Northwest Atlantic Fisheries Organization

Serial No. N4703 **NAFO SCR Doc. 02/84**

SCIENTIFIC COUNCIL MEETING – SEPTEMBER 2002

Spiny Dogfish (*Squalus acanthias L.*) of the Northwest Atlantic Ocean (NWA)

(Elasmobranch Fisheries – Oral)

Soldat V.T.

Atlantic Scientific Research Institute of Marine Fisheries and Oceanography (AtlantNIRO), 5, Dm. Donskoy Str., Kaliningrad, 236000, Russia
Tel.: 007 0112 22 55 47, Fax: 007 0112 219997, E-Mail: atlant@baltnet.ru

Abstract

This work is based on the results of Soviet and American cruises into the Northwestern Atlantic Ocean. The data on dogfish biology for 1968-1978 are presented and summarized in it. The main object of this work is to provide the theoretical basis of measures for rational exploitation of dogfish stocks in the Northwestern Atlantic Ocean. To achieve this object the following problems have been solved: the areas, time and conditions of fishing aggregations formation have been specified, the absolute abundance and biomass, optimal fishing length and age have been estimated. The researches performed allow to tackle the problem of quantitative assessment of food items consumed by the shark and to specify the place of dogfish in the regional ecosystem. The active fishery of dogfish resumed in 1990s has made these researches urgent again. This requires the research materials, which allow verify and supplement the basic results.

Introduction

Sharks, which after appropriate processing can become a valuable food product, constitute of significant reserve of the Northwest Atlantic fishery (Maksimov and Podsevalov, 1966; Aslanova, 1972; Shachkov, 1975; Bidenko *et al*., 1981). Major shark stocks condition allows to perform fishery with higher intensity and to increase essentially the catches (Azizova, 1973; Zolotova, 1978; Yanovskaya *et al*., 1983). Spiny dogfish *Squalus*, forming dense aggregations and accessible to modern fishing gears in the shelf waters off USA and Canada are especially promising to commercial utilization (Snythko and Geft, 1958; Pavlov and Zagorskaya, 1970; Aslanova, 1970). At present their fishery is obviously insufficient. These results not only in unjustified losses of fish raw material, but in conditions of intensive fishery, can also cause infringement of ecological balance with negative consequences to fish industry.

In NWA catches of spiny dogfish grew with the fishery extension. The catches significantly increased during the active exploration of NWA area by Soviet fishing fleet. Already in 1961, shark catches taken by the USSR fleet amounted to 9 389 tons (Table 1). Since 1978, spiny dogfish catches significantly decreased as a result of the Soviet fishery reduction in the economic zones of USA and Canada.

It is necessary to notice that for the entire period of NWA fishery exploration, the specialized shark fishery by the Soviet fleet was not properly arranged. Shark meat was not used in food purposes, while accidentally caught sharks were processed into meal or discharged into the sea. The basic reason of inefficient utilization of spring dogfish caught in NWA was the lack of traditional demand on production made from sharks at the markets of USA, Canada and USSR, certain problems in raw material processing and poor biological information constituting a basis of rational fishery arrangement.

The biological researches of spiny dogfish in Northwest Atlantic (NWA) were begun already in the 19th century (Atwood, 1865). They provided a general idea about the shark occurrence in the Atlantic coastal zone off the North America. The need for vitamin A produced from sharks liver, became a stimulus to the profound researches of spiny dogfish in Newfoundland waters during the World War II. The researches carried out in those years have significantly expanded the knowledge of its distribution and ways of migration in this area, catch length composition, fecundity and food items. The basic results of the researches are presented in works by V. Templeman (1944, 1954, 1963, 1965, 1976, 1984). In the same period the results of researches on fish distribution and biology in the Atlantic waters of USA shelf and Gulf of Maine were colligated (Bigelow and Schroeder, 1948; Bigelow and Schroeder, 1953; Bigelow and Schroeder, 1957). Following the vitamin A synthesizing in 1949, the specialized sharks fishery in USA was ceased and catches decreased considerably. The scientific interest to sharks also reduced. Many major biological aspects, necessary for scientific organization of spiny dogfish fishery remained partially or completely uncertain (Status of the Fishery Resources of the Northeastern United States for 1982, 1985).

The impulse of the shark further study in NWA gave the Soviet fishery exploration of the area accompanied by active scientific researches on the basis the information from fishing and research vessels. The joint Soviet-American researches including regular trawling surveys during 1967-78 provided the essential contribution to NWA ichthyofauna study. The results of fishery and research works provided the material required in detailed study of such biological aspects as spiny dogfish distribution area and its functional structure, feeding, sex and length-age structure of the stock, intra-species and inter-species relations; areas, time and conditions of commercial aggregations formation, stock size and allowable catch. The results multilateral analysis carried out on the basis of modern research methods allowed to prepare a theoretical substantiation of rational exploitation of the spiny dogfish stock in NW? the basic aspects of which are presented in this work.

The spiny dogfish biology had again attracted certain attention after resume of intensive shark fishery by USA fishermen in 1990s (Brodziak, *et al*., 1994; Rago, *et al*., 1994; Sosebee, 1998; McMillan and Morse, 1999). The intensive shark fishery has proved the basic conclusions outlined in the present works, concerning not only biology and recommendations for rational fishery organisation, but also concerning the shark role ecosystem of NWA.

Materials and Methods

The data of Soviet-American surveys of bottom fishes abundance in NWA became the basic source in the study of above mentioned problems of the spiny dogfish biology, distribution and abundance (Table 2).

Additional biological material was sampled at fish-scouting vessels "Belogorsk", 1975; "Quant", 1976; "Bakhchisaray", 1978, and others.

The spiny dogfish biomass and abundance was estimated based on the trawling surveys data obtained at random points (Cocran, 1953; Grosslein, 1969; Doubleday, 1981).

At American vessels "? lbatross-IV" and "Delaware-II" carried out the autumn surveys, the bottom trawl of American design "Yankee-36"was used. The winter trawling survey was carried out in 1978 at the Russian large-tonnage vessel using the bottom trawl "Hake-815". The parameters of trawls used in surveys are shown in Table 3.

The trawling duration was 30 minutes. In autumn trawlings were carried out for 24-hour periods, while in winter - only in light time of a day. Speed of the vessel with a trawl was 4.5 knots in the winter and 3.5 knots in other seasons. In the trawl cod-ends small-mesh insertions were fixed.

Based on the trawling surveys data the maps of distribution and relative abundance were drawn. The isolines were fitted for 1, 25, 50, 75, 100 ind. for American vessels and 1, 50, 100, 200, 500 ind. - for Soviet vessels.

To study the spiny dogfish vertical migrations the data on catches from several-day stations carried out practically in one location during 2-3 days with 2-hour intervals between trawlings were used.

The age was assessed applying the method proposed by the author (Soldat, 1982).

The estimation of natural mortality rate was carried out with the method by P.V. Turin (1972) and with the equation by Jackson (1939).

The age of optimum exploitation was estimated with the equation by Kutti and Qasim (1968).

The optimal intensity of the fishery was calculated with the method by Beverton and Holt (1969). The analysis of catch-per-recruit curve and instant fishing mortality was carried out with the method by Galand (Methodical recommendations..., VNIRO, 1980) and method by Rikhter (1970).

The optimal annual catch was determined with the formula by Baranov (1971a, b).

The data on materials used in researches are presented in Table 4.

Results of Researches

1. Systematics and Morphology

Squalus acanthias Linne, 1759

Synonyms*: S. Spinax* Olivius, 1780*; Spinax mediterraneus* Giste, 1848*; Spinax (Acanthias) suckleyi* Girard, 1954, etc.

The recommended Russian name – piatnistaja joliuchaja akula, katran (Lindberg *et al*., 1980). In the northern Russia its name is "nokotnitsa", in the Black Sea – "katran", in the Far East – "koliuchaja akula" (Lindbery and Legeza, 1956; Pinchuk, 1972). The most common Russian name is "koliuchaja akula".

In West Europe the most frequently name used is "Spurdog", in North America – "Spiny dogfish" (Bigelow and Schroeder, 1957, Garrick, 1960; Jones and Geen, 1976).

Squalus acanthias is the only species of the most widespread in the world acanthias group of Squalus genus. The detailed description of the spiny dogfish external and internal structure can be found in the works by Bigelow andSchroeder, 1953; Compagno, 1984; Hart, 1973.

The spiny dogfish differs from other species of Squalus with more backward location of abdominal fins (??ndurin and ? yagkov, 1984). The distance V-IID in sharks of Acanthias group is much shorter, than the distance ID-V, and is equal on the average to 67.3 % of its length, while in other groups this ratio exceeds 100%. Measurements showed that in spiny dogfish of NWA the distance V-IID equals to 67.3 % for fishes of 30-40 ?m in length and 54.4 % - for 85-95 cm. The basic morphological characteristics of spiny dogfish from NWA are presented in Table 5. The analysis of these data shows significant variability of plastic characteristics depending on length and sex of fish.

2. Distribution area and its functional structure

Spiny dogfish widely distribute in NWA (??rin, 1964; Bigelow and Schroeder, 1948, 1953; Leim and Scott, 1966; Jensen, 1966, 1969; Aasen, 1966, etc.). The distribution area covers shelf and adjacent waters off Northern America (Soldat, 1979). It extends from Cape Hatteras to Labrador, including subtropical, moderate and subarctic zones (Fig. 1).

Spiny dogfish is spawning for the whole year round. The most active spawning occurs in the cold period - from November to April. The birth of young spiny dogfish occurs in the southern part of the area on the sandy shallow shelf of USA and at the southern Georges Bank in rather cold and less saline waters of Labrador origin. Thus, the reproductive part of the area is restricted to these rather small shelf grounds. Immediately after the birth young sharks leave the shelf and migrate to the continental slope, where they are feeding and wintering in the deep waters. In the same deep-water shelf area off USA and continental slope large females are wintering. However, among them a partial differentiation is observed depending on biological condition and two-year reproduction cycle of females. Mature females of the current year spawning prevail in the grounds adjacent directly to the youth birth and wintering grounds. They are not mobile and are feeding poorly. Females of the next year spawning are more abundant in the grounds removed from spiny dogfish spawning areas. In the same areas the major males and juvenile sharks are wintering. They are feeding more actively than spawning sharks. Therefore the southern part of the area (USA shelf, Georges Bank) is not only the spawning ground of spiny dogfish but also wintering and feeding area of both newborn and larger sharks in a cold period of the year. The distribution of spiny dogfish in winter period is shown in Fig. 2.

With approach of spring the southern boundary of distribution shifts northwards (Fig. 3). The distribution area extends northwards covering extensive areas suitable for feeding. The shark aggregations distribute to entire Georges Bank, into the Gulf Maine and to the southern shelf of New Scotland. The distribution area increases also owing to a certain proportion of shark migration to the shallow shelf areas.

The summer period is characterized with a further shift of shark aggregations northwards (Fig. 4). In the northern part of the area some individuals reach Labrador. Feeding aggregations of spiny dogfish are formed off Newfoundland, in the Gulf of Maine and on the Browns Bank (Bigelow and Schroeder, 1953; Leim and Scott, 1966; Templeman, 1944, 1963; Scott, 1982). In the Gulf of Maine the spiny dogfish aggregations occur regularly in spring-summer period. The highest abundance of spiny dogfish is observed in the northern part - Gulf Fundy. Wintering aggregations are found in the deep-water western part of the Gu lf of Maine (Jensen, 1969).

In autumn the aggregations of dogfish migrate in the opposite direction, i.e. southwards (Fig. 5). This occurs very promptly and significantly depends on hydrologic peculiarities of the year. By the late autumn the basic part of the stock distributes in the southern part of the area and in wintering grounds.

Food items distribution affects essentially the spiny dogfish distribution during the feeding period. As the search works showed, in 1971 juvenile herring aggregations distributed in the Browns Bank area. In summer 1971 a large number of spiny dogfish feeding upon herring was found in the same area. These sharks were delayed in the feeding area and were not fully covered by the autumn trawling survey resulting in sharp reduction of shark abundance on the shelf of New England. The transition to feeding upon squid *Illex illecebrosus* may explain the changes characteristic of spiny dogfish distribution in 1975-1978. In this period *Illex illecebrosus* became one of the basic food items of spiny dogfish. The shark feeding upon squid aggregations did not undertake long migrations and distributed in the Georges Bank area. This explains substantial growth of spiny dogfish abundance in the autumn trawling survey zone.

3. **Migrations, population structure**

Spiny dogfish tagging experiments carried out in Newfoundland area and the Gulf of Maine (Templeman, 1944, 1954, 1958, 1963, 1976, 1984; Jensen, 1969) have shown that horizontal migrations usually occur along the coast. The specimens tagged in Newfoundland area were repeatedly caught in the Gulf of St. Lawrence, Gulf of Maine, and one shark was caught off the Cape of Henry. Less extended migrations were undertaken by individuals tagged in the Gulf of Maine. In general, the analysis of tagged specimen migrations showed the probable exchange of specimens between the removed parts of NWA.

The speed of spiny dogfish migrations is rather high. Thus, a female of 85 cm in length tagged in Newfoundland area passed the distance of about 1 000 miles for 132 days. The average speed of migration along a straight line is 14 km per day. The experimental works have shown that this speed is not the peak one for grey dogfish (Varich, 1971; Falk, 1962).

Based on the tagging data, Templeman (1954) assumed the existence of the northward migration in winter and the early summer, and southward migration in the late autumn. Later he found, that a certain proportion of sharks did not undertake regularly such long migrations, and could spend the winter in the feeding area. The ways of migrations are rather permanent. The schools of sharks appear in the same regions and in the same seasons, and the most tagged specimens are caught near the place, where they were tagged, even several years afterwards. The analysis of catch length composition, carried out based on the results of winter trawling survey, showed that the significant proportion of the stock represented by growing up sharks partially by females of the next year spawning do not annually migrate to reproduction areas on the New England Shelf while they spend winter outside this area. This is confirmed with reports about spiny dogfish wintering in the deep-water part of the Gulf of Maine, Gulf of St. Lawrence and in Newfoundland waters (Leim and Scott, 1966; Jensen, 1969).

Similar to many other fishes, spiny dogfish undertake diurnal vertical migrations (Jensen, 1966), i.e. in the dark time the sharks distribute in the upper water layers as compared to the distribution in the light time. The availability of such migrations is explained by the fact that spiny dogfish consume abundant, mainly pelagic fish and invertebrate species for which daily migrations are an important adaptive mean (Zusser, 1971).

The analysis of spiny dogfish catches obtained with the bottom trawls of different vertical opening, has shown, that in dark time the catches of spiny dogfish are much lower, than in the light time and depend on the trawls vertical opening (Table 6).

These data were used to draw the plot of night catches size against the trawl vertical opening (Fig. 6). If we carry out extrapolation and extend the plot upwards increasing the trawl vertical opening, the day-time and night catches will be equal at the opening of 6 m. Therefore, the vertical migrations of spiny dogfish in the New England shelf area are not significant and the sharks only ascend to a few meters above the bottom at night. In the day-time the sharks distribute in the near-bottom layer and can be caught with the bottom trawl.

However it should be noticed, that in the feeding period the sharks behaviour can considerably change. In Newfoundland area dogfish were observed in the day-time at the surface layer of water even visually (Templeman, 1965, 1984).

The problems of dogfish population structure in NWA were considered on the basis of the tagged shark migration routes study (Templeman, 1944, 1954, 1963; Jensen, 1969). Templeman assumed that a uniform independent population existed in the area considered. Later the same conclusion was made also by Jensen. The results of distribution, length-age composition of the stock and its dynamics researches, carried out in ?tlantNIRO, confirm the assumption of a single spiny dogfish population in NW? .

4. **Reproduction and maturation**

The first detailed description of spiny shark pre-natal development was given by Ford (1921). Further researches were carried out by the Soviet and foreign scientists in various areas of the World Ocean (Balashevich, 1957; Kondurin, 1973; Hisaw and Albert, 1947; Holden and Meadows, 1964; Wourms, 1977) and others. As to NWA, the most extensive study of this problem was carried out by Templeman (1944, 1954, etc.).

However, despite numerous researches, the stages of spiny shark maturity was presented only recently (??ndurin and ? yagkov, 1978; ? yagkov, 1982). These stages are applied to spiny shark from NWA in a simplified form, since the stages of females maturation were determined only based on urethra contents, and that of males – based on pterygopodes length and sperm availability in sperm sacks. Therefore, female maturity stages 1-2 and male maturity stages 2-3 were combined. The data on spiny shark biological condition in winter 1978 are presented in Tables 7 and 8.

As a result of females biological condition analysis a ratio between reproductive part of females stock in 1978 and 1979 and spawning equal to 51.4: 48.6 has been obtained. This allows to assume that the ratio between females of even and odd year-classes is equal to 1:1. Insignificant shortage of 1979 year-class females can be explained by their wintering in the areas not covered with the trawling survey.

Squalus acanthias is oviparous-viviparous shark. An embryo develops inside its mother but its growth proceeds basically at the expense of nutritious substances accumulated in the egg, since placenta is absent (Nikolskiy, 1971). Sharks of Squalus genus are characterized with a "conveyor" way of embryo development in two stages: the first stage – an ovule development in ovary, the second stage – an embryo development in the female uterus (Kondurin, 1974). These stages proceed simultaneously. Actually both of them proceed continuously, since the first stage is followed by the second immediately after the baby-shark birth and ovule impregnation. A cycle of eggs and embryo development is a relatively long process, extended for 4 years, and the interval between the moment of impregnation and the offspring birth is about 2 years. Therefore spiny dogfish females have a two-year reproduction cycle and produce offspring once every 2 years. Unlike females, spiny dogfish males have 1-year cycle and after maturation are able to mate every year (Kondurin, 1973).

Male maturation occurs at the length of about 60 cm, and at length of 70 cm all males are mature (Templeman, 1944). According to our observations, shark males in the New England area attain maturity at the length of 56-60 cm (Table 8).

The minimum length of mature female in Newfoundland waters was 71 cm (Templeman, 1944). Our observations show that in New England area dogfish females become mature at lengths above 70 cm. Mass maturation occurred in fish achieved 76-90 cm, while at the length above 95 cm all females were mature (Tables 9 and 10).

Spiny dogfish females are able to produce only few embryos (Templeman, 1944; Holden and Meadows, 1964). In NWA their number is from 2 to 13. Female fecundity increases with length. In young females up to 85 ?m in length the embryos number usually do not exceed 5, while in large females the mean fecundity increases to 6.8-10.5 (Tables 9 and 10). Only once a small female of 80 cm in length had 11 embryos. Relatively low fecundity was observed in females, caught in Newfoundland waters. There the number of embryos in large females of more than 90 ?m in length was 4.9 on average.

Procreation of spiny dogfish occurs in shallow coastal areas or at sea banks (Ford, 1921; Hickling, 1930). It associates with a cold period of the year and extends from November to April. However, it also occurs in summer (Bigelow and Schroeder, 1953). New-born sharks are 22-33 cm in length and of 30-100 g in weight. They are active and quite ready to vital functions. After the birth they immediately migrate from shallow to deep-water areas, where they grow rapidly, probably due to nutritious substances accumulated in the liver (Hickling, 1930).

The data on sex structure of spiny dogfish populations are rather inconsistent, basically as a result of differences in distribution and behaviour depending on sex and age (Probatov, 1957; Pavlov and Zagorskaya, 1970; Hickling, 1930; Bigelow and Schroeder, 1953). Most authors adhere to the opinion, that the sex ratio is close to 1:1 based on the data on embryos or youth sex ratio (??ganovskaya, 1933, 1937; Holden and Meadows, 1964; Jensen, 1966). However, they assumption exists that females numbers significantly (by 5 times) exceed males, based on the difference between females and males natural mortality rates (Springer, 1967). The winter trawling survey data showed that males comprised 50% of embryos, 52.4% in one-year shark catches, 50% in two -year old shark catches. In general, males comprised 56.3% of caught sharks. In large sharks the sex ratio considerably changes owing to different mortality rate and life duration of males and females. The calculations showed that males comprised 45% of the total spiny dogfish population in NWA.

5. **Feeding and trophic relations**

Spiny dogfish is a typical predator and consumes mainly fish and squids (Nikolskiy, 1971; Snitko and Geft, 1968; ??ndurin and ? yagkov, 1975; Templeman, 1944; Bigelow and Schroeder, 1953; Jones and Geen, 1977; etc.). The second important food items are Crustacea, worms, Coelenterata and other invertebrates, as well as alga. Therefore, it is possible to assign this species to ichthyotheutopages with a wide spectrum of food items (??ndurin and ? yagkov, 1975).

In the Northern Atlantic fish constitute 75% of spiny dogfish food items (Bennet, 1967). Its diet includes many important commercial fish species, such as herring, mackerel, cod, pollock, haddock, silver hake, flounder, etc (Holden, 1966; Leim and Scott, 1966; Grosslein *et al*., 1977). In NWA common species of fish and invertebrates constitute the basic food items of spiny dogfish (Fig. 7). Among them fish and squids amounted to more than 60% of food items found in shark stomachs. The fish and molluscs proportion reached 96% of the food contents by weight (Vinogradov, 1982). Crustacea constituted the basic food of young sharks up to 30 cm in length and occurred rather frequently in stomachs of large sharks. With increase of shark length its diet is diversified due to larger organisms, especially fish and squids. In sharks of more than 70 ?m in length the above food items proportion exceeds 70% (Tables 11 and 12).

Seasonal variability in a feeding revealed itself as follows: in autumn fish constituted 63.3% of consumed food items, while in winter only 31.4%. The other food items are represented by invertebrates.

Some distinctions in feeding related to spiny dogfish sex are also observed. In males food bottom organisms occur rarely than in female food. (??ndurin and ? yagkov, 1975; Holden, 1966). The above said peculiarities of feeding are explained with various ecology of juvenile and adult sharks, males and females (Kondurin and Myagkov, 1982). These difference shave been reflected in the cerebrum structure (Myagkov, 1974 and 1977). In juveniles and males cerebrum lobes related to vision are better developed while in females – those related to olfactory organs.

The study of the feeding quantitative aspect is complicated by the large number of empty stomachs being the result of feeding periodicity, rapid fast food digestion and probable food discharge during the trawl raising (Holden, 1966; Bennet, 1967). Besides, it is necessary to take into account a complex pattern of distribution caused by separate distribution of sharks depending age, sex and biological condition. This, in the feeding grounds the feeding intensity is higher than in reproductive grounds, where spawning females are not usually feeding (Springer, 1967).

Finally these peculiarities of a feeding resulted in underestimation of consumed food amount. Thus, according to Holden (1966), characterized by Konstantinov, 1970) "as rather moderate", food amount consumed by spiny dogfish in NWA exceeds the shark weight by 1.9 times. According to the data by Vinogradov (1982), a spiny dogfish in NWA consumes food in amount equal to 90% of its own weight during a year. This low food consumption most probably is explained by sampling in the areas of reproduction and wintering. The energy demands of sharks in these cases were covered at the expense of fat stocks in a liver, accumulated in the feeding period. Further researches showed, that spiny dogfish consumed food exceeding its own weight by 2.0-2.6 times (Bowman and Eppi, 1984; Waring, 1984).

The basic competitors of spring dogfish for food can be other shark species, rays and predatory fishes. However, as the trawling surveys have shown, the number of other shark species in New England area is not so large to create any serous competition. Only in the southern part of the area significant number of American smooth hound (*Mustelus canis*, Mitchill, 1815) appeared in catches, however, the area of both species joint distribution is rather small especially in summer.

As regards predatory fishes the similarity of food items was observed in anglerfish, red sculpin, cod, silver hake and white hake. The most similar food items are observed in anglerfish and red sculpin (Vinogradov, 1982; Grosslein *et al*., 1977). But the abundance of anglerfish in the area is not high, and food items similarity with sculpin does not exceed 12%. Taking into account a wide spectrum of spiny shark food items and it capability to consume abundant pelagic and demersal organisms (? yagkov, 1977), it is reasonable to assume, that predatory fishes do not create any significant competition. Besides they frequently become the prey of sharks. According to Springer (1967) a shark always has enough food.

Cannibalism is not typical to spiny dogfish in NWA. Own juveniles and other shark species have been never found in its stomachs. In teleost predatory fish stomachs a small spiny shark specimen of 23 cm in length was recorded only once. It was red hake (*Urophices chuss*, Walbaum) of 35 cm in length, which could pick up a dead baby-shark from the bottom. On this basis it is possible to conclude, that spiny dogfish have no enemies among teleost predatory fishes in the area. Among cartilaginous fishes some large sharks consume spiny dogfish (Templeman, 1963; Jensen, 1966). However, according to our observations, their abundance is not high in the area and they appear in warm season of the year, when the major aggregations of spiny dogfish migrate in northern part of the area. Therefore, spiny dogfish represent a final link of the trophic chain in the North-western Atlantic Ocean.

6. **Method of age assessment**

Modern mathematical models applied in assessment of the stock size and allowable catch are based on the population length-age composition researches. To provide high quality of these estimates a correct age assessment is very important. In NWA for region C3A the method of spiny dogfish age assessment has been developed by AtlantNIRO (Soldat, 1982).

Most researchers used spines in front of a dorsal fin to assess spiny dogfish age. They consider either marks on the spines surface (Kaganovskaya, 1933; Probatov, 1957) or annual growth zones on the spine cross-sections (Kondurin,1973), or both for control (Holden and Meadows, 1962). More complex methods are also applied (Ketchen, 1975; Jones and Geen, 1977). To assess female growth rates, the data on their sex maturity were applied as well (Templeman, 1944). The analysis of these methods has shown that the method of spiny dogfish age assessment based on the second dorsal fin spine age reading is the most promising one. However, the application of this method requires careful study of the pattern of annual growth zones formation closely related to sharks biology in the study area.

The comprehensive researches by Holden and Meadows (1962) have shown that the spine growth in spiny dogfish occurs in the internal side faced to the spine pulp and during age readings the "miss" of annual rings is probable. To provide precise age readings the correction factor is required taking into account diameter of the spine cross-section. For the purpose of this process simplification the table of correction factors has been prepared on the basis of the results of annual rings counting on the spine parallel cross-sections (grinds) (Table 13).

7. **Length composition, age and growth**

The scarce data on the catch length-age composition of the spiny dogfish in NWA are presented in Templeman (1944, 1954, etc.), Bigelow and Schroeder (1953), Jensen (1969) and others.

According to the data by Templeman (1944) in Newfoundland area the spiny dogfish specimens of 58-108 cm in length were found. The maximum length of males is 86 cm. The length frequency is described by means of one-peak curves with modal groups 71-75cm in males and 81-85 in females.

The data on the spiny dogfish composition in the New England area are based on the trawling surveys results (Table 14). The specimens of 21-111 cm in length were caught there. The length of males did not exceed 86 cm. In the winter period the specimens of 26-30 cm and 71-80 cm were the most numerous. The groups with low abundance were between these abundant length groups. In summer juvenile specimens up to 50 cm in length predominated in catches.

The length composition of spiny dogfish based on the autumn trawling surveys data are presented in Table 15. The length series are of complex pattern varying by years with several modal groups. This is explained not only by changes in spiny dogfish distribution, but also by various time of surveys fulfilment in different years.

The life cycle of spiny dogfish in different areas of the World Ocean is of various duration. In the Black sea 20 years old specimens were found (Probatov, 1957). The maximum age of females in the North-Eastern Atlantic is 21 years (Holden and Meadows, 1962). At the Far-East coast specimens up to 24 years old were met (??ganovskaya, 1933). The maximum age of spiny dogfish caught at the Pacific coast of the North America exceeds 40 years (Ketchen, 1975). In NW? the age of specimens of 105 cm in length is 28 years, and the assumed age of specimens above 110 cm in length exceeds 30 years.

The first experiments relevant spiny dogfish age assessments in NWA were carried out by Templeman (1944). However, the age readings were restricted to assessment of embryos and ripening female growth rates. The data on sharks growth a shark in other periods of life were obtained by him from the literary sources (Ford, 1921). These materials appeared far from true, since the scientifically grounded method of the spiny dogfish age assessment was proposed much later (Holden and Meadows, 1962). In this context the length composition of spiny dogfish catches from Newfoundland area was recalculated applying the length-age keys based on the trawling surveys carried out in the New England area during 1972-1978. The results are shown in Table 16.

Age composition of spiny dogfish catches fro the New England area based on the autumn trawling surveys data is presented in Table 17.

The length series are characterized by the abundance peak at the age of 1-2 years and gradual decrease of the older age-groups abundance with insignificant fluctuations. The only exception was 1978 when catches were principally represented by young sharks up to 6 years old.

In the winter about 30% of catch consisted of young sharks at the age of 2 years. Other age groups were represented by considerably lower numbers. In the spring the proportion of older age groups slightly increased. In the summer the balk of catch consisted of young sharks at the age of 1-2 year, while other age group were actually absent. By the autumn the number of large sharks in catches again increased. The complex pattern of catch length-age composition changes by seasons is explained by the older shark migration in the summer period outside the survey area.

The growth rate is the quantitative characteristic of the shark development. It can be traced in increase of the body size and weight of a body and is usually represented by the curves of growth (Mine and ?levezal, 1976). In Fig. 8 the curves of spiny dogfish embryos growth in Newfoundland area and the New England Shelf areas are shown. In Newfoundland waters the beginning of embryo formation occurred in summer months (June-July) (Templeman, 1944). Average length of embryos in July was 0.2 cm. Afterwards the fast growth is observed and by July of the next year the embryo length reaches 15-16 cm, and by November – more than 21 cm. The earlier embryo formation is observed in females, caught in the New England area (Hisaw and Albert, 1947). The curve of these embryos growth is somewhat shifted to the left, i.e. to the earlier period with a difference of 1.5 month at the embryo minimum length of 20 cm at the age of 2.5 months. Ketchen (1972) relates the noted differences in the embryo growth rate to the environment temperature difference in these two areas. The increase of these differences in large embryos can be explained by the large females with developed embryos primarily arrival to the New England area, where young sharks are both. The curve of growth is of S-shape, showing some decrease of the growth rate in the initial and the final periods of embryo formation.

After the birth the maximum length increment occurs during the first and the second years of life (Fig. 9). The annual increment in this period is equal to 6.6 cm. Then the growth rate slows down and amounts to 4-5 cm per year. At the age of maturity, i.e. 7-10 years in males and 12-18 years in females, the rate of growth decreases and the annual length increment are equal to 1.6 cm in males and 1.0 cm in females. At the age under 7 years the differences in the growth rate between males and females are insignificant. At 8 years old the growth rate of males slows down, while the intensive growth of females proceeds up to the age of 12 years. Since the life duration of males is less than that of females, they reach lower length. In catches females up to 110 cm in length are found, while the length of males does not exceed 86 cm.

The increase of spiny dogfish body weight is related to the linear growth. This is evident from the results of the relationship "length-weight" estimation:

$$\text{LogW females} = \log 0.002 + 3.148 \log \text{L females},$$
$$\text{LogW males} = \log 0.00r + 3.955 \log \text{L males}.$$

As it is seen from the equations, the spiny dogfish growth is isometric.

The plot of the body weight increases in more complex as compared to the body length increase. No significant reduction of the weight increase rate with age is observed in this case (Fig. 10). The weight increment is increased in the first 10 years in females and in the first 6 years in males, and only in oldest specimens the rate of weight increment slightly decreases.

The equation by Bertalanffy (1957a, b, 1960) for spiny dogfish females is as follows:

$$L_t = 104.5\ [1\text{-e} -0.095\ (t + 3.36)],$$
$$W_t = 5095\ [1\text{-e} -0.095\ (t + 3.36)]^{3.}$$

For males:

$$L_t = 91.8\ [1\text{-e} -0.106\ (t + 3.68)],$$
$$W_t = 2772\ [1\text{-e} -0.106\ (t + 3.68)]^{3.}$$

The value of *to* is –3.36 yeas for females and –3.68 years for males, i.e. in general corresponds to period of eggs and embryos pre-natal development.

The factor K characterizes the relative growth rate. It amounts to 0.095 for females and 0.106 for males, evidencing rather low growth rate of spiny dogfish. It is close to ?=0.11, obtained for NWA area (Holden and Meadows, 1962, 1964; Holden, 1968).

8. **Natural mortality and stock size**

The analysis of the trawling surveys results in NW? showed that winter trawling survey 1978 was the optimal one both in period and method for the spiny dogfish stock size estimation. This survey was carried out in January-March and completely covered wintering aggregations in the New England area. The bottom trawl "Hake-815" with the vertical opening of 5-6 m was used in the surveys. Trawlings were carried out only in the light time at the speed of

4.5 knots. All factors mentioned promoted the trawl catchability improvement relative to spiny dogfish and the catchability factor was assumed equal to 1.

According to the winter trawling survey data the minimum abundance of spiny dogfish in the New England area is estimated as 423 mln. ind. The comparison of catch and the minimum stock size revealed insignificant role of fishery in spiny dogfish stock formation. The annual catch of spiny dogfish from 1977 to 1986 did not exceed 2 % of the minimal biomass. Based on the data of winter trawling survey in 1978 the spiny dogfish biomass amounted to 45.1% of the total fish biomass caught, while the annual catch had never exceeded 1% of the total catch in NWA. This allows to assume that the spiny dogfish population in NWA is underfished.

To estimate mortality the data on certain age-groups abundance and variations by time caused by fishery and other reasons are required. On the assumption of reliable sampling the fishery can provide useful data on abundance and its dynamics (Baranov, 1971; Beverton and Holt, 1969; Zasosov, 1975, and others). The reliable data for the stock size and length-age composition estimation can be obtained also with the direct accounting methods, including trawling surveys. For this purpose the following is required: regular surveys, trawl catchability factor, total cover of the stock distribution area and identical selectivity for all length-age groups.

As regards spiny dogfis h these conditions have been observed. Both factor of selectivity and catchability factor are variables dependent on fish length, peculiarities of distribution, behaviour and other factors. The researches of length composition showed that specimens of the younger and middle ages are not sufficiently represented in the catches. Therefore, their mortality estimation with usual methods becomes impossible and it is necessity to search other ways of researches.

One of the methods based on the most general biological regularities that allow further assessments is the method by P. V. Turin. It is theoretically substantiated and described in details in publications (?urin, 1963, 1972, etc.). The method was tested not only with freshwater species, but also with some sea fishes (Efanov, 1974; Borisov, 1976; Boronin, 1981). It involves less rigid requirements to the trawling survey methods. Instead of the total distribution area coverage it is possible to restrict surveys to the reproductive zone and the trawl selectivity should be identical only for spawning specimens.

The winter trawling survey 1978 meets these methodical requirements. The total coverage of the spawning stock is provided by the survey area and period and coinciding with reproduction and wintering periods. High catchability is provided by trawlings fulfilment at the day-time, high-speed of trawlings and trawl parameters, while the identical selectivity is provided by a small-mesh insert application. This method has certain advantages since it allows to estimate natural mortality by age groups (Bulgakova and Efimov, 1982).

Taking into account, that the spiny dogfish population in NW? is underfished, the analysis of catch length and age composition of the winter trawling survey was carried out with the method by Turin. Length composition, average weighted by the catch, was recalculated applying length-age keys. The obtained data on the catches age composition in the survey area are presented in Table18. Further analysis of age composition was carried out in the sequence, proposed by Turin (Tables 19, 20). Taking into account significant differences in male and female biology of spiny dogfish, all subsequent calculations were carried out separately by sexes. The catches age composition is estimated in per mille then the series were smoothed by 3-year sliding values. The age series have been completed using logarithmic plots, where the bottom part of the curve corresponding to the older ages, is fitted on the basis of actual values, while the top part is completed using curves natural mortality (Fig. 11).

To draw the natural mortality curves, additional data on the catches age composition in the Newfoundland area, where, as has been found earlier, a part of population migrates, are used. These materials were obtained from trawlings carried out in April-May 1978 on the southern slopes of the Grand Newfoundland Bank (Table 21).

The catch period and occurrence of non-abundant in the New England area age-groups in the catches allow to assume that the missing part of spiny dogfish females stock was fished in this area. According to the equation by Jakson (1933) the survival coefficient factor of females at the age of 13-20 years is S = 0.88, and the annual mortality rate if Y = 0.12 or 12%. Taking into account migration of ripening sharks from Newfoundland area to New England it is possible to assume that it is slightly overestimated. Therefore, by averaging the total age array of both areas has been obtained. The annual mortality rate at the age of 13-20 years is assumed as 7%. However, the averaging results in slight underestimation of mortality rate. The actual value of this parameter is between 7 and 12%.

Applying the assumption by Turin on the gradual change of natural mortality with age, the curves of spiny dogfish female natural mortality at the age of 13-20 years have been completed. The curves of male natural mortality have been completed in the same way. The age of mass maturation of 8 years in males and 11.5 years in females is assumed as the inflection point.

The annual mortality rate for the males age array middle range at the age from 6 to 11 years is 9.2% and for females at the age from 6 to 20 years – 8.7%. The averaged annual mortality rate in the middle age groups is equal to 9%, being consistent with the instant mortality rate Z = 0.09. Taking into account, that the spiny dogfish population in NW? is underfished, the total mortality rate is assumed to be about equal to the natural mortality. From Tables 19 and 20 it is evident, that mortality rate of females at the age of 20-22 and 27-28 years and males at the age of 16-17 years is slightly higher as a result of the fishery impact.

As to the older and younger age-groups, the gradual increase of natural mortality is observed after the average age. While the estimation of mortality rate of older age-groups was carried out directly base don the actual data, in the younger age groups it has appeared impossible in view of extended birth period of young sharks and migration of a certain proportion of specimens from the survey area. Therefore, the model by Turin has been supplemented with the factors, taking into account females fecundity and maturity. It allowed to determine the top point of the survival curve in the model by Turin and to update the young shark mortality estimate. The annual mortality of females at the first year of life is equal to 45% (M = 0.60), and males – 48%, (M = 0.65). It should be noted, that introduction of new-born young sharks abundance estimate into the model completely fixes the position of the natural mortality and survival curves.

High abundance of spiny dogfish in NWA was noted by many researches (Bigelow and Schroeder, 1963; Jensen, 1966; Leim and Scott, 1966). Gulland (1971) gave the assumed biomass estimate 100-200 thous. tons. More precise data on the stock size were obtained after processing the trawling surveys data. They are presented in Edwards (1976); Edwards and Bowman (1978). According to their data the spiny dogfish biomass was about 1 mln. t in the period from 1963 to 1965, 1 mln 24 thous. tons in 1968-1969 and 362 thous. tons in 1972-1974. However, the data of the autumn and spring trawling surveys, which (as was mentioned above) not always reflected the stock dynamics, became the basis of researches. Besides, the trawl catchability coefficients of unknown reliability were applied. A sharp reduction of the stock in 1972-1974 mentioned by Edwards also gives rise to doubts since sharp variability of abundance is not typical of fishes with long life cycle and sustainable recruitment (Noskov, 1979). The data of the spring trawling survey in 1978 estimated the minimum biomass as 450 thous. tons, also evidence a good condition of the spiny dogfish stock.

Taking into account the above considerations, the spiny dogfish stock assessment was carried out based on materials of the winter trawling survey 1978 (Soldat, 1981, 1982). To provide a complete picture of the stock structure these survey data were entered into the model by ?urin. The results of these assessments are presented in Tables 22 and 23. The abundance and biomass of males were obtained on the basis of female stock size. Total number of females estimated by the reconstructed logarithmic diagram is 3463.1 individuals, and males – 2804.7 (Tables 19 and 20). Males constitute 81% of female number. Therefore the total male stock size can be assessed. From Table 23 it is evident, that the males stock amounts to 525.1 mln. ind. or 293.9 thous. tons. The total spiny dogfish stock in NWA amounted to 1173.7 mln. ind. or 1067.7 thous. tons. Comparing these estimates with fishery statistics it is possible to conclude, what even in the years of the most intensive spiny dogfish fishery in NWA its catches did not exceed 2% of the stock.

The researches showed that the spiny dogfish population can be assigned to the type of stocks with long life cycle and abundance dynamics determined principally by intra-population factors (Soldat, 1991). These stocks are notable for the steady and uniform recruitment and their stocks are not subject to significant fluctuations (Noskov, 1979). Therefore, in fishery management ensuring a catch at the optimal level or slightly below, it is possible to assume a constant annual catch value (Dementyeva, 1976). However it is necessary to note, that at catches exceeding the optimal level, the stocks will be soon undermined and recover very slowly.

The optimal level of a certain year-class exploitation can be determined applying a mathematical model of a catch developed by Beverton and Holt (1969). The calculations showed, that the optimal fishery intensity is reached at F = 0.11. It is in good agreement with the theoretical considerations by P.V. ?urin about the adaptive abilities of fish populations providing for F_{opt} at the level of M. The optimum catch is 18.1 thous. tons for females and 7.1 thous. tons for males (Soldat, 1991).

"The rational fishery in natural basins should provide exploitation of the ecosystem as a single unit… It provides for recovery of ecosystems existing in the basin so that to ensure the highest efficiency of the basin…." (Nikolskiy, 1974).

In the North-western Atlantic Ocean considerable reserves for the fishery effic iency improvement are available. They are significantly related to the spiny dogfish being not only a predator, but also a top link of the trophic succession. Therefore the second stage of the rational fishery arrangement can be the reduction of predator abundance, in our case of spiny dogfish. By such way it is possible to reach the stock increase and accordingly the catch of prey fishes (Alverson and Stansby, 1963; Gulland, 1971; Ketchen, 1975).

However, at present no developed model of spiny dogfish interrelations with other fish species is available. The researches by Kogen *et al*. (Stomach contents…., 1981) showed that predator impact upon their preys can become a significant, if not a major factor of fish production formation. Grosslein *et al*. (1977) noted that consumption of fishes on the Georges Bank by silver hake only exceeded the production of all fish species at the age of 1 year and older. The impact of the spiny dogfish can become not less significant, especially taking into account large size of its stock.

The problems relevant to spiny dogfish feeding were considered earlier. It was noted, that the annual consumption of food organisms per weight unit of this shark is comparatively non-significant. In the New England area, where reproduction occurs, the consumption of food organisms comprises 0.92 of the shark weight. In the feeding grounds the consumption is higher regions amounting on the average 1.9 in the Northern Atlantic. Thus, the total consumption of food organisms by the spiny dogfish population in the North-western Atlantic Ocean amounts to about 2 mln. tons.

Taking into account rather low allowable removal of spiny dogfish, high biomass and value of consumed food items represented by commercial fish and invertebrate species, it is obvious, that keeping this predator abundance at the high level contradicts the principles of the rational fishery. It is rather simply to attain some reduction spiny dogfish abundance by fishery arrangement at the level of the optimal catch or is slightly below in the areas of dense wintering aggregations formation at the Mid-Atlantic Bight. The control of spiny dogfish stock state and its preys can be easily executed by means of regular trawling surveys.

Acknowledgements

I express the deep gratitude to the following scientists-biologists, rendering considerable assistance to me in preparation of this article: V. Scornyakov – Doctor of Biology, A. Noskov – Doctor of Biology, V. Rikhter - Doctor of Biology and V. Chur - Doctor of Biology.

References

Aasen O. Om mulighetene for piggafiske vestatlantener om sommer//Fiskets Gang. 1966.-N15.-P.281-265.

Alverson D.L., Stensby M.E. The Spiny Dogfish (*Squalus acanthias*) in the Northeastern Pacific//Fish and Wildlife Service.-Washington, 1963.-47 p.

Aslanova N.E. Common shark species of the World Ocean //Inf. review. / CNIITEIRH. Vol.1. Fishery of the World Ocean resources.-1972.-Issue.5.-P.10-47. (In Russian).

Atwood N.E. Notes on dogfish and other sharks//Proc.Boston Soc.Nat.Hist. -1865. -Vol.10. -P.103-104.

Azizova N.A. Scantily exploited commercial fish species in the Northern Atlantic Ocean //Inf.review./ CNIITEIRH. Vol.1. Fishery of the World Ocean resources.-1973.-Issue.1.-P.1-27. (In Russian).

Balashevch G.A. On the problem of gonads development in *Squalus acanthias* L.//Scientific papers of Rostov-on-Don University.-1957.-Vol.57, issue.1-P.27-41. (In Russian).

Baranov F.I. On the problem of biological basis of fishery//Selected Works. M. 1971.-Vol.3.-p.12-56. (In Russian).

Baranov F.I. On optimal fishery rate//Selected Works. M., 1971a.-Vol.3.-p.115-129. (In Russian).

Bennet B.R. The Food of the Dogfish, *Squalus acanthias* L//Marine Reserch.-1967,-N4.-19 p.

Bertalanffy L. Wachstum//Helmske-Lenderken-Stark Handbuch der Zoologie.-1957a, Bd.8, lfg.10, Teil 4.-S.1-68.

Bertalanffy L. Quantitative laws in metabolism and growth//Quart.Rev.Biol.-Vol.32 (3), 1957b .-S.217-231.

Bertalanffy L. Principles and Theory of growth.-Amsterdam, 1960. -P.137-259.

Bidenko M.S., Perova L.I., Kukuev E.I., Sukhovershin V.V. Commercial fishes of the Atlantic Ocean .-M.: Light and Food Industry, 1981.-177 p. (In Russian).

Bigelow H.B., Schroeder W.C. Fishes of the western North Atlantic//Mem.Sears Found.Mar.Res. -1948.- N1, Pt.1. -P.1-576.

Bigelow H.B., Schroeder W.C. Fishes of the Gulf of Maine//Fish.Bull.of the Fish and Wildl.Serv. -1953.-Vol.53. -577p.

Bigelow H.B., Schroeder W.C. A study of the sharks of the suborder Squaloidea// Bull.Mus.Compar.Zool.Harv. -1957.-Vol.III (1).-P.1-150.

Biverton R.D., Holt S.D. Dynamics of commercial fishes abundance.-M.: Food Industry. -1969.-248 p. (In Russian).

Borisov V.M. The results of P.V.Turin's method application to assess natural mortality of Arctic-Norwegian cod *Gadus morhua morhua* L.//Problems of Ichthyology.-1976.-Vol.16, Issue.5.-P.886-898. (In Russian).

Boronin V.A. Some parameters of green notothenia optimal exploitation //Stocks condition and principles of rational fishery in the Atlantic Ocean: Collected papers./AtlantNIRO.-KaLiningrad, 1981.-P.19-23. (In Russian).

Bowman R., Eppi R. The predatory of Spiny Dogfish in the Northwest Atlantic// Int.Counc.Expler.Sea.C.M. -1984.-G:27.-16 p.

Brodziak J., P.J. Rago, H. Sosebee. Application of a biomass dynamics model to the spiny dogfish stock in the Northwest Atlantic. 1994. -Woods Hole, MA: NOAA/NMFS/NEFSC Ref. Doc. 94-18.

Bulgakova T.I. Efimov Yu.N. Methos of possible catch assessment taking into account the relationship of fish natural mortality and age //Problems of Ichthyology.-1982.-Vol.22, Issue.2.-P.200-206. (In Russian).

Cocran W.G. Sampling technicus.-New-York. J.Willy and Sons Inc., 1953.-330 p.

Cohen E. Spiny dogfish *Squalus acanthias*//Grosslein M.D., Azarovits T.R. Fish distribution: Mesa New-York Bight Atlas Monograph. 15.-New-York, Sea Grant Institute Albany, 1985.- P.1-55.

Bidenko M.S., Perova E.I., Kukuev E.I., Sukhovershin V.V. Commercial fishes of the Atlantic Ocean . -M.: Light and food Ind., 1981,-177 p. (In Russian).

Compagno L.J.V. Sharks of the world//FAO Species Catalogue.-1984. Vol.4, Part1.-249 p.

Dementyeva T.F. Biological basis of fishery prediction. -M.: Food industry , -1976,-239 p. (In Russian).

Doubleday W.G. Manual on groundfish surveys in the Northwest Atlantic//NAFO Scientific Council Studies.-1981.-N2.-P. 1-55.

Edwards R.L. Middle Atlantic fisheries recent changes in populations and outlook//Amer.Soc.Limnol.Oceanogr.Spec.Symp. -1976. -Vol.2. -P.302-311.

Edwards R.L., Bowman R.E. An estimate of the food consumed by Continental Shelf fishes in the region between New Jersey and Nova Scotia//Symposium on predator-prey systems in fish communities. -Atlanta, 1978. -P.1-58.

Efanov V.N. Yellow-tail flounder *Limanda ferruginea* (Storer) stocks condition and rational fishery in New England.: Abstract of Thesis of Doctor of Biology.-Kaliningrad , 1974.-19 p. (In Russian).

Falk U. Wie schnell schwimmen marine Nutzfische? Fischerei-Forschung. -1962. Heft 3.-S.8-9.

Ford F. A contribution to our knowledge of the life histories of the dogfish landed at Plymouth//J.Mar.Biol.Ass.U.K. -1921. -Vol.13. -P.468-505.

Garrick J.A.F. Studies on New Zeeland Elasmobranchii. Pt.12//Trans.Roy.Soc., N.Z.-1960. -Vol. 88, 3. -P.519-557.

Grosslein M.D. Groundfish survey methods//NMFC-Woods-Hole: Massachusetts Laboratory Reference N69-, 1969.- 34 p.

Grosslein M.D., Langton R.W., Sissenwwine N.P. Recent fluctuations in pelagic fish stocks of the Northwest Atlantic-Georges Bank region, in relation to species interactions//Rapp. P-V.Reun.Cons.int Explor.Mer. -1977. P.374-404.

Gulland J.A. The fish resources of the ocean//FAO Fisheries technical papers. -1971.-N97. -425 p.

Hart J. Pacific fishes of Canada. -Ottawa, 1973.-740 p.

Hickling C.F. A contribution towards the life-histort of the spurdog// J.Mar.Biol.Ass.U.K. -1930. -Vol.16. -P.529-576.

Hisaw F.L., Albert A. Observations on the spiny dogfish *Squalus acanthias*// Biol.Bull.: Woods-Hole. -1947.-Vol.92.-P.187-199.

Holden M.J. The food of the spurdog, *Squalus acanthias* (L.)//J.Cons. -1966. -Vol.30. -N2. -P.255-266.

Holden M.J. The rational exploitation of the Scottish-Norwegian stocks of spurdogs (*Squalus acanthias* L.)//Fishery Invest Series 2. -1968. –Vol. 25. -N8. -28 p.

Holden M.J., Meadows P.S. The structure of the spine of spur dogfish (*Squalus acanthias* L.) and its use for ege determination//J.Mar.Biol.Ass.U.K. -1962. Vol.42.-N2.-P.179-197.

Holden M.J., Meadows P.S. The fecundity of the spurdog (*Squalus acanthias* L.)// J.Cons. -1964.-Vol.28. -N3. -418-424.

Jackson C.H.H. The analysis of an animal population//J.of Animal Ecology. -1939. N8 (2). -P/182-194.

Jensen A.C. Life history of the spiny dogfish//U.S.Fish.BULL. -1966. -Vol.65. -N3. -P.527-554.

Jensen A.C. Spiny dogfish tagging and migration in North America and Europe//Research Bulletin, 1969. -Vol.6. -P.72-78.

Jones B.C., Geen G.H. Taxonomic reevaluation of the spiny dogfish (*Squalus acanthias* L.) in the northeestern Pacific Ocean//J.Fish.Res.Board.Can. -1976. Vol.33.-N11. -P.2500-2506.

Jones B.C., Geen G.H. Age determination of an elasmobranch (*Squalus acanthias*) by X-ray spectrometry//J.Fish.Res.Board Can. -1977.-Vol.34. -N1. -P-44-48.

Jones B.C., Geen G.H. Food and feeding of spiny dogfish (*Squalua acanthias*) in British Columbia waters//J.Fish.Res.Board Can. -1977. -Vol.34. -P2067-2078.

Kaganovskaya S.M. Method of estimation of spiny dogfish (*Squalus acanthias* L.) age and catch composition //Bulletin of Far-East Branch of Science Academy of USSR.-1933, N1-3.-p.139-141. (In Russian).

Kaganovskaya S.M. Materials on the fishery biology of spiny dogfish (*Squalus acanthias*)//News /TINRO.-1937, vol.10-p.103-115. (In Russian).

Ketchen K.S. Size at maturity, fecundity and embrionic growth of the spiny dogfish (*Squalus acanthias*) in British Columbia waters//J.Fish.Res.Board Can. -1972. -Vol.29. -N12. -P.1717-1723.

Ketchen K.S. Age and growth of dogfish *Squalus acanthias* in British Columbia waters//J.Fish.Res.Board Can. -1975. -Vol.32. -P.43-59.

Kondyurin V.V. Some data on spiny dogfish (*Squalus fernandinus*) biology in the South-Eastern Atlantic shelf //Trudy /Kaliningrad Technical Institute of Fisheries.-Kaliningrad, 1973,issue.46.-P.44-53. (In Russian).

Kondyurin V.V. On the method of spiny dogfish *Squalus fernandinus* Molina age assessment in the South-Western African shelf // Trudy /Kaliningrad Technical Institute of Fisheries.-Kaliningrad, 1973,issue.46.-P.99-108. (In Russian).

Kondyurin V.V. Sex maturity and relationship to females growth rate of spiny dogfish *Squalus fernandinus* Molina in the South-Eastern Atlantic Ocean// Trudy /Kaliningrad Technical Institute of Fisheries.-Kaliningrad, 1973,issue.46.-P.109-113. (In Russian).

Kondyurin V.V. Spiny dogfish *Squalus fernandinus* Molina of the South-Eastern Atlantic Ocean: Abstract of Thesis of Doctor of Biology.-Kaliningrad, 1974.-18 p. (In Russian).

Kondyurin V.V., Myagkov N.A. Feeding of some common shark species.// Fisheries.-1975.-N9.-P-1-6. (In Russian).

Kondyurin V.V., Myagkov N.A. Maturity stages of viviparous sharks // Scientific-technical progress and problems of industrial fishery .-M.,1978.-P.7-9. (In Russian).

Kondyurin V.V., Myagkov N.A. Morpho-biological characteristics of two shark species *Squalus acanthias* L. and *Squalus fernandinus* Molina sensa Smith (Squalidae, Elasmobranchii) from the South-Eastern Atlantic Ocean //Problems of Ichthyology .-1982.-Vol.22, issue.2.-P.214-223. (In Russian).

Kondyurin V.V., Myagkov N.A. Sharks Squalus L. of the Western Atlantic Ocean //Problems of Ichthyology.-1984.-Vol.24, Issue.4.-P.667-669. (In Russian).

Konstantinov K.G. Life-cycle, fishery and utilization of sharks.-Murmansk, 1970.-101 p. (In Russian).

Kutty M.K., Quasim S.Z. The estimation of optimum age of exploitation and potential vield in fish populations//J.Cons.-1968, -vol.32.-N2.-P. 49-255.

Leim A.H., Scott W.B. Fishes of the Atlantic Coast of Canada//Fish Res.Board Can. -1966. -N155. -485 p.

Lindberg G.U. , Gerd A.S., Rass T.S. Glossary of marine commercial fishes names of the world fauna. -L.: Nauka, 1980.-564 p. (In Russian).

Lindberg G.U., Legeza M.I. On two forms of spiny dogfish *Squalus acanthias* L.//Zool. Journal-1956.-Vol.36, Issue.11.-P.1685-1688. (In Russian).

Maksimov V.P., Podsevalov V.N. Sharks of the Atlantic Ocean.-Kaliningrad, AtlantNIRO.-1968.-56 p. (In Russian).

Mc Millan D.G., Morse W.W. Essential fish habitat source document: Spiny dogfish, *Squalus acanthias*, life history and habitat characteristics//NOAA Technical Memorandum NMFS-NE-150. Woods Hole, Massachusetts, September 1999.

Methodical recommendations on the principles of fishery regulation and methods of fish populations assessment.-M.: 1980.-23 p.- All-Union NIRO. (In Russian).

Mina M.V., Klevezall G.A. Animals growth .-M.: Nauka, 1976.-291 p. (In Russian).

Myagkov N.A. Morphological peculiarities of males and females cerebrum in spiny dogfish Squalus//Zool. Journ.-1974.-Vol.53, Issue.9.-P.1324-1329. (In Russian).

Myagkov N.A.. Two forms of sharks cerebrum stipulated by their ecology // Journ. of General Biology.-1977.-Vol.38, N2.-P.305-309. (In Russian).

Myagkov N.A. Methodical manual for sampling and preliminary analysis of sharks.-M.-All-Union NIRO.-1982.-28 p. (In Russian).

Nikolskiy G.V. Particular ichthyology. -M.: Higher School, 1971.-427 p. (In Russian).

Nikolskiy G.V. Theory of fish school dynamics .-M.: Food Industry,-1974.- 448 p. (In Russian). (In Russian).

Noskov A.S. On types of fish schools dynamics and long-term prediction of fish catches //Study of commercial fish abundance dynamics in the Atlantic Ocean: Collected papers./AtlantNIRO.-Kaliningrad, 1979.-P.3-6. (In Russian).

Pavlov M.A., Zagorodskaya L.D. Biology and outlook of shark fishery in the Northern Atlantic Ocean //Inf.Review./CNIITEIRH. Ser.1. Fishery Ichthyology and Oceanology.-1970, Issue .2-P.98-104. (In Russian).

Pintchuk V.I. Systematics of sharks of the World Ocean .-M.: Food Industry , 1972.-P.240. (In Russian).

Probatov A.N. Materials of Spiny dogfish (*Squalus acanthias* L.). study in the Black Sea //Scientific papers of Rostov-on-Don University, 1957.-Vol.57, Issu.1.-P.5-26. (In Russian).

Rago P.J., Sosebee H., Brodziak J., Anderson E.D. Distribution and dynamics of Northwest Atlanthic spiny dogfish (*Squalus acanthias*). 1994. -Woods Hole, MA: NOAA/NMFS. NEFSC Ref. Doc. 94-19.

Rikhter V.A. On the problem of long-living fish species regulation //Stocks assessment and fishery regulation in the Atlantic Ocean O. Collecyed papers./AtlantNIRO.-Kaliningrad, 1977.-p.3-12. (In Russian).

Scoot J.S. Depth, temperature and salinity proferences of commen fisheries of the Scotian Shelf//J.of Northwest Atlantic Fish.Scienc. -1982. -Vol.3. -N1. -P.29-39.

Skachkov V.P. Sharks utilization for food purposes.-M.: Food Ind. Edition, 1975.-53 p. (In Russian).

Snitko V.A., Geft V.N. Spiny dogfish and its fishery //Fish. Ind..-1968,- N5, -P.8. (In Russian).

Soldat V.T. Biology, distribution and abundanse of the spiny dogfish in the Northwest Atlatic//ICNAF. -Res.Doc.79/VI/102. -1979. Serial N5467. -9 p.

Soldat V.T. Assessment of spiny dogfish mortality and abundance in the North-Western Atlantic Ocean //State of stocks and principles of rational fishery in the Atlantic Ocean: Collected papers./AtlantNIRO.-Kaliningrad, 1981.-P.70-77. (In Russian).

Soldat V.T. Age and size of spiny dogfish (*Squalus acanthias*) in from the Northwest Atlantic/NAFO.-Scientific Council Studies. -1982. -N3. -P.47-52.

Soldat V.T. Mortality and abundance of juvenile spiny dogfish in the North-Western Atlantic Ocean //All-Union Conference on the theory of abundance formation and rational exploitation of commercial fishes -M.: VNIRO, 1982. -P.298-299. (In Russian).

Soldat V.T. Spiny dogfish (*Squalus acanthias* L.) of the North-Western Atlantic Ocean and recommendations on its rational fishery. //Abstract of Thesis of Doctor of Biology /VNIRO -1991.-M. 23 p. (In Russian).

Sosebee K. Spiny dogfdish//Status of fishery resources off the Northeastern United States for 1998/NOAA Technical Memorandum NMFS-NE-115. P.112-113.

Springer S. Social organization of sharks populations.-Sharks, scates and rays. -Baltimore, Maryland: Johns Hopkins Press. -1967. P.149-174.

Status of the fishery resources off the northeastern United States for 1982// NWFC-Woods Hole: Collected Reprints. -1985. -Vol.III. P.1-129.

Templeman W. The life-history of the spiny dogfish (*Squalus acanthias*) and the vitamin A values of dogfish liver oil//Res.Bull.Div.Fish.Resour.Newfoundland. -1944. -Vol.15. -102 p.

Templeman W. Migrations of spiny dogfish tagged in Newfoundland waters// J.Fish.Res.Board Can. -1954. -Vol.11. -N4. -P.351-354.

Templeman W. Distribution of sharks in the Canadian Atlantic//Fish.Res.Board Can. -1963. -N140. 78 p.

Templeman W. Mass mortalities of marine fishes in the Newfoundland area prosumelly due to low temperature//ICNAF -Spec.Publ. -1965. N6. - P.137-147.

Templeman W. Transatlantic migrations of spiny dogfish (*Squalus acanthias*)// J.Fish.Res.Board Can. -1976. -Vol.33. -N11. -P.2605-2609.

Templeman W. Migrations of spiny dogfish, *Squalus acanthias*, and recapture success from tagging in the Newfoundland area, 1963-1965//J. of Northwest Atlantic Fishery Sc. -1984.-Vol5.- N1. -P.47-53.

Torin Yu.A. Sharks fishery in the Atlantic Ocean //Fish. Ind.-1964, N9. -P.54-57. (In Russian).

Turin P.V. Biological basis of fishery regulation in inland basins. -M.: Food Ind. Edition, 1963.-120 p. (In Russian).

Turin P.V. "Normal" curves of fish survival and growth rate as a theoretical basis of fishery regulation //Scientific basis of fishery in the inland basins of USSR.-L., 1972. -P.71-128. (In Russian).

Varitch Yu.N. Analysis of alive dogfish Анализ *Squalus acanthia* streamlining applying the informational system //Zool.Journal-1971.-Vol.50, Issue.1.-P.126-129. (In Russian).

Vinogradov V.I. Feeding, trophic relations of silver hake *Merluccius bilinearis* (Mitchill) and red hake *Urophycis chuss* (Walbaum) in the Georges Bank area and adjacent waters: Thesis of Doctor of Biology .-Kaliningrad, 1982.-241 p. (In Russian).

Waring G.T. Changes in population structure and abundance of spiny dogfish off northeast coast of the United States//NAFO, Scientific Council Meeting. -1984. -SCR Doc.84 (IX). -14 p.

Wourms J.P. Reproduction and development in chondrichthyan fishes// Amer.Zool. -1977. -Vol.17. -N2. -P.379-410.

Yanovskaya N.V., Kudryavtseva A.V., Morozova R.R. et al. World fishery fish and non-fish species in 1975-1980. -M. : ВНИРО. -1983 -257 p. (In Russian).

Zasosov A.V. Dynamics of commercial fishes abundance.-M.: Food Industry, 1976,-312 p. (In Russian).

Zolotova Z.K. Outlook of sharks fishery in the World // Inf. Review/CNIITEIRH. Ser.1. Fishery utilization of the World Ocean resources.-1978.-Issu.6.-P.1-29. (In Russian).

Zusser S.G. Diurnal vertical migrations of marine planktonphage fishes.-M.:Food Industry, 1971,-224 p. (In Russian).

Table 1. Spiny dogfish catches (t) in the Northwest Atlantic Ocean (ICNAF, NAFO, Statistical Bulleting, 1966-1988).

Years	USSR	Total catch	Years	USSR	Total catch
1964	-	8429	1975	22331	22500
1965	188	7885	1976	16681	17233
1966	9389	12750	1977	6942	7513
1967	2418	3488	1978	577	1889
1968	3950	5097	1979	105	3383
1969	8889	10195	1980	351	3806
1970	4924	6052	1981	516	8401
1971	10792	11639	1982	27	7388
1972	23302	23821	1983	-	5413
1973*	12783	17388	1984	291	4858
1974	20444	24552	1985	-	4052

* Before 1973 statistical data on all shark species had been used where spiny dogfish constituted 95% .

Table 2. Trawling survey data used.

NN	Survey year	Survey period	Vessel name	Number of trawling stations
1	1968	10.10-25.11	“Albatross-4”	260
2	1969	8.10-8.12	“ Albatross -4”	211
3	1970	15.10-1.11	“ Albatross -4”	123
4	1971	5.06-29.06	“? rgus”	100
5	1971	29.09-25.10	“ Albatross -4”	186
6	1972	28.09-19.11	“ Albatross -4”	231
7	1973	16.09-25.10	“ Albatross -4”	121
8	1974	12.03-4.05	“ Albatross -4”	325
9	1974	22.03-6.04	“Chronometer”	74
10	1974	24.09-1.11	“ Albatross -4”	174
11	1975	29.08-18.11	“ Albatross -4” “Delaware-2”	185
12	1976	7.09-12.11	“ Albatross -4”	186
13	1977	26.09-12.11	“ Delaware -2”	267
14	1978	29.01-20.03	“Argus”	167
15	1978	12.09-18.10	“ Delaware -2”	150

Table 3. Parameters of trawls used in the trawling surveys.

Trawl type	Horizontal opening (m)	Vertical opening (m)
Yankee-36	11.0	3.2
Yankee -41	11.8	4.6
Hake-815	16.5	5.5

Table 4. Data used in shark researches.

Data	Number (ind.)
Length measurement	66600
Morphological measurements	75
Biological analysis	1516
Fecundity samples	381
Feeding samples	1728
Aging samples	2097
Including data for winter 1978	1503

Table 5. Morphological characteristics of spiny dogfish of NWA.

Plastic characteristic	Females				Males	
	84 - 95 ?m		30-50 ?m		30-50 ?m	
	25 ind.		25 ind.		25 ind.	
	Estimate	δ	Estimate	δ	Estimate	δ
% of the body length						
Lc	90.00	0.10	88.43	0.23	89.21	0.18
aID	35.02	0.14	36.48	0.16	36.25	0.18
aIID	66.77	0.24	65.00	0.25	65.72	0.21
aF	20.34	0.13	22.40	0.10	22.32	0.18
aV	57.44	0.54	52.27	0.17	51.86	0.23
IDV	19.78	0.19	16.71	0.16	16.45	0.16
VIID	10.74	0.11	10.46	0.13	11.60	0.12
DD	30.19	0.15	27.78	0.15	28.71	0.21
VC	21.28	0.15	22.16	0.16	23.13	0.15
ID	5.52	0.07	4.87	0.07	4.91	0.06
hID	5.86	0.06	5.95	0.10	6.10	0.09
IID	3.87	0.04	3.67	0.04	3.76	0.04
hIID	3.88	0.06	3.97	0.05	3.99	0.05
F	5.88	0.06	6.01	0.08	6.00	0.08
lP	14.43	0.14	12.95	0.11	12.93	0.13
V	5.85	0.04	5.40	0.08	5.12	0.10
Cs	19.15	0.11	21.24	0.15	21.30	0.12
Ci	10.22	0.11	10.37	0.12	10.69	0.08
C	16.58	0.09	18.45	0.15	18.34	0.08
% of the head length						
an	25.82	0.20	26.67	0.27	26.48	0.29
aO	38.96	0.21	40.71	0.38	40.84	0.21
aB	50.97	0.30	53.08	0.52	53.35	0.25
O	18.35	0.14	21.48	0.33	21.79	0.20
B	36.13	0.35	31.87	0.46	32.80	0.30
nn	22.72	0.28	22.15	0.28	21.75	0.22

Plastic characteristics have been changed according to the scheme by Myagkov (1982).

Table 6. Ratio of spiny dogfish day-time and night catches depending on the trawl vertical opening.

Trawl vertical opening, m	Ratio of night/day-time catches, %
3.2	21.6
4.5	50.5
4.5	65.0
4.6	67.4

Table 7. Ovaries development of spiny dogfish females based on the winter trawling survey 1978.

Length, ?m	Maturity stage					Number (ind.)
	I - II	III	IV	V	VI	
51-55	49					49
56-60	46					46
61-65	55					55
66-70	49					49
71-75	38					38
76-80	27	5	2	10		44
81-85	36	21	6	24		87
86-90	13	48	5	13	2	81
91-95		36	5	10	2	53
96-100		31	2	3	7	43
101-105		16		3	1	20
106-110		3		1	1	5
Total	313	160	20	64	13	570

Table 8. Testicles development of spiny dogfish males based on the winter trawling survey 1978.

Length, ?m	Maturity stages					Number (ind.)
	I	II - III	IV	V	VI	
21-25	26					26
26-30	61					61
31-35	28	3				31
36-40	20	17				37
41-45	7	51				58
46-50	1	44				45
51-55		49	1			50
56-60		29	21	2		52
61-65			16	26	1	43
66-70			2	83	6	91
71-75				119	7	126
76-80				71	3	74
81-85				27	2	29
Total	143	193	40	328	19	723

Table 9. Maturation and fecundity of spiny dogfish females based on the autumn trawling surveys 1974-1976.

Females length, ?m	Number of fish examined, ind.	Number of mature fish, %	Mean fecundity
61-65	12	0	-
66-70	10	0	-
71-75	18	12	2.0
76-80	20	45	6.2
81-85	37	81	4.7
86-90	65	94	5.4
91-95	48	98	6.8
96-100	12	100	6.8
Total	222	-	-

Table 10. Maturation and fecundity of spiny dogfish females based on the winter trawling survey 1978.

Female length, ?m	Number of fish examined, ind.	Number of mature fish, %	Mean fecundity
75-77	10	0	-
78-80	14	29	4.2
81-83	27	41	3.8
84-86	23	83	5.0
87-89	26	81	5.3
90-92	15	100	6.2
93-95	10	100	6.3
96-98	15	100	7.1
99-101	12	100	7.6
102-104	3	100	9.0
105-107	2	100	9.0
108-111	2	100	10.5
Total	159	-	-

Table 11. Frequency of food items occurrence in spiny dogfish stomachs in autumn, 1969-1976 (%).

Length group, cm	Number of samples	Number of empty stomachs,%	Food items						
			Fish				Invertebrates		
			Herring	Mackerel	Gadoid	Non-identif	Squids	Crustacea	Coelenterata
up to 50	352	93	-	18.8	-	59.4	15.6	-	-
50-70	99	90	10.0	10.0	10.0	20.0	10.0	40.0	-
above 70	528	91	8.3	2.1	4.2	41.6	25.0	14.6	4.2
All groups	979	91	5.5	8.9	3.3	45.6	16.7	17.8	2.2

Table 12. Frequency of food items occurrence in spiny dogfish stomachs in winter, 1978 (%).

Shark length group, cm	Number of samples	Number of empty stomachs,%	Food items							
			Fish					Invertebrates		
			Mackerel	Flatfish	Gadoids	Sand eel Butterfish Clupeids Red-fish	Non-identif. species	Squids	Crustacea	Coelen-terata
Up to 30	78	85	-	-	-	-	-	8.3	91.7	-
31-50	158	59	-	-	-	-	8.2	10.2	63.2	18.4
51-70	216	71	-	1.6	1.6	7.9	22.2	35.0	31.7	-
Above 70	297	82	9.3	9.3	3.7	7.4	27.8	8.3	16.6	16.6
All groups	749	76	2.8	3.4	1.7	5.1	18.5	18.5	39.9	10.1

Table 13. Corrections of spiny dogfish age readings depending on (otolith) section diameter.

Males		Females	
Section diameter, mm	Correction, years	Section diameter, mm	Correction, years
1.65-1.70	+1	1.70-1.80	+1
1.75-2.20	+2	1.85-2.30	+2
2.25-2.50	+3	2.35-2.65	+3
2.55-2.80	+4	2.70-2.90	+4
2.85-3.05	+5	2.95-3.10	+5
3.10-3.25	+6	3.15-3.40	+6
3.30-3.45	+7	3.45-3.70	+7
3.50-3.60	+8	3.75-3.90	+8
		4.10-4.20	+9
		4.25-4.35	+10
		4.40-4.50	+11

Table 14. Length composition of spiny dogfish catches in New England area. %.

Length. ?m	Seasons			
	Winter	Spring	Summer	Autumn
21-25	2.7	0.9	2.5	0.3
26-30	18.4	12.4	47.1	7.5
31-35	4.2	6.9	29.9	15.4
36-40	2.2	3.5	11.5	8.4
41-45	2.2	1.2	4.7	5.9
46-50	3.1	1.9	1.4	4.8
51-55	5.2	1.1	1.1	3.9
56-60	4.5	0.9	0.5	3.6
61-65	4.8	2.8	0.2	3.8
66-70	6.5	7.3	0.2	6.9
71-75	14.5	24.4	0.1	13.8
76-80	13.7	11.4	0.1	8.8
81-85	3.7	5.7	0.2	5.2
86-90	4.7	9.6	0.3	5.9
91-95	5.9	6.9	0.2	4.0
96-100	3.0	2.9	+	1.5
101-105	0.6	0.2	-	0.3
106-110	0.1	+	-	+
111-115	+	-	-	-
Number of fish measured. thous. ind.	8.3	7.4	9.7	41.2

Table 15. Length composition of spiny dogfish catches in autumn, 1968-1978.

Length, cm	Survey years										
	68	69	70	71	72	73	74	75	76	77	78
21-25	0.7	0.1	0.5	0.6	0.1	0.5	0.1	0.2	0.1	0.1	0.2
26-30	10.2	1.8	7.2	6.9	5.2	1.1	3.9	12.3	4.9	4.8	12.8
31-35	9.5	4.1	6.7	8.3	5.7	1.3	2.3	18.0	16.8	1.7	32.0
36-40	8.6	4.2	4.9	6.3	3.6	2.8	11.8	10.1	10.9	6.6	11.2
41-45	7.0	4.8	7.2	7.9	3.0	3.1	9.0	4.1	6.3	3.9	4.8
46-50	6.4	4.6	6.8	13.3	4.4	7.2	3.7	2.3	4.6	7.1	2.1
51-55	2.6	4.1	5.6	9.6	5.4	6.4	1.0	1.7	3.9	8.6	5.2
56-60	2.4	2.3	3.3	7.5	4.9	4.0	0.7	2.0	5.4	5.0	6.3
61-65	2.7	3.8	2.0	5.7	10.2	5.2	1.6	2.3	4.6	4.1	4.6
66-70	1.6	12.8	7.2	7.5	11.7	3.0	4.6	5.4	6.3	3.6	2.4
71-75	20.5	23.2	17.8	9.1	9.2	4.4	1.1	1.0	1.9	7.5	4.0
76-80	9.2	12.3	10.6	6.5	7.0	9.1	8.8	9.2	11.5	9.0	3.7
81-85	5.8	10.6	7.8	4.4	6.6	8.8	3.0	4.4	4.2	6.4	1.7
86-90	2.9	7.8	8.6	5.4	13.7	11.7	6.0	7.0	2.9	8.5	2.7
91-95	0.7	2.8	2.7	0.5	7.2	7.6	6.1	5.8	2.9	9.6	3.5
96-100	0.2	0.7	1.1	0.5	1.9	2.3	2.8	2.0	0.7	3.4	2.4
101-105	+	+	-	-	0.1	0.5	0.5	0.2	0.1	1.0	0.4
106-110	+	-	-	-	+	+	+	-	+	0.1	+
111-115	-	-	-	-	-	-	-	-	+	-	-
Number of fish measured, thous. ind.	6.4	4.8	1.7	1.7	2.1	2.4	5.8	4.3	4.8	1.5	5.7

Table 16. Age composition of spiny dogfish catches in Newfoundland area, %.

Age, years	Females	Males	Age, years	Females	Males
5	-	0.1	17	6.9	3.0
6	0.6	0.7	18	5.8	2.7
7	2.4	3.3	19	3.2	1.3
8	4.3	7.2	20	4.0	0.4
9	3.8	8.2	21	5.0	0.1
10	6.1	7.6	22	2.2	
11	9.2	1.4	23	1.2	
12	8.2	16.1	24	1.7	
13	1.4	12.4	25	0.3	
14	5.6	12.4	26	0.3	
15	10.3	8.2	27		
16	7.7	3.9			

Table 17. Age composition of spiny dogfish catches in New England area during autumn, 1968-1978, %.

Age, years	Survey years										
	68	69	70	71	72	73	74	75	76	77	78
1	11.4	3.1	8.0	8.5	5.2	12.8	12.4	15.7	10.9	7.9	22.9
2	20.9	9.4	14.4	16.8	8.7	15.3	28.7	26.2	24.7	16.0	35.7
3	5.9	4.3	6.0	9.5	18.2	4.8	5.3	2.7	4.8	5.2	3.7
4	3.9	3.1	4.5	7.5	2.5	3.9	3.2	1.8	3.4	4.4	2.6
5	3.7	4.4	54.8	11.2	5.4	6.8	1.8	2.2	5.1	8.2	5.2
6	3.6	4.3	4.5	9.7	7.4	6.1	1.4	4.2	6.5	7.0	7.1
7	3.0	2.8	2.4	4.4	6.4	3.4	1.7	2.1	3.7	3.1	3.1
8	3.9	4.8	2.8	2.9	3.9	1.3	1.9	2.0	2.5	1.5	1.1
9	5.9	7.0	4.5	3.4	4.2	1.5	3.4	3.4	3.9	2.0	1.2
10	4.7	5.5	3.8	2.5	2.6	1.1	3.1	2.7	3.2	1.7	0.9
11	8.2	9.4	7.2	3.8	1.1	2.2	6.0	5.2	6.2	3.3	1.7
12	5.4	6.9	5.6	3.2	3.0	3.6	4.7	4.5	5.7	3.9	1.7
13	4.0	4.9	3.9	2.2	2.0	2.1	3.3	3.1	3.7	2.5	1.1
14	3.6	4.7	3.7	2.1	2.0	2.3	2.9	2.8	3.3	2.4	1.0
15	3.1	4.9	4.0	2.4	2.8	4.0	2.6	3.0	3.1	3.4	1.2
16	2.1	3.7	2.9	1.7	2.3	3.1	1.5	1.9	1.6	2.4	0.7
17	2.3	4.8	4.1	2.4	4.3	5.0	2.2	2.7	1.5	3.7	1.1
18	2.0	4.4	4.1	2.5	4.8	5.2	2.4	2.9	1.5	3.8	1.1
19	0.9	2.2	2.1	1.2	2.7	2.9	1.3	1.7	0.8	2.3	0.7
20	0.6	2.1	2.1	0.9	3.8	4.2	3.0	2.9	1.4	4.5	1.6
21	0.5	1.5	1.6	0.6	2.8	3.1	2.3	2.2	1.0	3.5	1.4
22	0.1	0.6	0.7	0.2	1.4	1.7	1.4	1.3	0.6	2.2	1.0
23	0.1	0.4	0.4	0.1	0.8	1.0	1.0	0.8	0.3	1.4	0.5
24	0.1	0.4	0.4	0.1	0.8	1.2	1.0	0.9	0.4	1.6	1.2
25	0.1	0.3	0.3	0.1	0.6	0.9	0.8	0.7	0.3	1.2	0.7
26	+	0.1	0.2	0.1	0.3	0.5	0.5	0.4	0.2	0.8	0.5
27	+		-	-	+	-	-	-	+	0.1	+
28	-		-	-	-	-	-	-	+	-	-

Table 18. Age composition of spiny dogfish catches in New England area, % (winter 1978).

Age, years	Females	Males	Age, years	Females	Males
1	360	251	15	24	38
2	49	47	16	34	24
3	59	18	17	24	24
4	44	22	18	35	19
5	34	29	19	24	8
6	31	41	20	20	2
7	30	58	21	39	4
8	26	73	22	32	-
9	14	39	23	23	-
10	10	38	24	12	-
11	10	51	25	10	-
12	8	87	26	14	-
13	15	51	27	2	-
14	16	76	28	-	-

Table 19. Estimates of spiny dogfish females mortality.

Age, years	Abun-dance, ‰	Smoothed by 3-year sliding mean	Supplemented by log. plot	Total mortality rate, %	Natural mortality rate, %	Catch rate, %
1	360	-	(708)	-	-	0
2	49	156	(389)	45	45	0
3	59	51	(284)	27	27	0
4	44	46	(227)	20	20	0
5	34	36	(194)	15	15	0
6	31	32	(175)	10	10	0
7	30	29	(159)	9	9	0
8	26	23	(145)	9	9	0
9	14	17	(133)	8	8	0
10	10	11	(122)	8	8	0
11	10	9	(113)	7	7	0
12	8	11	(104)	8	8	0
13	15	13	(95)	8	8	0
14	16	18	(87)	8	8	0
15	24	25	(80)	8	8	0
16	34	27	(74)	8	8	0
17	24	31	(67)	9	9	0
18	35	28	(60)	10	10	0
19	24	26	(54)	10	10	0
20	20	28	(48)	11	10	1
21	39	30	(42)	13	12	1
22	32	32	35	17	15	2
23	24	23	28	28	20	8
24	12	15	19	35	32	5
25	10	12	12	37	37	0
26	14	9	6	50	50	0
27	2	-	2,4	60	58	2
28	-	-	0,7	71	68	3
	1000	-	3463.1	-	-	-

Table 20. Estimates of spiny dogfish males mortality.

Age, years	Abun-dance, ‰	Smoothed by 3-year sliding mean	Supplemented by log. plot	Total mortality rate, %	Natural mortality rate, %	Catch rate, %
1	251	-	(708)	-	-	0
2	47	105	(368)	48	48	0
3	18	29	(261)	29	29	0
4	22	23	(201)	23	23	0
5	29	31	(167)	17	17	0
6	41	43	(150)	10	10	0
7	58	57	(137)	9	9	0
8	73	57	(126)	8	8	0
9-	39	50	(115)	9	9	0
10	38	43	(105)	9	9	0
11	51	59	(94)	10	10	0
12	87	63	(84)	11	11	0
13	51	71	(73)	13	13	0
14	76	55	62	15	15	0
15	38	46	50	19	18	1
16	24	29	38	24	22	2
17	24	22	27	29	26	3
18	19	17	18	33	32	1
19	8	10	11	39	38	1
20	2	5	6	45	45	0
21	4	-	2,7	55	55	0
22	-	-	1,0	63	63	0
	1000		2804.7	-	-	-

Table 21. Age composition of spiny dogfish females catches in Newfoundland area (April-May 1978).

Age, years	Number, %	Age, year	Number, %
8	0.8	18	5.2
9	2.1	19	5.0
10	6.5	20	4.5
11	8.9	21	3.9
12	9.8	22	3.9
13	10.5	23	3.2
14	9.4	24	2.1
15	8.4	25	1.5
16	6.8	26	1.1
17	6.2	27	0.1

Table 22. Estimate of spiny dogfish females stock based on winter trawling survey data 1978.

Age, years	Age composition in log plot	Mean length, cm	Mean weight, g	Minimal estimate	
				Abundance, mln. ind.	Biomass, thous.t
1	708	28.2	80	132.6	10.6
2	389	36.1	180	72.9	13.1
3	284	47.7	430	53.2	22.9
4	227	53.5	620	42.5	26.4
5	194	56.7	750	36.3	27.3
6	175	60.0	805	32.8	26.4
7	159	61.9	980	29.8	29.2
8	145	66.9	1250	27.2	34.0
9	133	71.6	1540	24.9	38.3
10	122	75.2	1800	22.8	41.0
11	113	78.0	2030	21.2	43.0
12	104	81.5	2330	19.5	45.4
13	95	83.0	2470	17.8	44.0
14	87	85.9	2750	16.3	44.8
15	80	85.8	2740	15.0	41.1
16	74	87.6	2910	13.9	40.4
17	67	88.2	2980	12.5	37.2
18	60	89.1	3080	11.2	34.5
19	54	93.3	3550	10.1	35.9
20	48	92.3	3440	9.0	31.0
21	42	94.0	3650	7.9	28.8
22	35	96.8	4000	6.6	26.4
23	28	98.3	4200	5.2	21.8
24	19	96.6	3950	3.6	14.2
25	12	98.3	4200	2.2	9.2
26	6	100.0	4430	1.1	4.9
27	2.4	104.0	5015	0.4	2.0
28	0.7	-	-	0.1	-
Total	3463.1	-	-	648.6	773.8

Table 23. Estimate of spiny dogfish males stock based on winter trawling survey data 1978.

Age, years	Age composition in log plot	Mean length, cm	Men weight, g	Minimal estimate	
				Abundance, mln.ind	Biomass, thous. t
1	708	26.3	65	132.6	8.6
2	368	33.9	146	68.9	10.1
3	261	40.3	240	48.9	11.7
4	201	45.3	345	37.7	13.0
5	167	49.6	450	31.3	14.1
6	150	52.9	545	28.1	15.3
7	137	58.8	745	25.7	19.1
8	126	64.3	970	23.6	22.9
9	115	66.7	1060	21.5	22.8
10	105	68.7	1170	19.7	23.0
11	94	71.9	1350	17.6	23.8
12	84	73.4	1435	15.7	22.6
13	74	74.0	1470	13.9	20.4
14	62	75.7	1550	11.6	18.0
15	50	77.2	1670	9.4	15.6
16	38	76.4	1610	7.1	11.5
17	24	76.0	1588	4.5	7.1
18	18	80.7	1890	3.4	6.4
19	11	82.0	1990	2.1	4.1
20	6	85.0	2210	1.1	2.5
21	2,7	79.0	1780	0.5	0.9
22	1,0	-	-	0.2	0.4
Total	2804.7	-	-	525.1	293.9

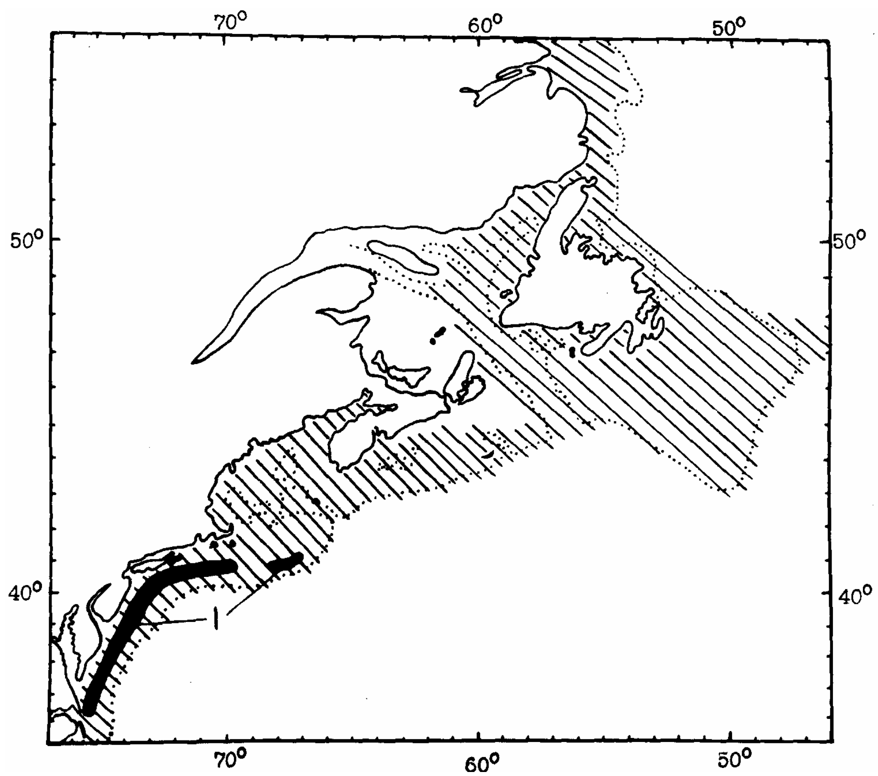

Fig. 1. The area of spiny dogfish distribution. 1. Locations of young sharks birth.

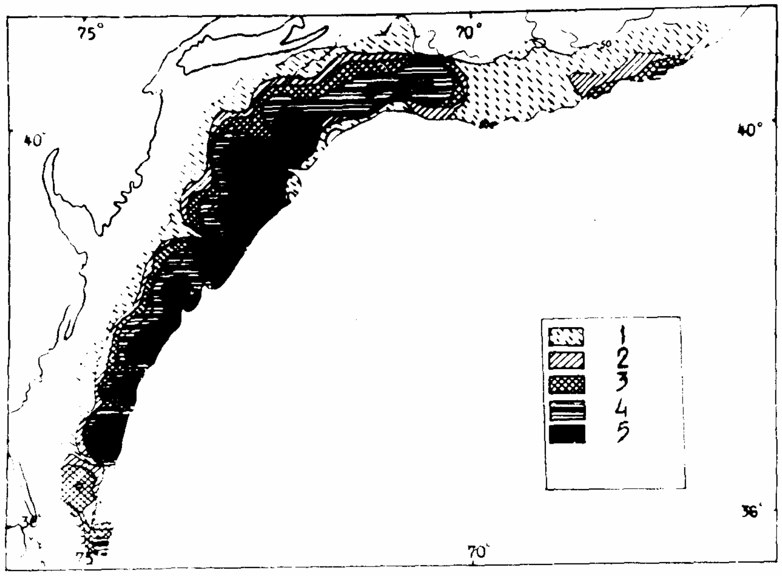

Fig. 2. Distribution of spiny dogfish in winter 1978. Catch, individuals/trawling: 1. 1-50; 2. 51-100; 3. 101-200; 4. 201-500; 5. Above 500.

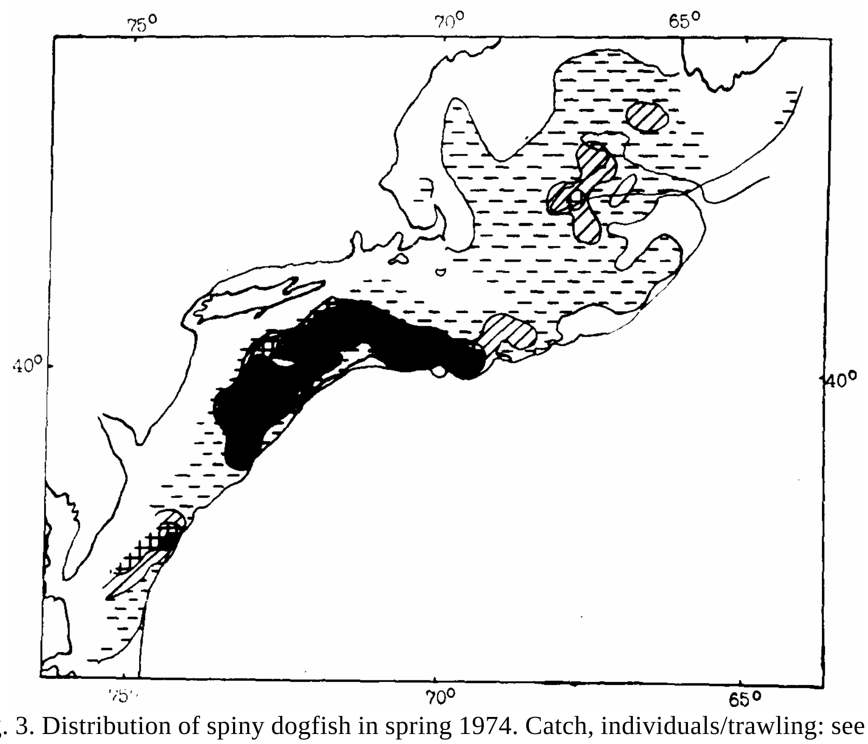

Fig. 3. Distribution of spiny dogfish in spring 1974. Catch, individuals/trawling: see Fig.2.

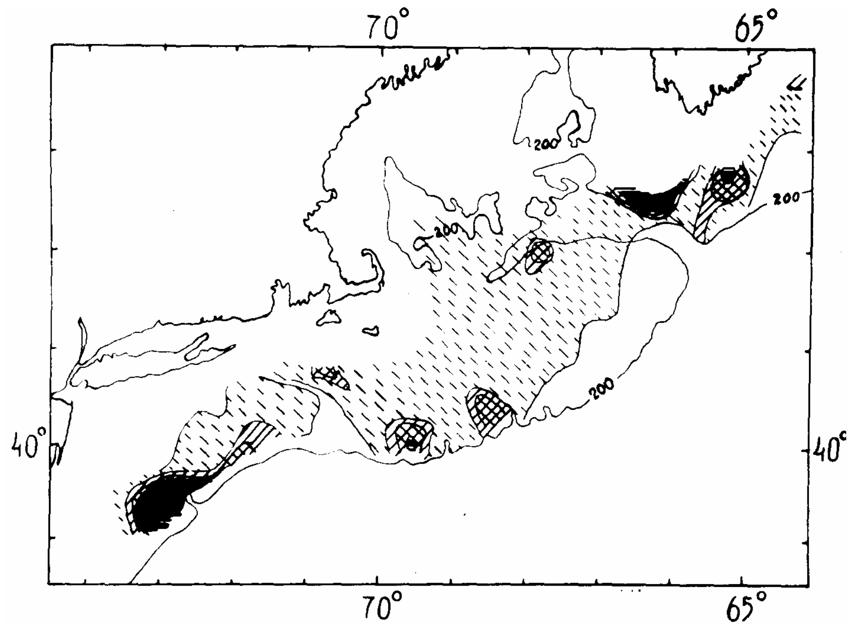

Fig. 4. Distribution of spiny dogfish in summer 1971. Catch, individuals/trawling: see Fig.2.

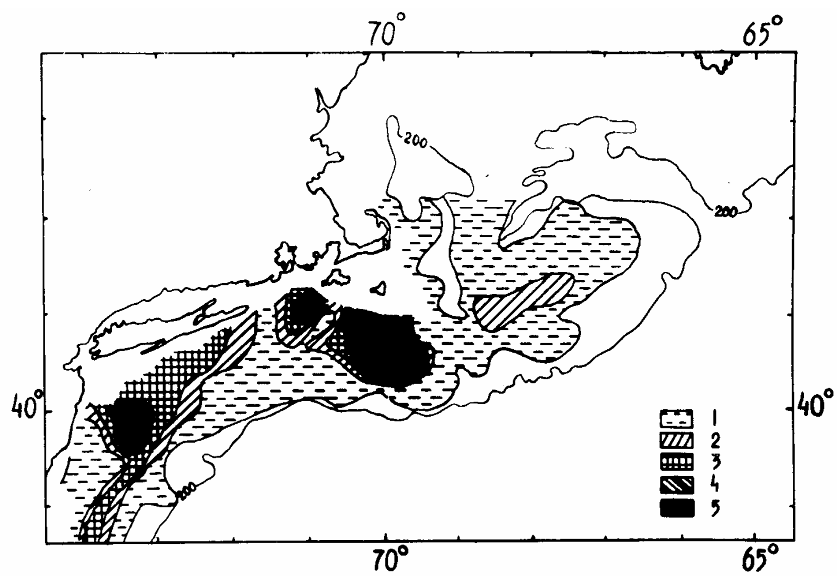

Fig. 5. Distribution of spiny dogfish in autumn 1968 ?. Catch, individuals/trawling: 1. 1-25; 2. 26-50; 3. 51-75; 4. 76-100; 5. Above 100.

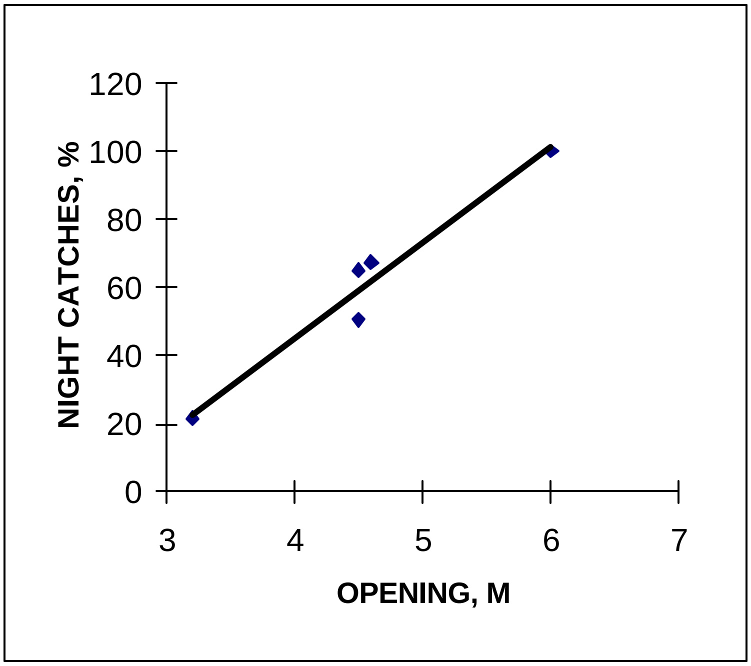

Fig. 6. Proportion of spiny dogfish day-time and night catches in relation to trawl vertical opening.

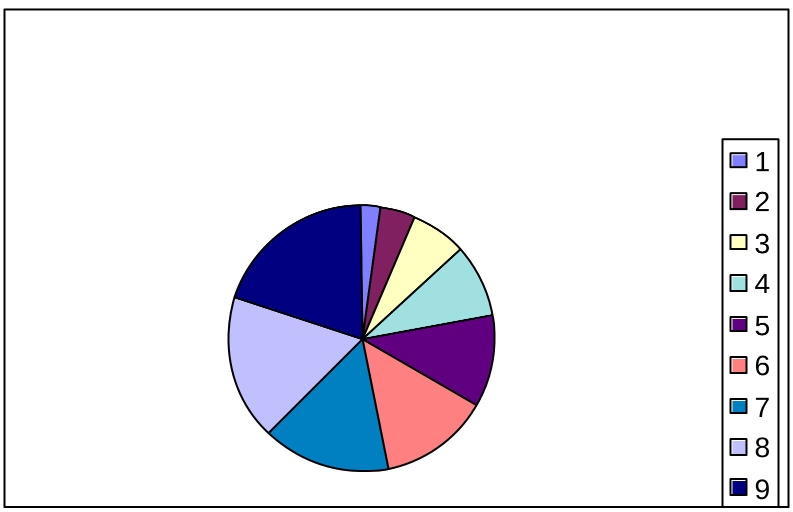

Fig. 7. Frequency of food items occurrence in the spiny dogfish stomachs. 1. Herring, 1.9%. 2. Mackerel, 4.9%. 3. Gadoids, 1.5%. 4. Flatfishes, 5.7%. 5. Fish (species unidentified), 27.8%. 6. Squids, 18.7%. 7. Crustacea, 32.8%. 8. Molluscs, 2.3%. 9. Coelenterata, 4.9%.

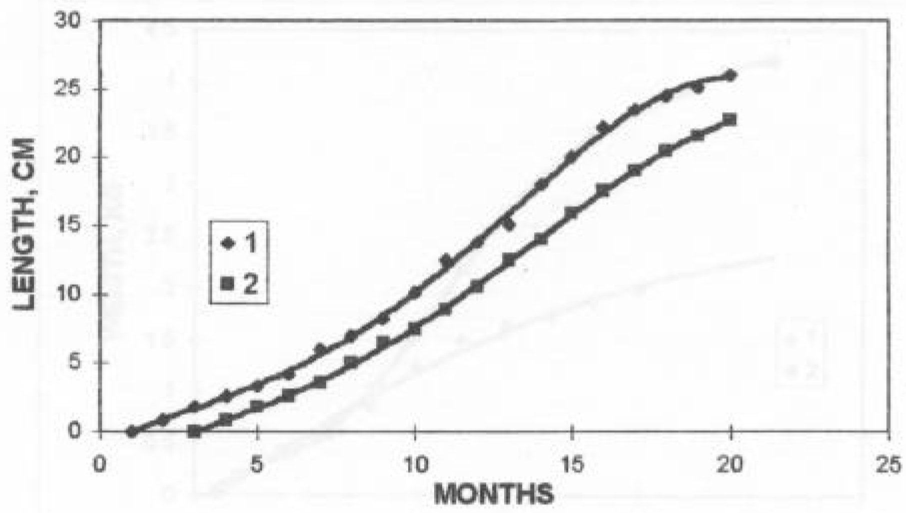

Fig. 8. Growth of spiny dogfish embryos in the NWA . 1. New England (Hisaw, Albert, 1947; 2. Newfoundland (Templeman, 1944).

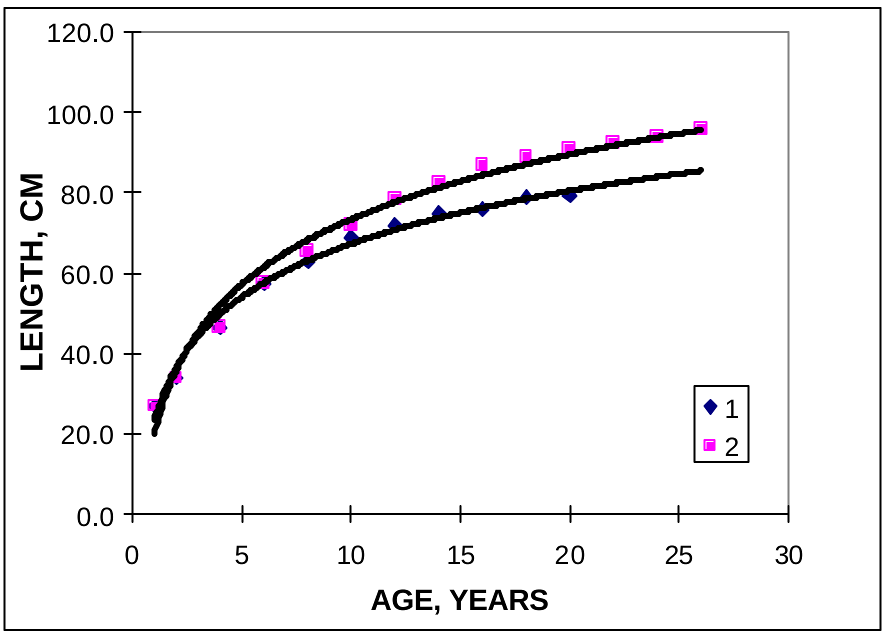

Fig. 9. Males (1) and females (2) body length by age (data of winter trawling survey 1978).

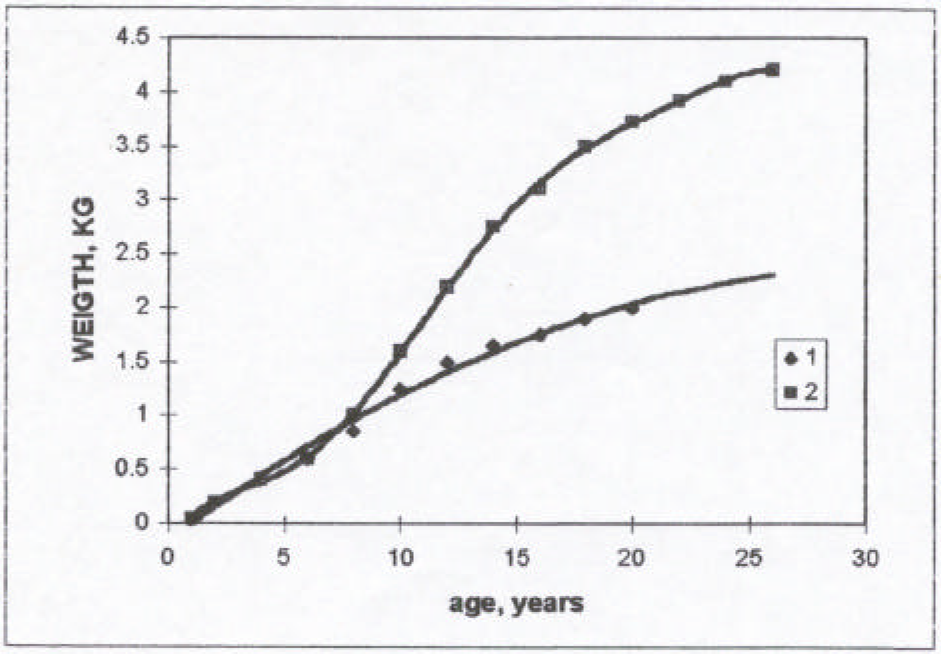

Fig. 10. Males (1) and females (2) body weight by age (data of winter trawling survey 1978).

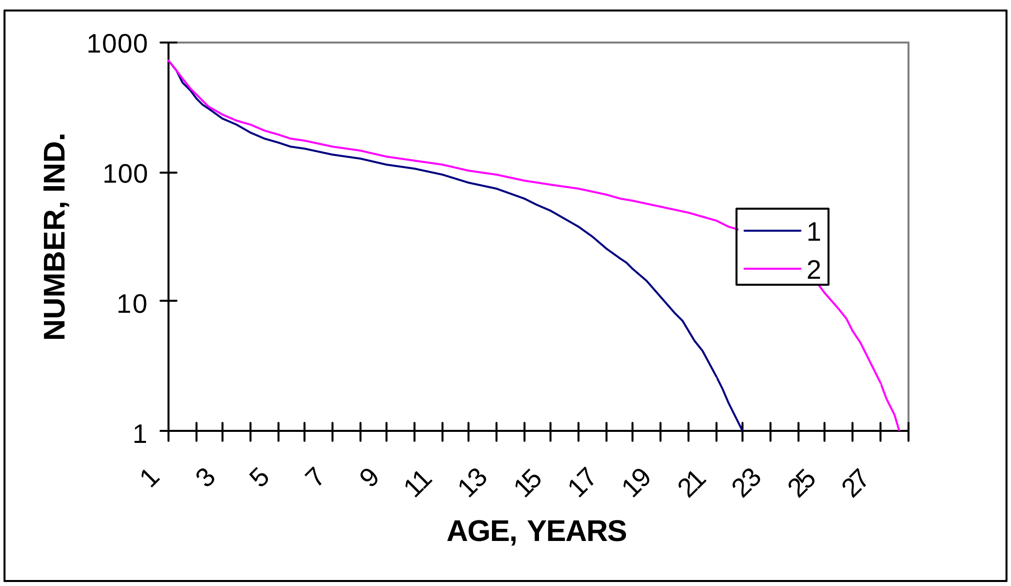

Fig. 11. Males (1) and females (2) survival.