separate populations of a species, the allocation of a single fish to a specific stock may not be possible, because intra-stock variation in individual meristic counts can be almost as large as inter-stock variation.

Whilst meristic characters may indicate when juvenile fish come from stock-specific nursery environments, the differences, if due to environment alone, may only be identifiable or reliable within years.

Morphometric analyses have frequently provided a valuable means of distinguishing fish from different origins and, as one component of a multidisciplinary study of stock identity, they can provide useful results. Fish, however, are phenotypically more variable than most other vertebrates, and very large samples of fish may be required to elucidate morphometric differences between stocks. The methodology may not be validated without the support of complementary studies describing the interactions between genotype, environment and stages of development (Ihssen *et al*., 1981). Furthermore, given the large size and relatively low abundance of many elasmobranch fish, the collection of sufficient biological material can be logistically difficult.

The examination of calcified structures (e.g. scales and otoliths) is a common means by which to attempt stock discrimination in teleost fish. However, such calcified hard parts are lacking in elasmobranchs and will not be considered further.

(6) Genetics

Observations of differences in morphology and life-history patterns among con-specific fish populations led to the expectation of genetic differentiation within many fish species, and constitutes the basis for the "genetic stock": a reproductively isolated unit which is genetically different from other stocks (Jamieson, 1974). The results of genetic studies have often been assumed to provide a reliable basis for stock identification, because they consider fixed genotypic differences between individuals and stocks, surviving successive generations within stable breeding populations, rather than phenotypic differences that may be environmentally influenced. For the present purposes, however, this idea appears to be less applicable to marine fish because there are few barriers to migration between populations breeding in the sea, and the amount of gene flow between populations needed to maintain genetic homogeneity is very small (e.g. Grant and Utter, 1984). Carvahlo and Hauser (1994) review the genetic tools that have been used to provide information on stock structure.

Apart from applications to salmonid populations, genetic studies have rarely provided information which is of value to those addressing fishery management problems (Utter, 1991). Indeed other methods, such as tagging studies, have yielded better small-scale resolution, because they are more sensitive to the effects of short-term environmental and population events (Ihssen *et al*., 1981).

The chief difficulties arise when genetic analyses fail to provide evidence of stock separation. This does not necessarily indicate that there are no components within the fishery which have sufficient reproductive integrity to be treated as stocks for management purposes. Indeed, some species populations may comprise a number of stock units which have sufficient integrity in the medium term to be managed independently, since they respond independently to the effects of exploitation. The transfer of a few individuals between stocks (and thus the maintenance of genetic homogeneity within the population as a whole) may have little consequence to fishery managers.

With respect to elasmobranch fishes, there are few published studies that examine genetic differences in sharks (Heist, 1999). Species for which some data are available include *Isurus oxyrinchus* (Heist *et al*., 1996a), *Rhizoprionodon terraenovae* (Heist *et al*., 1996b), and other carcharhiniform sharks (Heist and Gold, 1998). Many shark species exhibit low genetic variation (Smith, 1986).

(7) Life-history parameters

Fish populations exhibit a range of life-history parameters to fit particular ecological demands. Individual traits such as growth rate, size at maturity or longevity can be described parametrically and have provided a basis for differentiating stocks, though their extreme plasticity in response to short-term environmental variation often reduces their value. Furthermore, the collection of samples that provide results that are truly representative of the population is not easy and observed differences in life-history parameters can be due to inadequate sampling.

For species that have a wide geographical range, the collection of samples from a variety of sites can be problematic, and the use of published studies can be hampered by differences in sampling protocol and the times of data collection.

Knowledge of population structure, growth parameters and size/age at maturity can provide an important basis for the initial recognition of stock management units and the design of stock identification studies over broad spatial scales. However, such parameters cannot be used to indicate whether stocks are genetically discrete, or whether fish are exhibiting characteristic phenotypic responses to their local environment or the effects of exploitation. Accordingly, they are not a reliable means by which to define stocks in the long-term. As with meristic and morphometric techniques, life-history analyses may indicate differences between fish sampled from discrete regions, but are unlikely to enable small samples of fish to be identified to specific stocks. Thus, their use in areas where stocks mix is extremely limited.

RESULTS: Stock identity of nine case-study species (DELASS project)

The following section summarises an interpretation of the available information for nine case study species in the DELASS project, in relation to stock identity for carrying out preliminary assessments.

(1) Leafscale gulper shark (*Centrophorus squamosus*)

The leafscale gulper shark is distributed over the NE Atlantic from Iceland to Senegal, but landings data by species are only available for Portugal and the Azores. French fisheries land leafscale gulper shark and Portuguese dogfish (see below) as *siki*. Data are available from experimental fishing and surveys, from Norway, Spain, Scotland and ireland (Girard, 2000). Males and immature females dominate samples west of Ireland and Britain and at Hatton Bank, while individuals <80 cm are only available in Portuguese surveys. Data on stock identity are inconclusive, though available evidence suggests that this species is highly migratory. The DELASS project concluded that the stock to be assessed should be the NE Atlantic.

(2) Portuguese dogfish (*Centroscymnus coelolepis*)

Portuguese dogfish is distributed over the NE Atlantic from Iceland to Senegal and also occurs off South Africa in depths down to 3 600 m. Landings data are available for France and Portugal, though France (and Ireland for 2000 and 2001) only have data for two species combined, *C. coelolepis* and *C. squamosus*, known as "siki". Very few small individuals have been recorded in the NE Atlantic. There is a lack of knowledge on migrations, though it is known that females move to shallower waters for parturition and vertical migration seems to occur (Clarke et al. 2001). Stock identity is difficult given that, for many countries, deep-water sharks landings often consist of several species. The DELASS project concluded that the stock to be assessed should be the NE Atlantic.

(3) Kitefin shark (*Dalatias licha*)

The Azorean fishery for kitefin shark started in the early-1970s, but data are fragmented. There are no tagging data, and no knowledge of horizontal migrations, but kitefin shark are caught wherever temperatures are around 10–11°C. Norwegian data (Hareide and Garnes, 2001) suggest that *D. licha* mainly occurs in ICES area X, and the DELASS project concluded that this ICES area was the most appropriate area for stock assessment.

(4) Spurdog (*Squalus acanthias*)

Spurdog has a world-wide distribution, but tends to be most abundant on shelf waters. France, United Kingdom, Norway and Ireland all take spurdog in directed fisheries and as an important by-catch in trawl fisheries. Other European make smaller landings. There are no detailed studies on parasites nor on genetics and, though life history parameters are well established, different methodologies have been applied which make comparisons difficult. Several tagging experiments have been carried out which show a wide dispersal around north-western Europe, though few individuals cross the Atlantic (Vince, 1991). The use of survey information is hampered by spurdog aggregating by sex and size. The DELASS project concluded that the stock to be assessed should include the following ICES areas: Norwegian Sea (II a), Skagerrak (III a), North Sea (IV a-c), Iceland and Faroe Is (V a-b), north-western Scotland (VI a-b) and the English Channel, Irish Sea and Celtic Sea (VII a-f). Landings from adjacent areas (e.g. Greenland, Barents Sea, Baltic and offshore waters (XII)) are low and, although *Squalus* spp. are taken in the Bay of Biscay and Cantabrian Sea (VIII) and off Portugal (IX), these landings could be comprised of *S. acanthias* and *S. blainvillei*. Additionally, very few fish tagged around the British Isles have been recaptured in the Bay of Biscay.

(5) Blackmouth catshark (*Galeus melastomus*)

Blackmouth catshark is widely distributed over the NE Atlantic and Mediterranean, and landings data are available for Spain and Portugal, with CPUE data from Norway and Ireland. It is heavily discarded in large-vessel fisheries in the north and in artisanal fisheries in the south. Estimates of relative abundance and length frequencies are available from Portuguese and Irish deep-water surveys. Although there is little information regarding the movements of scyliorhinids, many species tend to have localised populations and they are unlikely to undertake large-scale migrations. Hence, it is assumed that blackmouth catshark populations are essentially local, with one large population in which pseudo/meta-population segments can be distinguished and treated as management units. Though it may be reasonable to nominate two stocks, one off the Portuguese continental coast and one in VII/VI, there are insufficient data to distinguish between them. It was decided to only undertake an assessment for area the waters off the Portuguese mainland (IX a), as this in where the only appropriate data are available.

(6) Lesser-spotted dogfish (*Scyliorhinus canicula*)

The geographical distribution of lesser-spotted dogfish extends from Senegal to Norway, including the Mediterranean. It is generally not commercially exploited and the discard rate in the commercial fishery is very high (up to 90% in VIIIc). The only useful available data are from ICES area VIIIc for Spain. Tagging has resulted in most recaptures being reported from within a distance of 10 miles from the release area, and it seems that the species' distribution is continuous but with localised aggregations which are consistent over time. In the Cantabrian Sea, juveniles are found mostly in the eastern part, in deeper waters than adults, and they also occur in colder water. However, no information is available from shallow coastal areas. English surveys rarely catch juveniles, though hundreds of egg cases are caught in the Bristol Channel. There have been few studies on life-history parameters, though further north specimens grow bigger than in Spanish waters. Because lesser-spotted dogfish do not show a clear geographical migration, an assessment could in principle be based on localised populations within any arbitrary ICES division. The DELASS project concluded that assessing this species within the Cantabrian Sea (VIII c) was appropriate.

(7) Blue shark (*Prionace glauca*)

Results from National Marine Fisheries Service, UK and Irish tagging programmes show the blue shark undertake extensive movements throughout the North Atlantic (Kohler *et al*., 1998). There is little movement across the equator, or into the Mediterranean, indicating that any assessment of this species should be undertaken for the whole of the North Atlantic.

(8) Cuckoo ray (*Leucoraja naevus*)

Cuckoo ray occurs in the North Sea, Irish Sea, Celtic Sea and off north-west Scotland. Life-history parameters are available for several areas, though ageing is difficult, and results from the Celtic Sea are similar to those obtained for the North Sea. For most rays, no landings data or length frequency distributions are available by species, but French landings data are available for cuckoo ray by area since 1985 and survey data are available from western waters. The DELASS project concluded that the assessment area should focus on the Celtic Sea (ICES areas VII g, h, j).

(9) Thornback ray (*Raja clavata*)

Although thornback ray are one of the dominant species in commercial landings of "skates and rays", most commercial landings data are for all *Raja* species combined and data by species are only available for France. However, survey data are available by species from the ICES International Bottom Trawl Survey (1991 to 1996). Tagging data illustrate that fish do not move far (Walker *et al*., 1997), and there seems to be little mixing between the North Sea and the English Channel. Based on available literature, and analysis of the distribution patterns in survey data, the composition of the commercial landings and tagging data. The assessment area for *R. clavata* was defined as the southern and central North Sea (ICES areas IV b-c)

CONCLUSIONS

There have been considerable changes in the exploitation of marine fisheries in the last two decades and, for most elasmobranch species, research programmes have not been developed which enable sound management proposals to be made in relation to biologically meaningful stock units. It appears that our approach to stock identification must be more flexible if advice is to be given which will enable management to respond to changes in a fishery within a realistic time period. Ideally, an appropriate method for stock identification would allow individuals sampled from landings of marine species to be assigned to specific stocks. In the meantime, the stock manager has to be content with producing an overall view of the stock composition in a particular fishery at a particular time.

Information requirements

Although characteristics such as maturity ogives, length-weight conversion factors, morphometrics and meristics, parasites, genetics and chemical contaminants, may have a role in classical studies of stock identity, the natural variability and difficulty in measuring these at the population level in elasmobranchs suggest that they are not good indicators of stock separation.

Whilst parasitological approaches to stock identification appear to offer promise as indicators of stock separation, there is little data available for elasmobranch species. Similarly, there are few instances where the application of genetic techniques has provided information which could have been adopted by managers.

Information on population demography (age/length structure, spatial distribution of various life stages) does, however, enable us to recognise the relationships between fisheries and resource, and to point out where sampling should take place.

Probably the most useful stock identity information comes from tagging studies. Though tagging programmes are expensive, they do provide some of the best evidence for stock migrations and separation. Integrated studies which have the support of a tagging experiment are most likely to produce working hypotheses on stock identity which could be adopted and used by fishery managers (Vince, 1992). Tagging studies may also provide data for age validation and growth determination, subjects which are an important component in stock identification studies. Unfortunately, the numerous tagging studies which have been conducted have targeted only a minority of elasmobranch species, and further carefully planned tagging exercises are needed to establish the relationships between fish in adjacent regions. Where fish caught by the main fisheries have been tagged and recaptured, this will indicate a) the main range and migrations and b) which fisheries share the stock. Even when the species has not been tagged in the area of interest, it is useful to know the scale of its movement elsewhere. Are there long-distance movements between spawning, nursery and feeding areas, or is the species very local in its movement? In this connection, it is also very useful to know environmental parameters that are associated with the species' distribution, so that hydrographic data may be used to show likely boundaries of movement.

Undoubtedly, a comprehensive understanding of their life history is an almost essential pre-requisite to successful identification of stocks. Similarly, information on species populations which are well sampled by resource surveys at various stages in their life cycle (eggs and juveniles in nursery areas), and as adults by commercial landings and effort data, may also be interpreted for distribution, movements and, ultimately, the identity of the component stocks.

Lastly, a good description of the fisheries exploiting the stock is essential, not just to help with stock identity, but to help plan a sampling programme with which appropriate data can be collected for the assessment of stocks in relation to exploitation and biological sustainability.

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TABLE 1. A summary of the availability of data with which stock units have been identified regarding the nine case study species considered by DELASS.

Stock identity information	***C. squamosus***	***C. coelolepis***	***D. licha***	***S. acanthias***	***G. melastomus***	***S. canicula***	***P. glauca***	***L. naevus***	***R. clavata***
Landings data	1	1	1	2	2	1	1	1	1
Survey data	1	1	1	1	1	2	1	2	2
• **Distribution**	1	1	1	2	2	2	2	2	2
• **Nursery areas**					1	1	1	2	2
• **Spawning areas**						1		1	1
Tagging				2		1	2		1
Migrations				2		1	2		1
Life history: Age				1	1	1	1	1	1
• **Length**				2	2			1	
• **Growth**				1		1		1	
• **Maturity**				1		1		1	
• **Fecundity**	2	2	2	2		1	2	1	1
Parasites				1	1	1	1	1	1
Genetics									1
Behaviour									

blank: No published information
1: Some data available, but further data/analyses required
2: Data available and sufficient