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by

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by

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ABSTRACT

Spurdog landings are made on all parts of the Irish coastline but most heavily concentrated on the west of the country. The fishery expanded to a maximum catch of just under 8,000 tonnes in 1985. The species had been pursued most intensively in the north west but effort is shifting southwards.

This account of the south west Ireland fishery is based on material collected between April 1987 and March 1988, inclusive; information was collected by questionnaire and 5,300 individual fish were examined. Ageing was undertaken using the posterior spine: ages in the commercial catches ranged between 5 and 40+ years. The growth characteristics of the south-west Ireland spurdogs resemble those of the Scottish-Norwegian fish but the Irish populations have a lower L_∞.

Female maturation takes place at a shorter length than in other populations hitherto investigated from British or Irish waters; the length at 50% maturity is slightly more than 74cm which corresponds with an age of 14 years. The fecundity of the south west Ireland spurdogs is relatively high. Mortality coefficients (Z) of fully recruited spurdogs are calculated from age 17 as 0.24 for females and 0.30 for males.

Two life tables are constructed. The first, which is intended to ascertain the numbers of female whelps required to maintain numbers, suggests that the stocks are close to being overfished. The second life table examines the age structure of the breeding female component of the population but its outcome is inconclusive.

In terms of its organization the south west Ireland spurdog fishery can be considered as two separate fisheries: a trawl and a gill net fishery, the latter being regarded as the more detrimental to the prospects of a sustained yield.

INTRODUCTION

Dogfish were regarded as a nuisance by Irish fishermen until the late 1970's. Commercial interest dates from 1977 after which the fishery expanded rapidly. National landings to date are as follows:

1977	116 tonnes	1982	1,152 tonnes
1978	25	1983	4,233
1979	119	1984	6,235
1980	97	1985	7,987
1981	405	1986	4,509

Dogfish are landed on all coasts but most catches are made along the western seaboard although there has been a change in relative effort from north to south in the recent past. Fig 1. shows the distribution of landings in 1985 when the fishery was heavily concentrated on the Co. Donegal coastline in the northwest. The emphasis has since moved south to Co. Kerry; landings from four important western fishing ports are presented in Table 1. The expansion of landings into Dingle is symptomatic of a rise in fishing effort in the vicinity. Fenit, a neighbouring port, registered 11.6 tonnes of dogfish in 1985 and 750 in 1987. The dogfish fishery developed in Co. Donegal where the fish were taken using monofilament gill nets which were also employed as floating gear for the capture of salmon. The decline in landings in Donegal suggested by the figures in Table 1 should not be construed as indicating a loss of interest in dogfish. On the contrary, the rise in landings in Co. Kerry is in large measure due to the efforts of the Burtonport fleet.

The term "dogfish" in Irish fishery statistics refers almost exclusively to *Squalus acanthias* (L). Some lesser spotted, *Scyliorhinus caniculus* (L) and greater spotted dogfish, *S. stellaris* (L) have been retained at times. They are not however consumed and are landed only because they qualify for compensatory payments under the E.C. intervention system. Analysis of the details of intervention payments during 1983-1986 when spurdogs and other species were separately identified reveals that, of 3,927 tonnes for which payments were made, only 504 (12.8%) were of species other than spurdogs. This figure greatly exceeds the proportions of those species landed nationally. As a percentage of total landings made from 1983-1986 (22,964 tonnes) other species account for 0.02% and the official statistics are taken to refer to spurdogs only.

A growing appreciation of the value of spurdog as a food fish has prompted investigations of aspects of its biology relevant to commercial fisheries in both the Atlantic and the Pacific. Long Life, slow growth, late maturation and low fecundity characterise a species susceptible to heavy fishing but spurdog has proved more resilient than theory would suppose. This paper examines a fishery in which there is a rapidly growing interest and makes observations relevant to the management of the fishery. The investigations described here were undertaken during the period April 1987 — March 1988 at Dingle, a centre which receives landings from a large area of the south west; catches at Rossaveal in Co. Galway and Carrigaholt, Co. Clare, were also examined.

Although catches of spurdogs fluctuate, monthly landings of various sizes were made throughout the period of investigation. Nationally, the consumption of spurdog is miniscule; in Co. Kerry it is almost non existent, so all dogfish are exported out of the region, the majority before any processing has taken place. Occasionally the fish may be reduced to fillets and belly flaps which are frozen for export. Sampling was necessarily opportunistic, with as much information being gathered as commercial operations permitted.

DEFINITION OF STOCK

Aasen (1964) considered there was one North East Atlantic spurdog stock but Holden (1965), largely as a result of tagging work, proposed several, of which the most important were: a Scottish-Norwegian, a Channel and an Atlantic stock. A fourth stock, made up of fish described by Hickling (1930), might exist off south west Ireland, and the existence of smaller coastal populations was not ruled out.

Squalus acanthias is known to undertake long migrations in the Atlantic and Pacific oceans (Templeman, 1944, 1958, Kaufman, 1957), Holden (1968) showed, as had Aasen (1964), that fish tagged in the area of the Scottish-Norwegian stock were later recovered in the Celtic Sea or off the south west coast of Ireland and suggested the co-existence of migratory and sedentary components within the main stock divisions.

Gauld (1979) proposed that the spurdogs of ICES Divisions IVa, IVb and VIa comprised a single Scottish-Norwegian stock and that there was no evidence of immigration of fish from outside the North Sea north of Scotland.

The concept of multiple stocks around the British Isles is not universally accepted. Holden (1968) described the evidence for separate Atlantic and Norwegian stocks as "sufficient if not conclusive". Gauld and MacDonald (1982) were unable to validate the existence of distinctive Atlantic, Scottish-Norwegian, Norwegian fjord and Scottish west coast stocks, all of which were inferred from tag returns. They also reported evidence for the mixing of spurdogs from the north east and north west Atlantic.

For the purposes of this paper the spurdogs of inshore ICES Area VIIj and the south west corner of Area VIIb are regarded as a unit, without prejudice to their isolation from or membership of a larger stock complex. Apart from the information provided by mark and recapture, there have been few physical characteristics on which populations might be conclusively distinguished. Holden (1965) stated that it was feasible to discriminate populations from the southern North Sea and the Scottish Norwegian area on the formation of the spines. Details of growth and reproductive biology have been shown to differ from one area to another; Gauld (1979) and Holden and Meadows (1964) suggest that fecundity can change considerably in time. Such biological characteristics must be used cautiously in stock definition.

INVESTIGATIVE PROCEDURE

Mature spurdogs occupy unisexual shoals, and a brief methodology was developed to ascertain the origin and nature of material which could not be subjected to detailed examination. A questionnaire requesting information on consignments of spurdog was circulated in the autumn of 1987. Details of the method and place of capture were sought as were data on the numbers of each sex occupying three boxes of known weight taken at random from the catch. In determining the type of shoal from which the catch derived, a tolerance of 20% was allowed i.e. up to 20% of a "male" shoal could consist of females and vice versa. A mixed shoal contained the sexes in more equal proportions. According to these criteria there was no doubt about the nature of 95% of consignments so characterised (Table 2).

A census of landings included determination of sex and total length (defined here as the length from the tip of the snout to the tip of the upper lobe of the caudal fin in its natural position). Additionally spines were removed for ageing and the whole fish was weighed. An effort was made to gather information on a monthly basis on fecundity which involved opening the body cavities of 50 females. Ovarian eggs were counted and weighed; candled ova and embryos were counted as were embryos and the latter were also measured and weighed. The stomach contents of these fish and associated males were cursorily examined and weighed. Occasionally the stomach contents of predominantly male consignments were also examined.

RESULTS

Ageing

Ageing of the fish was undertaken on the posterior spine or, when that was damaged, on the smaller anterior spine. Samples of spines were read by the author and Mr. J. Gauld of the DAFS Marine Laboratory in Aberdeen and throughout the investigations small sub-samples of spines taken at random from the main collections were sent to Gauld for verification. The outcome of these dual readings is summarised in Table 3 from which it will be clear that although there was very little unanimity on particular spines the mean ages of a series arrived at by both readers showed close agreement.

Spurdogs can live to a considerable age. McFarlane and Beamish (1985) recorded fish of from 17-70 years old in the Canadian Pacific. Prolonged exposure abrades the spines which, if not broken, become worn and difficult to interpret. Ketchen (1975) devised a method of deducing age from the dimensions of the spine base but this requires assumptions of uniform growth within a population. Spurdogs from south west Ireland displayed considerable variability in length at age and the ages attributed to the oldest are estimates based on the predominant pattern of spine banding in a particular consignment. In the course of the south western Ireland investigations more than 95% of spines from fish aged less than 25 years were confidently aged while ages were determined for approximately 75% of the older spurdogs. Less than 0.2% of the fish were aged at 40+.

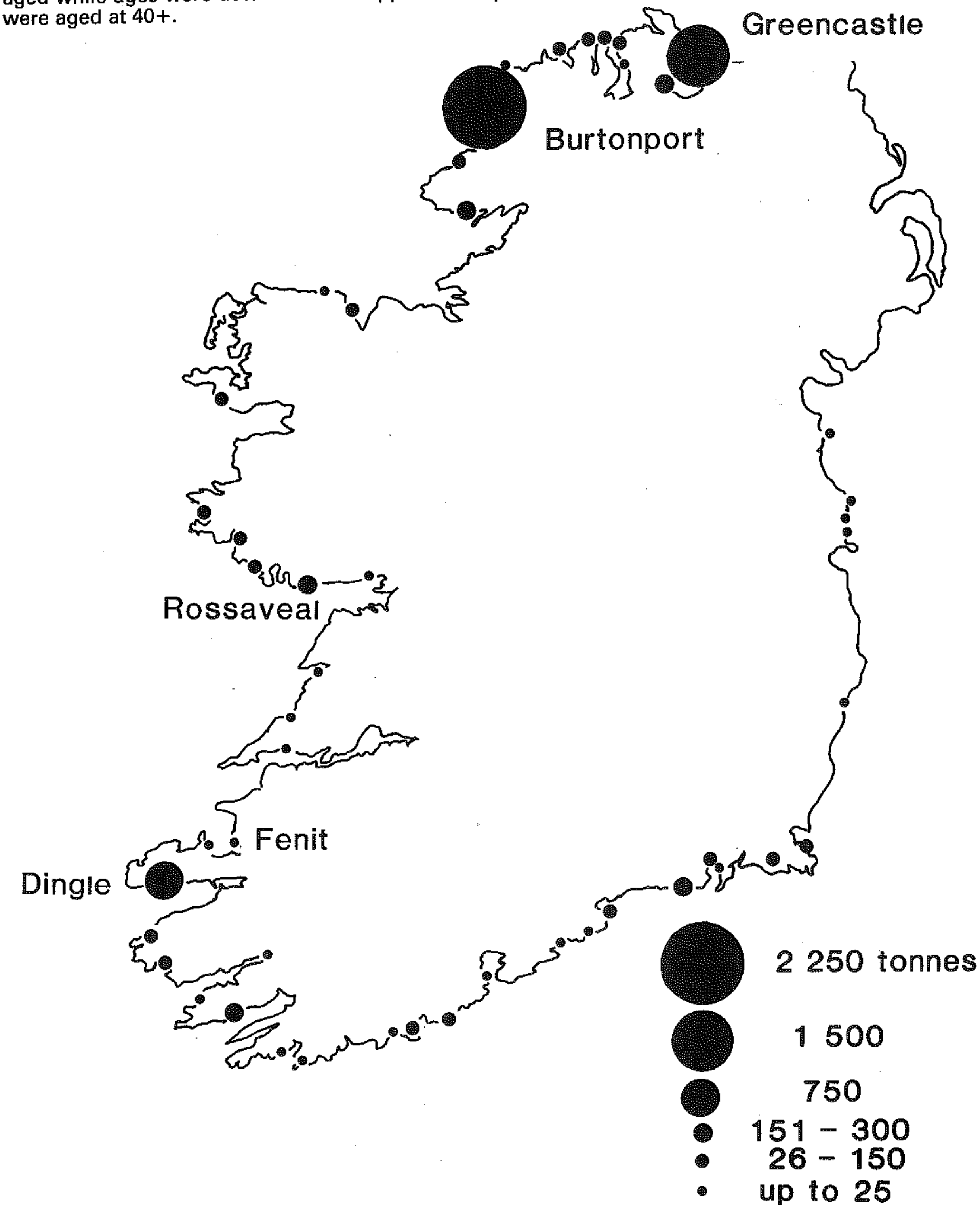

Figure 1. Spurdog landings in 1985; ports are those referred to in the text.

Maturation

Three stages of female maturation were recognized, in accordance with the criteria used by Jones and Geen (1977) and Gauld (1979):

1. Immature: Thread-like uteri without any obviously developing ova in the ovaries. At their base, near the vent, the uteri are expanded into white ribbons for a length of 1 or 2 cm. Ovarian ova consist of a mass of perhaps 40 or 50 barely distinguishable components.

2. Maturing: Uteri expanding and thickening; in external appearance the broad ribbons extend forward for a length of perhaps 10 or 11 cm; still white and non-vascularised in appearance. Some developing ova individually distinct, their individual weight upwards from about 1 g; less numerous than in stage 1, possibly 10 or fewer.

3. Mature: Embryos or candled ova in the uterus except immediately following parturition. Uteri highly vascularised; flaccid when empty.

Some difficulty was encountered in identifying the transition from stage 2 to stage 3. Hisaw and Albert (1947) demonstrated that, in mature spurdogs, there are four phases of ovarian growth and development which correspond with the embryos of the previous generation. As the development of the embryo progresses the ova grow in anticipation of fertilization soon after parturition. The candled ova are accompanied by small ova and large corpora lutea and very small embryos with large yolk sacs are accompanied by expanding ova etc. Ovarian expansion continues as the embryos gain weight and their yolk sacs diminish. Approaching parturition the next generation of ova are at their largest, ready to move into the oviduct for fertilization.

The largest ovarian ova encountered off south west Ireland weighed approximately 36g and fish with ova of 18g were regarded as mature (stage 3). Ford (1921) and Templeman (1944) related ovum volume to its diameter. Ketchen (1972) decided, on the basis of egg dimensions, that a female was mature at an ovum diameter of 2.5 cm which is more than half of the maximum of about 4 cm which he encountered in the spurdogs of British Columbia. The method he used is open to criticism because spurdog ova, although globular in shape, are not perfectly spherical.

To clarify the position 29 ova ranging in weight from 1 to 20g were fixed in formaldehyde, weighed, and their longest and shortest dimensions measured. The regressions of axes length on weight are:

Longest axis (l)

$\log l = 2.1397 + 0.3288 \log wt$ $\quad r = 0.9878 \quad P < 0.0001$

shortest axis (d)

$\log d = 2.1249 + 0.3080 \log wt$ $\quad r = 0.9811 \quad P < 0.0001$

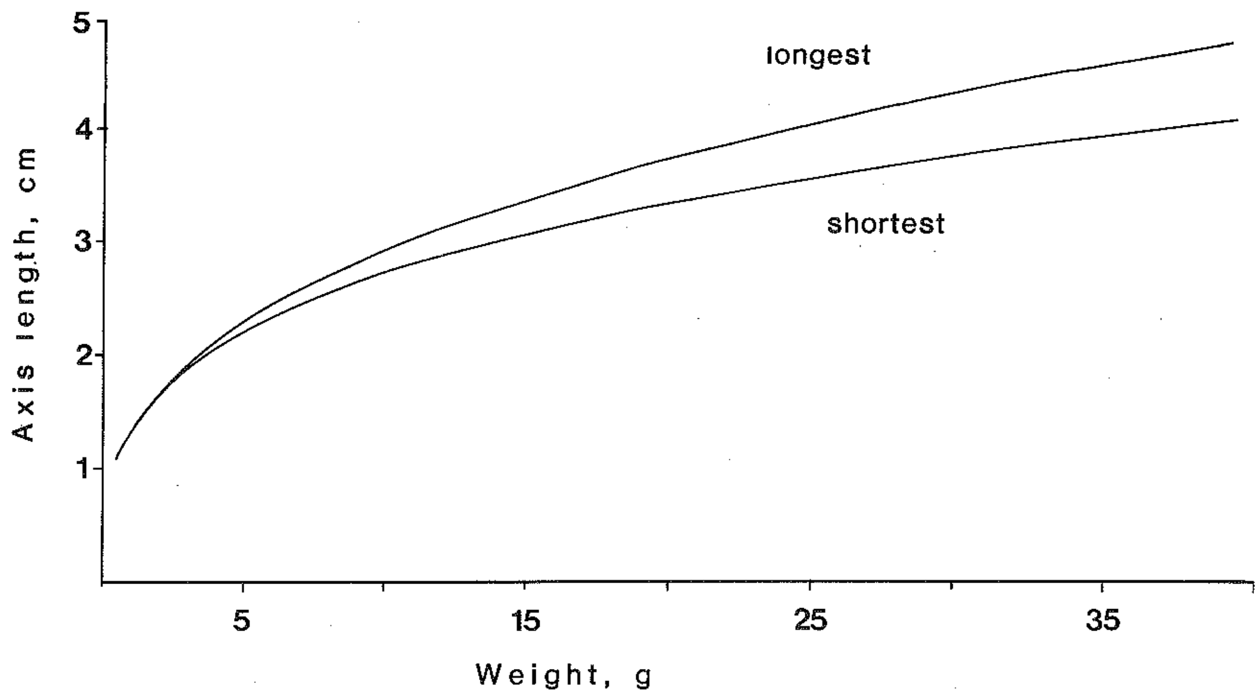

Figure 2. Regressions of longest and shortest axes of ovarian eggs on their weight.

The regressions are shown graphically in Fig. 2 which supports the use of crude linear measurements to indicate approximate ovum volume. The regressions do however suggest that Ketchen's definition of maturity at a threshold of 2.5 cm corresponds with 25% of fully developed ovum weight (or volume). Ketchen's work was used by Jones and Geen (1977) in the compilation of their life tables for spurdogs in British Columbia and the application of his threshold which was lower than that derived from the present work would result in a relatively higher percentage of the Irish fish being placed in stage 2 than stage 3.

Sexual Composition of Catches

Hickling (1930) made observations on aspects of the biology of spurdogs off the south west coast and the phenomena which he described have since been corroborated by other workers. Immatures form shoals of mixed sexes. As they grow they divide into unisexual shoals and frequent progressively deeper water, its depth being proportional to their size and shoals being composed of dogfish of fairly uniform dimensions. Females display a preference for a rough substratum while males are usually found over a sandy or marly bottom. Females move inshore to whelp after which, it is generally assumed, they encounter the males and are impregnated on their journey back to deep water.

These features of spurdog biology explain both the characteristics of catches and their location in the south west. All-male shoals have a lower average individual weight than shoals of only females while shoals of mixed sexes are distinguished by a prevailing lower average individual weight than either of the others (Fig. 3). Landings from deeper waters tended to be from mainly male shoals whereas large catches of mature females were made inshore, especially during the autumn months when whelping is taking place (Fig. 4).

The ground frequented by spurdogs imposes limitations on the kind of gear used to capture them, trawls in deep water where the substratum is smooth and gill nets over shallow, rocky terrain. The gear, in turn, is likely to reinforce the characteristics of the landings made by it. Gill nets, in particular, are selective of fish of larger size and although they have been known to take predominantly male spurdogs, their tendency will be towards over-emphasis of females in the areas they fish.

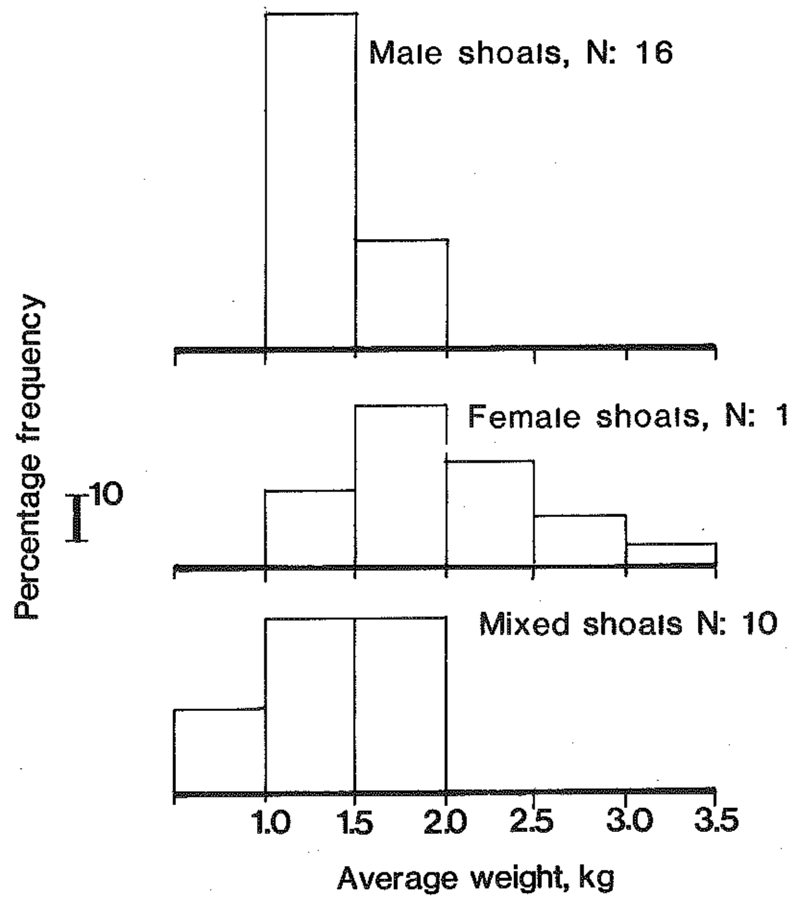

Figure 3. Average catch weights in consignments taken by gill net and trawl of spurdogs presumed to originate in all male, all female and mixed sex shoals. Data come from questionnaire and census investigations.

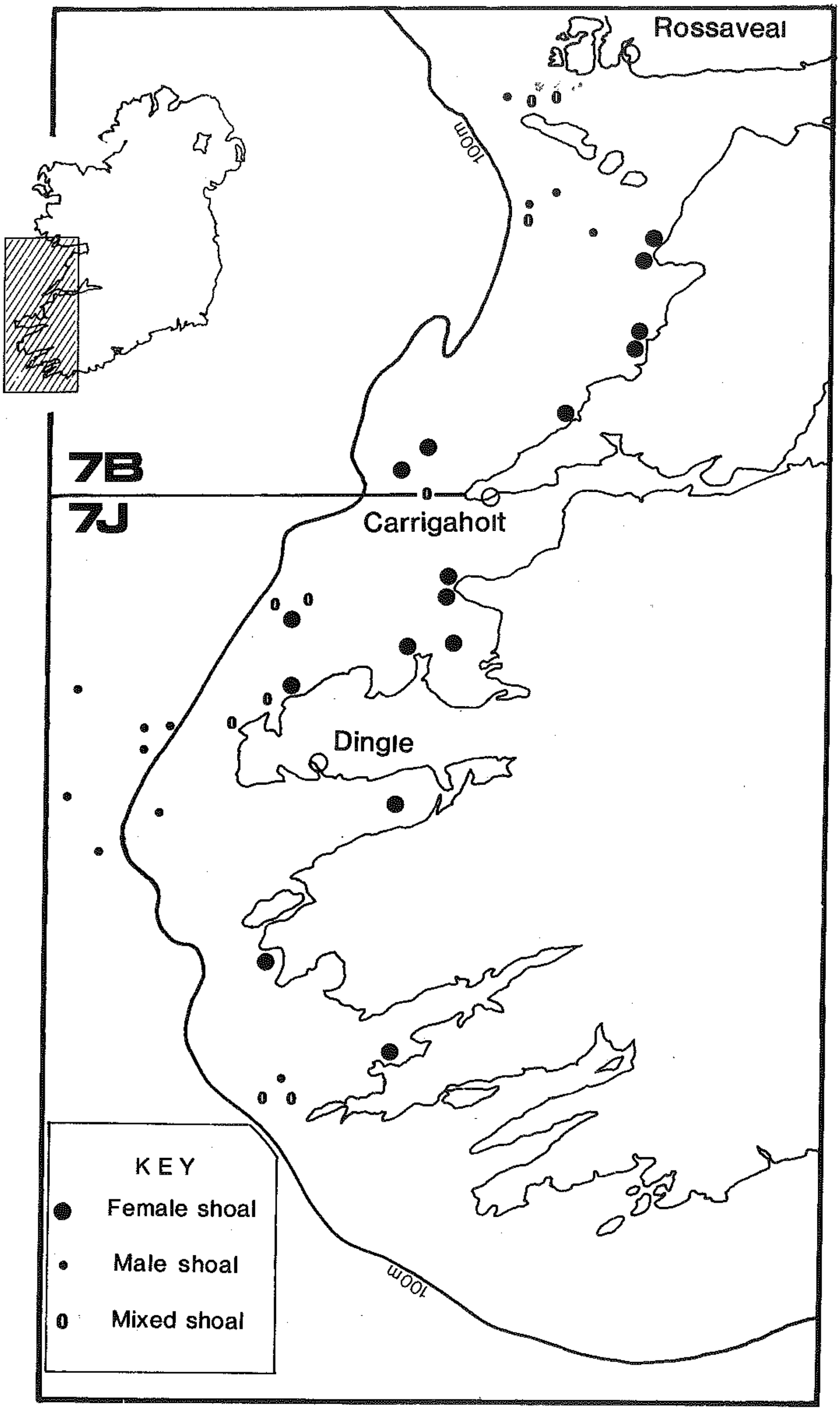

Figure 4. Locations of catches and the likely nature of the shoal from which they came. information from questionnaire and census investigation. The ports at which sampling took place are marked.

The percentage composition and average weights of gill net and otter trawl catches by male and female spurdogs is given in Tables 4 and 5 respectively.

Some of the characteristics of the 26 samples on which most data were collected are set out in Table 6 which illustrates the selective influence of the gill nets (GN). Their catch has an overall greater length than that of trawls (OTB). Average lengths, weights and ages of both sexes as well as the percentage of females and the percentage mature were higher from gill nets than from trawls. Pairwise comparisons of the average lengths (sexes combined) (Fig. 5) indicate much variation; the limited clustering ($P < 0.05$) tends to be among samples taken with the same kind of gear.

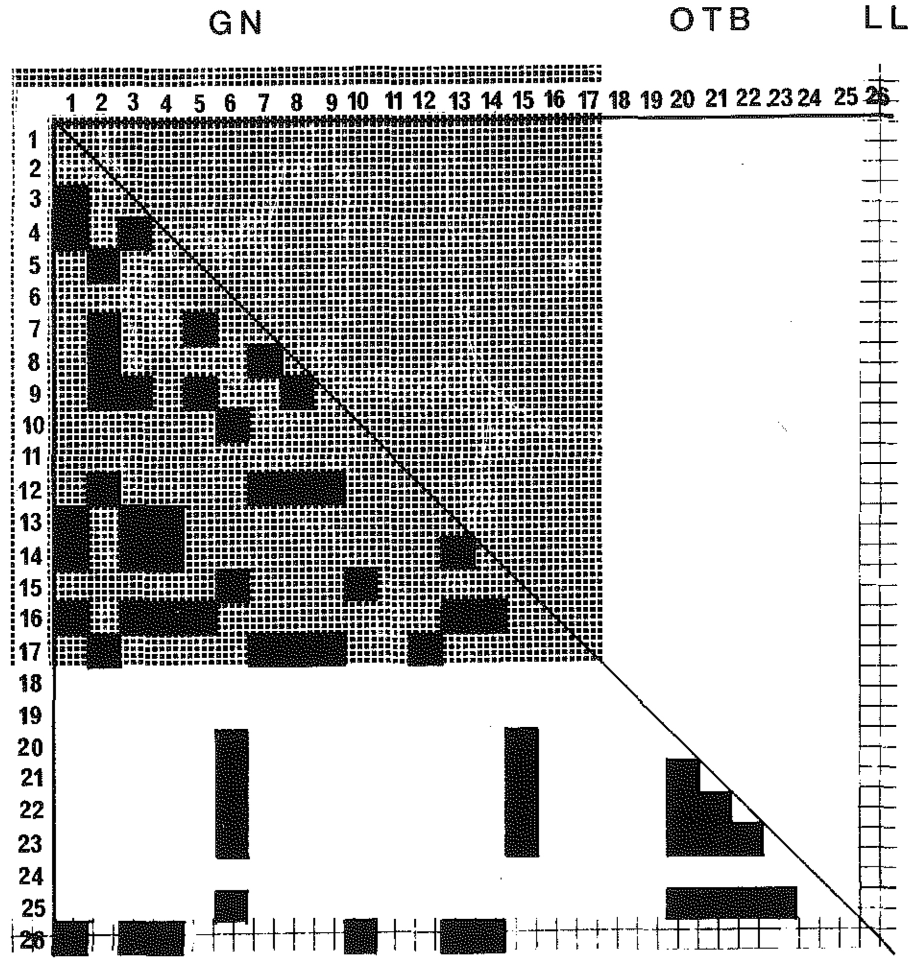

Figure 5. Pair comparisons for significance of the total length of spurdogs (AvLt, all) from 26 samples (Table 6). Black squares indicate no significant difference ($P > 0.05$). GN .. gill net, OTB .. bottom trawl and LL .. long line.

Growth

A total of 1,788 female and 1,070 male spines were interpreted. The average observed lengths at age are summarised in Fig 6 and Ford-Walford plots were carried out on these. Of the various assessments of spurdog growth which have been undertaken that of Holden and Meadows (1962) on the Scottish-Norwegian stock has greatest relevance. Their calculations of L_{∞} and K were made graphically, by eye, rather than by calculation and they are repeated by formula to facilitate comparison with data from the south western fishery. The calculation of t_0 gives very variable readings and, in the case of both Holden and Meadows's and the Irish data the t_0 value was averaged from five calculations made on observed lengths at ages 9-19.

The computations are summarised beneath:

	L_{∞}	K	t_0
Males			
Holden and Meadows (original)	79.9	0.21	—2.0
Holden and Meadows (recalcd)	86.0	0.14	—3.13
This work	79.9	0.16	—1.69
Females			
Holden and Meadows (original)	101.4	0.11	—3.6
Holden and Meadows (recalcd)	104.0	0.11	—3.28
This work	98.8	0.09	—1.57

The growth curve is fitted using the data, according to the von Bertalanffy equation (Fig. 6).

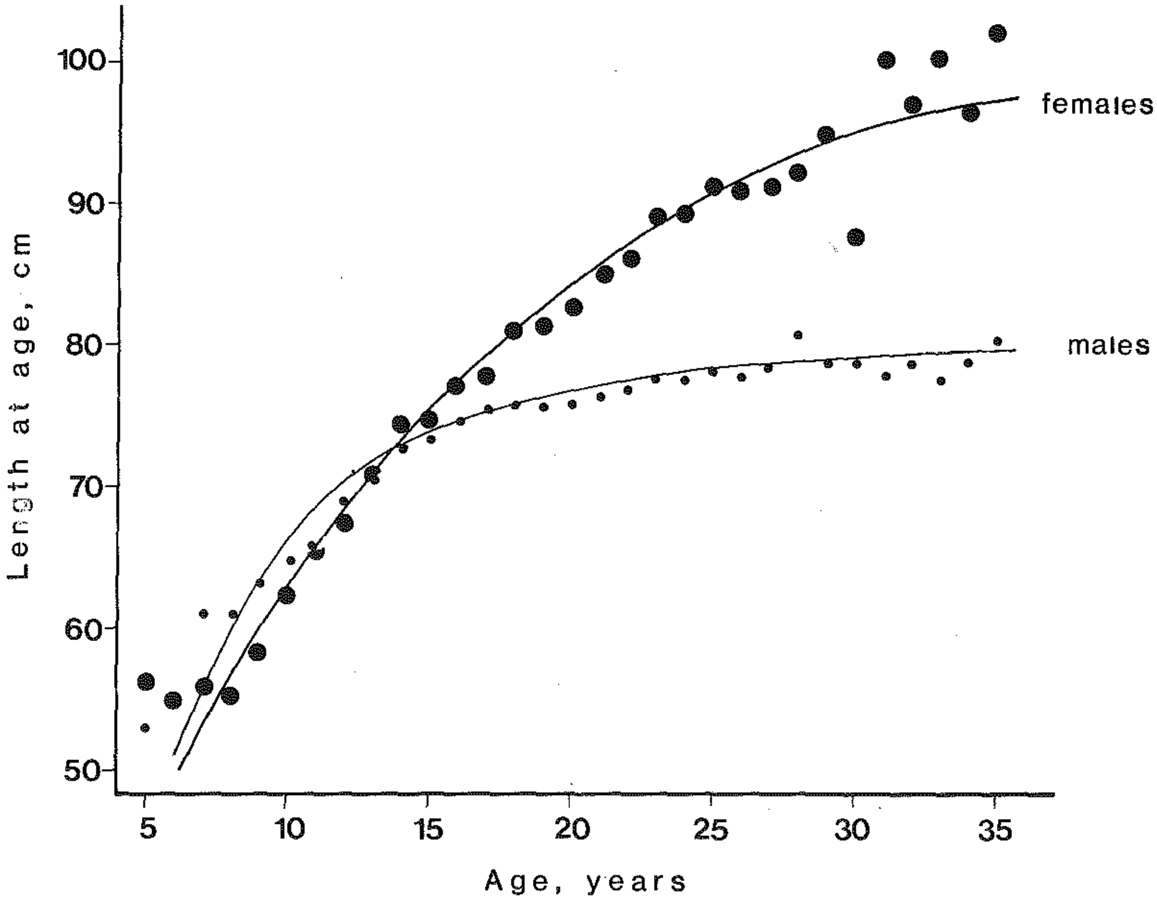

Figure 6. Observed length at age data for male and female spurdogs. The calculated growth curves are fitted using von Bertalanffy growth equations.

Maturity

The reproductive characteristics of the south west Ireland female spurdogs were established on approximately 50 females opened each month throughout the sampling period. Their percentage distribution over three categories of reproductive status is set out in Fig. 7, the dividing lines being fitted by eye. The 50% mature point is located at slightly more than 74 cm in length which corresponds with an average age of 14 years. The 50% point is very low when compared with other assessments: Templeman (1944) gave a length of 77 cm for spurdogs off Newfoundland. Gauld (1979) reported 83 cm for the Scottish-Norwegian stock, a measurement similar to Holden and Meadows's (1964). In that stock the mean length at 50% maturation had remained static from one assessment to another some 15 years later, a period over which the fecundity of the stock had apparently increased by 42% (Gauld, 1979). The only previous observations from south west Ireland were made by Hickling (1930) who described maturity as setting in between 75 and 80 cm with a 50% "onset of pregnancy" at 81 cm. Thus his figure, while lower than those reported from the Scottish-Norwegian fishery is slightly higher than the results reported here.

Taking a number of maturation assessments into account there would appear to be a latitudinal influence on length at maturity, stocks situated further north taking longer to develop. Studies from the north west Pacific give a length at maturity of 90-95 cm for a southern stock (Yamamoto and Kibezaki, 1950) and 104-109 cm for a more northern stock (Sato and Inukai, 1934). Ketchen (1972) gave a figure of 93.5 cm for 50% maturity of females off the west coast of Canada. He also observed that females in the north Pacific mature at an average length of 92-100 cm compared with 77-82 cm in the Atlantic.

Of the range of biological characteristics reviewed here the small size at female maturation off south west Ireland would seem to be the most distinctive.

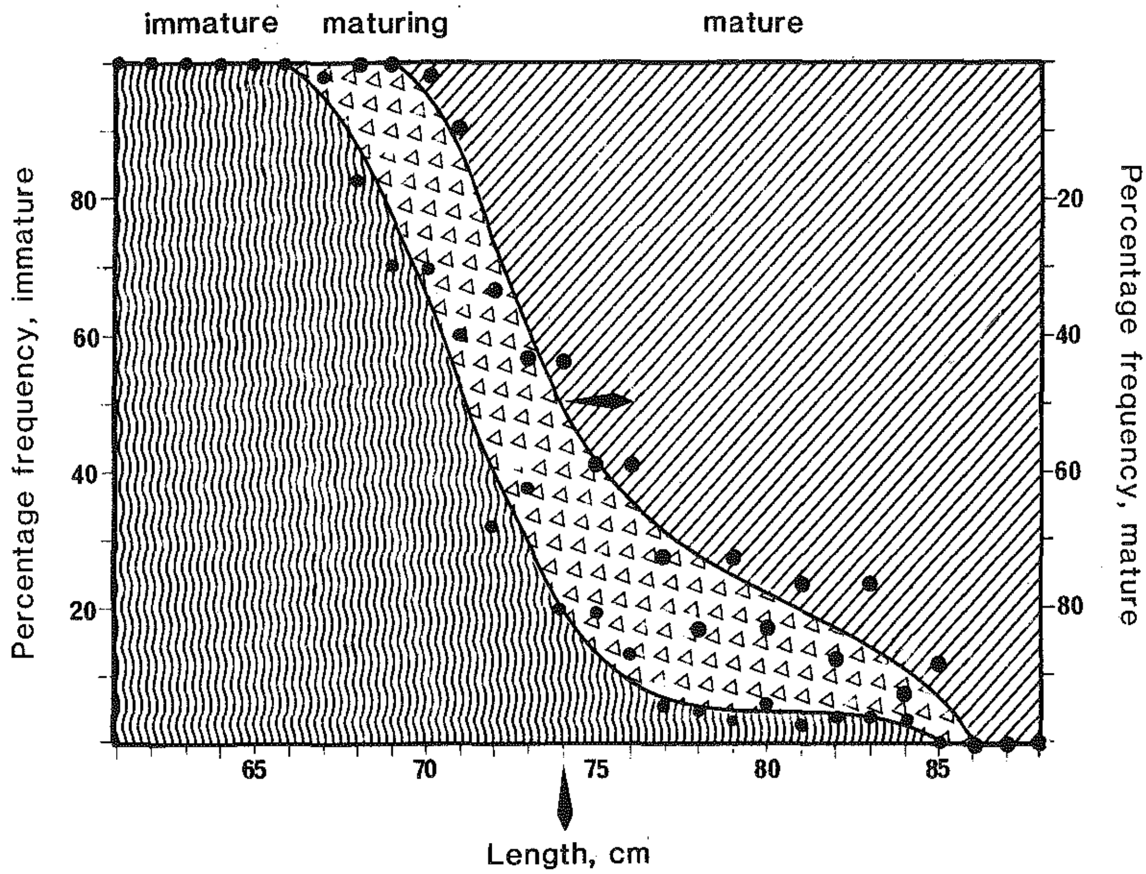

Figure 7. Reproductive status of female spurdogs between 61 and 88 cm in length, 50% maturity indicated.

Fecundity

The fecundity of the spurdog may be described on the ovarian ova, candled ova or free embryos all of which increase in number as the fish grow. Their numbers and the length of the parent are not strongly correlated however and they have not been treated in the same way by all investigators. Ketchen (1972), Jones and Geen (1977) and Gauld (1979) used linear regressions while Holden and Meadows (1964) employed a logarithmic relationship. Both Gauld (1979) and Holden and Meadows (1964) also transformed their data by obtaining the mean numbers of reproductive criteria at each 1 cm parent length interval prior to correlation.

For the analysis of the Irish material a linear and a multiplicative regression were both used on the raw data and the results are set out in Table 7.

The slopes of the multiplicative regressions (b) are far from 3.0 except in the case of the candled ova and the correlation coefficients are in all cases stronger for the linear than the multiplicative correlations.

Because ovarian ova undergo atresia it was considered prudent to calculate separate regressions at thresholds of 5 and 16g, the former being close to Ketchen's definition of maturity (Fig 2), the latter being the weight used herein to define maturity. The two give almost identical results indicating that egg number has stabilised at the dimensions used by Ketchen. However, although ovarian egg number may have stabilized within the range given here, atresia is a possible explanation for the slight further reduction to the numbers of candled ova; also addled (infertile) eggs of more than 20 g were occasionally encountered in the course of the investigations. These correlations are expressed in real terms at three different parent lengths in Table 8. Calculated by multiplicative regression, the numbers of candled ova are between 5 and 8% fewer than where a linear regression is used. And finally, there is a further reduction from the numbers of candled ova to free embryos, by 26% in parents of 100 cm. This is attributed to the premature loss of embryos during capture. There is much evidence to support that happening and boxes of gravid females are invariably accompanied by aborted embryos. Observations suggest that the constraining action of gill nets may result in heavier loss of embryos than other methods of capture.

Numbers of candled ova are therefore used to indicate the fecundity of the south west Ireland fish. A selection of calculations of fecundity arising from this and related investigations are presented in Table 8 from which comparisons of free embryo numbers, which are regarded as unreliable indicators, are omitted.

The fecundity of spurdogs from south west Ireland is high when compared with Holden and Meadows's (1964) estimates though lower by about 12-15% than Gauld's (1979) assessment of that stock revealed.

Mortality

In the course of the investigations in south west Ireland 2,812 female and 2,685 male spurdogs were examined. The vast majority came from trawls and gill nets although several consignments of long line caught fish were also examined.

Observations of spine age were used to construct a length at age key and measured-only samples were distributed proportionately among the age groups, trawl and gill net catches being treated separately. To ascertain the relative contributions of trawl and gill net to the landings, the purchasing records of a centrally located fish buyer were analyzed. More than 300 records dating from early 1985 were abstracted which accounted for 201 tonnes of fish, 36.8% of which could be attributed to gill nets and the balance to trawls. On these proportions were based the analysis of the south western fishery although it is appreciated that this division of catch refers more exactly to the earlier part of the sampling period and that, towards its conclusion, gill nets were making a much larger contribution to the total.

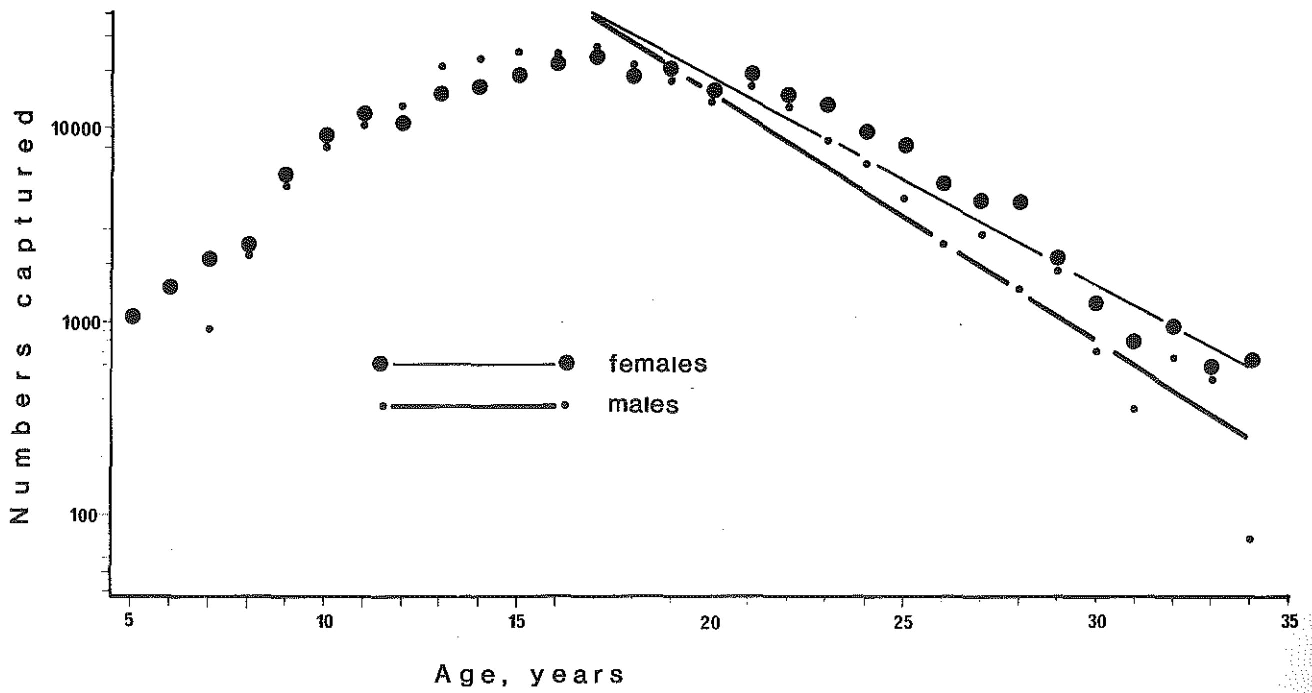

Figure 8. Catch curves for male and female spurdogs in the south west Ireland fishery, regressions on which the total mortality coefficients (Z) are calculated are superimposed.

Total mortality coefficients were calculated on a notional total catch of 100,000 tonnes, 36,800 coming from gill nets and 63,200 from trawls. The sex ratio of fish in the gill nets was 74.7% female: 25.3% male (Table 4); average weights of females and males were 2.20 and 1.51 kg respectively (Table 5). Making adjustments for these, the composition by weight of the female component of the gill net catches was 81.1% or 29,860 t; males accounted for 38.2% or 6,940 t.

Representation by sex in the trawl catch was 36.3% female and 63.7% male, their average weights 1.89 and 1.35 kg respectively. Taking these weighting factors into account, females made up 44.4% of trawl landings, totalling 28,061 t while males accounted for 55.6% totalling 35,139 t.

Raising the aged length frequency distributions of spurdogs from different types of gear to these tonnages produced the distribution of aged spurdogs presented on a logarithmic scale in Fig 8. For both sexes recruitment is taken to be complete at age 17 and the total mortality coefficient (Z) is calculated from this point. For females Z has a value of 0.2433, the higher value of 0.2986 for males being a result of the predominant contribution of trawls to the total. The data in Fig. 8 come from two sources: trawls which exploit the younger and gill nets the older year classes. Adjusting their relative contributions towards gill nets has the effect of increasing the value of Z. The truth in the south west Ireland fishery is more likely to lie in a total mortality coefficient of 0.2 for the younger female age groups of, say 15-20 years, increasing to 0.3 among fish of 20+.

An additional complication is the fact that gill nets are selective and retain fish whose growth approximates the mesh size (Fahy, 1979); the result, in a long lived species of variable growth rate is the selective retention of the faster growing of the younger age groups and the slower growing older fish. However the logarithmic regression of numbers of age class may ameliorate its bias.

Life Table Construction

Model 1: the number of whelps necessary to ensure replacement

Aasen (1964), Holden (1968) and Wood, Ketchen and Beamish (1979) proposed a coefficient of natural mortality (M) of 0.1 in spurdogs and this figure has been widely used since. It derives from the assumption that in a slow growing species the value of M approximates to the growth coefficient K rather than being supported by experimental observation. Holden (1965) pointed out that the Grimsby market will accept spurdogs of 40 cm total length or greater and some few fish of as young as 5 years were brought ashore in south west Ireland. Holden (1968) divided female mortality into three phases: a period of very low mortality for the first five years followed by a period of increasing mortality until, at age 15, the value of Z rose to 0.314.

In order to compile a life table for female spurdogs in the south west fishery Holden's value of M is adopted for the first six years, the estimated value of 0.2433 (Z) is introduced from age 17 and, in the interim period of ages 7 to 16, intermediate values of Z which rise linearly by annual increments are proposed to reflect increasing recruitment. These figures are the basis of the scenario in Table 9. Going through this column by column:

An age range of 0 to 40 is considered, 10 years longer than postulated for the North Sea stock by Holden and Meadows (1964). Average lengths at age derive from the application of the von Bertalanffy equations to the growth data. Percentage maturity at age is read from the maturity at length diagram (Fig 7) and the numbers surviving at a particular age are as calculated above from a total in mid-year 0 of 10,000. Numbers to mature are the numbers to survive at a particular age multiplied by the percentage of that age class to mature. The number of female whelps per year is calculated from the regression of numbers of candled ova on parent length x0.25 which incorporates into the calculation a sex ratio of 50:50 plus the fact that breeding takes place every other year. And finally, the total number of female whelps is obtained by multiplying the potential numbers of female whelps annually by the numbers of potential parents in each year class.

Summing the progeny of each age class in the final column gives a total of 10,013 female whelps or just the number required to maintain the population structure at the assumed rates of mortality. While there is fairly wide acceptance for an m value of 0.1 (references given above) and the Z value of 0.2433 is deduced, with reservations, from the calculated age structure of the landings, the intermediate values of M are supposition. Were the exercise to be repeated on the basis of M = 0.1 until age 17 total female progeny per year would amount to approximately one and a half times the required cohort number in year 0.

All of this is to accept that the coefficient of natural mortality M is as low as 0.1; were this to be the case in the south western fishery and were its reproductive potential to be uninfluenced, as yet, by intensifying fishing pressure, the total number of female whelps born annually would be three and a half times replacement numbers in year 0. Alternative explanations for this high figure would include a recent increase in fecundity of the stock or a higher than assumed value for M.

Model 2: the number of female whelps necessary to maintain one breeding female of modal mature age in the population.

An alternative approach was devised by Jones and Geen (1977). Its objective is to estimate the number of female embryos required to produce one breeding female at the modal length of mature females. No assumptions are made about natural mortality; instead a greater reliance is placed on the observed length

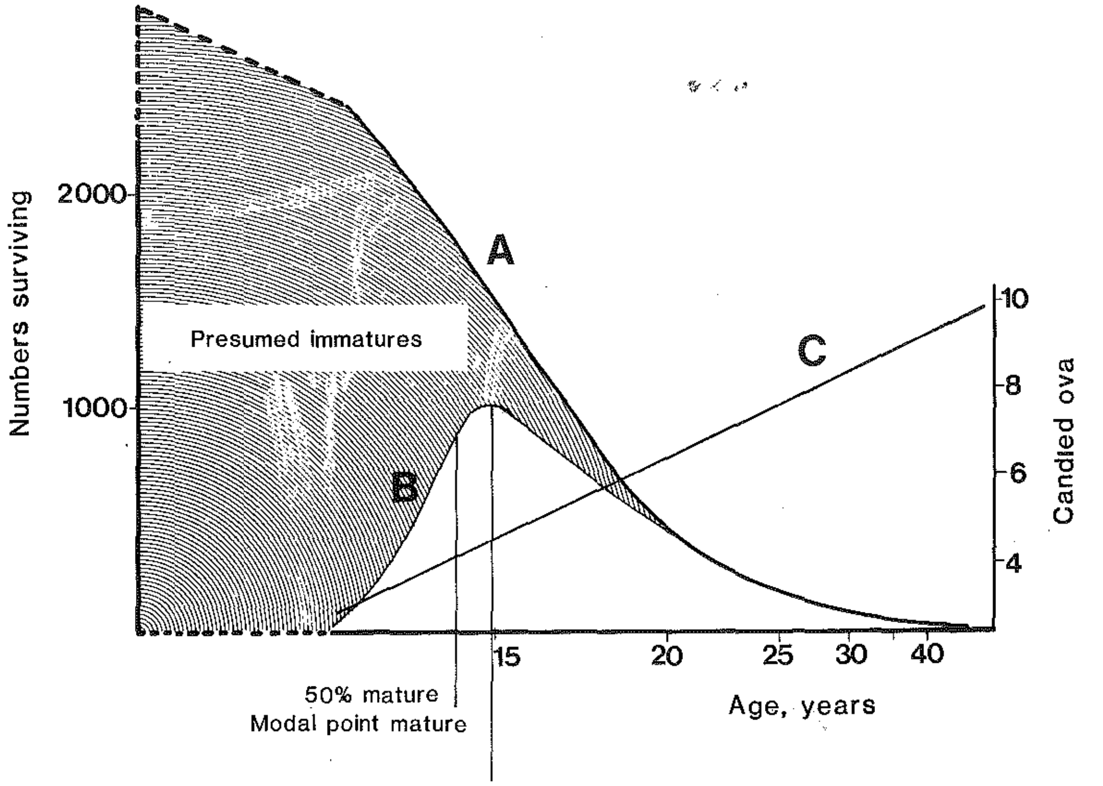

Figure 9. Diagramatic presentation of the data on which life table model 2 (Table 10) are prepared. Curve A is the smoothed female catch curve in Fig 8. Curve B is length at maturity data (Fig 7) expressed in terms of the survival curve and line C is the regression of candled ova on parent length (Table 7).

frequencies of the catch. The data on which the life table is based are presented in diagramatic form in Fig 9 where A is the mortality curve calculated from the age frequency distribution of the catch. This curve may be extended back to an arbitrary number at birth. B is the length at maturity curve from Fig 7, expressed in terms of the survivorship curve and line C is the regression of numbers of candled ova on parent length.

Data are arranged in Table 10. An age range of 12, the first in which female maturity is encountered, to 40 years, similar to that in model 1, is considered (Column 1). The percentage to mature in each age group are read from Fig 7 (Column 2). Numbers surviving to the beginning of these year classes are calculated from the logarithmic regression of catch numbers on age (Column 3) and the numbers of these which mature are obtained by multiplying the numbers to have survived in a particular year class by the percentage maturity (Column 4).

The numbers breeding are next expressed as a percentage of the modal age, year 15 (Column 5) (kx) and the numbers which survive (Column 3) are also expressed as a percentage of the numbers breeding at modal age. However, because female spurdogs breed every other year, a true account of the population structure can be obtained only by doubling the numbers surviving (Column 6) (lx). The number of embryos produced by a breeding female is calculated from the regression of candled ova on parent length (Table 7) (Column 7).

A sex ratio of approximately 50:50 at birth has been universally reported and females breed every other year so the number of female embryos produced by a mature female is expressed as the calculated progeny from one of the fecundity regressions multiplied by 0.25 (Column 8). And, finally, the total number of female embryos produced by a population of a certain size (lxmx) is obtained by multiplying the data in Columns 6 and 8 (Column 9).

From these figures the relative numbers at birth (l_o) are determined by balancing the numbers of embryos produced by the breeding stock (Σlxmx) and the number of breeding females (Σkx) according to the formula:

$$\frac{\Sigma lxmx}{(lo)\ \Sigma kx} = 1$$

Jones and Geen (1977), working on spurdogs of a long-lived British Columbia stock with an age range of from 20 to 70 years for this exercise, concluded that 3.57 female embryos at birth (l_o) were required to maintain one breeding female at modal age 35. She, in turn, belonged to a age class of 2.27 survivors. Thus, over a period of 35 years there was a deduced loss of 36%, a figure which they considered to be appropriate for a long lived and slow maturing species with few natural enemies.

Spurdog stocks in the Pacific are much longer lived than those in the Atlantic Ocean and it is reasonable to postulate lower rates of natural mortality there but the figure Jones and Geen provide of a 36% reduction — which corresponds with a mortality coefficient (M) of 0.01 — is unrealistically low. Were l_o doubled to 7.14, the loss at age 35 would be a more realistic 68% which, expressed as a natural mortality coefficient, is somewhere in the region of 0.033. Returning to the possible relationship between the natural mortality coefficient M and the growth coefficient K, the latter was calculated from the length at age data for the Pacific fish, fitted by von Bertalanffy growth equations and presented by Jones and Geen (1977) at 0.036, very close to the coefficient of natural mortality likely to operate in the British Columbia spurdogs.

In the case of the south west Ireland fishery $\Sigma lxmx = 20.58$ and $\Sigma kx = 7.39$, making l_o 2.78 which is to say that 2.78 female embryos would be required for the survival of one mature female of modal age. The size of the year class of which that female would be a member would be 2.99, suggesting a negative mortality over 13 years.

Further experiments with this life table suggest that the exercise may be best applied to devising an index to a breeding population, taking account of not merely the modal length of mature females but also the spread of females above the mode. Recalculated for a south west Ireland population whose mortality coefficient M is 0.1 throughout, this representing the situation in an unexploited stock, the following computations emerge:

$$\Sigma lxmx = 45.79 \qquad \Sigma kx = 13.83 \qquad l_o = 3.31$$

In this model the modal age of breeding females is at age 16. The single breeding female belongs to a cohort of 2.6 females and, as deduced from the calculations, they are the survivors of a cohort of 3.31 whelps. To achieve these numbers a mortality coefficient of 0.015 would have had to apply; in fact, the model was constructed about a mortality coefficient of 0.1 where the cohort size in year 0 was 10,000 or, expressed in terms of breeding females, 6.43.

DISCUSSION

The commercial spurdog fishery in Ireland is a new phenomenon undergoing a rapid expansion and the species has acquired a considerable economic importance to the fishing communities of the western seaboard. Although little information has hitherto been available on the biology of the fish in Irish waters, sufficient is known of spurdog fisheries elsewhere to dissuade too impetuous an expansion: there are documented accounts of declining fisheries following over-exploitation in both the Pacific and Atlantic oceans.

Whether the south west Ireland population belongs to a larger stock unit is an open question. Of its characteristics reviewed here the only remarkable and distinguishable one is the early age at maturity of the females and that might well be a result of geographical situation. It is possible that the south west Ireland population is a part of a larger stock complex or that it is one of a number of separate western coastal stocks; for our purposes it is regarded as the latter.

Because landings from the western spurdog fisheries have expanded rapidly and interest is increasing to the extent that large fishing fleets are prepared to move long distances specifically to fish for them, the thrust of this investigation will be to recommend how best the fishery might be regulated to ensure some kind of continuity or survival of the stock rather than how it should be managed for optimum yield. At this time there are in existence, in effect, two co-existing fisheries whose catches have different characteristics and which exploit fairly separate components of the population. This, on a much larger scale, is the manner in which the Scottish-Norwegian fishery was pursued and there are strong similarities between the organization of the two. Most of the pioneering investigations were carried out on the Scottish Norwegian fishery and its geographical proximity and biological similarity make it an appropriate one with which to compare the south west Ireland fishery.

The Scottish sector of the stock was exploited largely by trawl while the Norwegians line fished and concentrated their effort on females of greater than 80 cm (Holden 1965, 1968). Holden and Meadows (1964) and Holden (1968) predicted a decline in the fishery which did not however materialise. Instead Gauld (1979) provided figures on landings which suggested that the British sector of the fishery continued to provide a steady yield whereas the Norwegian share of the catch declined fairly steadily from 25,700 tonnes in 1960 to an estimated 10,000 tonnes in 1978.

The earlier prediction of collapse of the Scottish-Norwegian stock was based on calculations that, at the observed fecundity prevailing at the time, the number of progeny was not adequate to ensure cohort replacement. Gauld (1979) re-examined the fecundity of spurdogs from the fishery and concluded that it had increased by 42% in the interim in response, he assumed, to more intense fishing pressures.

There are three potential mechanisms by which spurdog populations might adjust to fishing pressures, first identified by Holden (1973). They are compensatory growth, compensatory natural mortality (M) and compensatory reproduction. Using an age structure model, Wood, Ketchen and Beamish (1979) examined the likely consequences of all three. Their calculations were based largely on assumption (of the same kind as those presented here, in the case of natural mortality), there being no observed data on which to proceed. They favoured compensatory change in the rate of natural mortality (M) as the principal mechanism for density-dependent response, arguing that a decrease in natural mortality from 9 to 5% annually would substantially increase the yield of a spurdog fishery. Supporting evidence for their theory was drawn from the recovery of the Canadian fisheries in the 1950s, following their collapse in the previous decade although the authors allowed that the resurgence might have been due to immigration from other stocks.

According to the age structure model, an unrealistically high increase in reproductive rates would be required to bring about a recovery in depleted spurdog numbers. Holden (1973) favoured such a mechanism and provided examples of variations in fecundity in several spurdog populations in support of his thesis but did not however, demonstrate heightened fecundity as a consequence of increased fishing pressure, a fact noted by Wood, Ketchen and Beamish (1979). As far as is known, the only work which quantifies enhanced fecundity is that of Gauld (1979) which Wood et al did not consider.

The fecundity of spurdogs is a major consideration in the several assessments of their commercial potential now in existence. Correlations between the various indicators of reproductive activity (ovarian ova, candled ova and embryos and free embryos) on parent length indicate considerable variation. In addition, the size of ova and of embryos at birth can alter from one fish to another and, Gauld (1979) observed, the body cavity could accommodate more whelps than it usually does although he conceded that this might be a physiological requirement, of gas interchange for instance.

Raised fecundity levels in the Scottish-Norwegian stock would then appear to have contributed to their viability or, at least to be indicative of an increased fishing pressure, but the potential for an increased fecundity in the south west Ireland stock is unknown. Because this is the first assessment of this population it is not feasible to state whether the observed levels of fecundity are already raised in response to increasing catches but that would be a reasonable interpretation of the data.

Both life tables (Tables 9 and 10) are a mixture of observation and assumption so several scenarios are reviewed in the course of considering each of them. Viewing the matter conservatively, the prospects for any kind of sustained fishery in the context of a deepening concentration of effort on the mature females which constitute a large proportion of the total landings at the present time, must be viewed pessimistically, particularly in the light of the Norwegian experience.

As gill nets are the main cause for concern in the south west Ireland fishery it is appropriate to consider how they might be altered to permit a greater escapement. The girth and length of 91 female spurdogs captured by long line are set out in Fig 10. The "5 inch mesh" is the standard monofilament net once used legally for the capture of salmon. In fact its bar size (x) measures 2.5 inches — 6.4 cm — knot to knot and

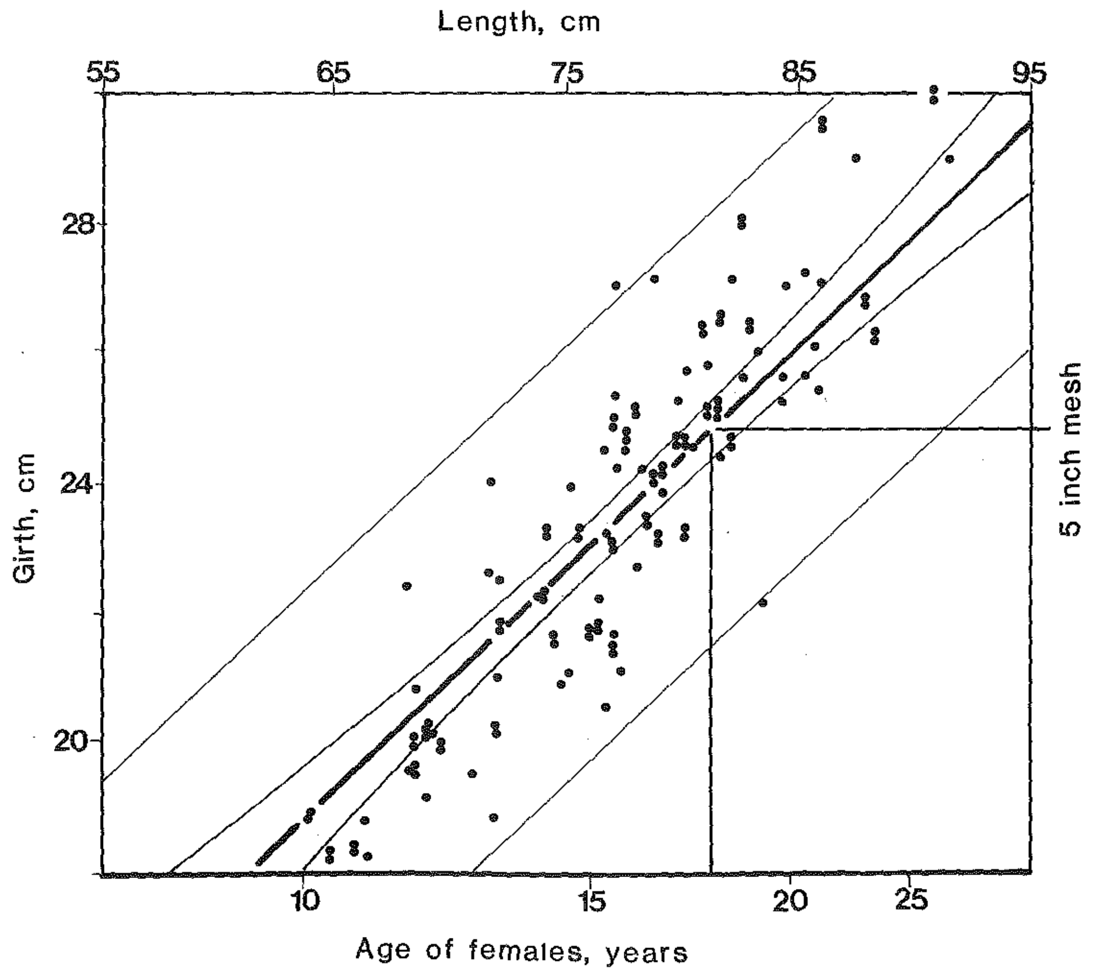

Figure 10. Regression of girth on length and age of 91 female spurdogs captured by longline. Mesh perimeter of 5 inch gill net included. Confidence and prediction limits both at 95% level.

the mesh perimeter is 10 inches — 25.4 cm — in length. Although gill nets are selective, they can retain fish of a variety of lengths, hence ages, particularly when the girth of those fish alters with change in reproductive status (Table 6).

From Fig 10 it can be seen that the mesh size impinges on the regression of girth on length above the modal breeding age. Because the length at age of these fish varies considerably and because their girth alters with reproductive condition the mesh size is not likely to permit escapement of all fish of less than modal breeding age and any larger mesh, in addition to directing effort further away from the males, will increase the take of older females which make a large reproductive contribution to the population. Jones and Geen (1977) who considered a comparable situation in the British Columbia spurdog fishery concluded that maximum annual catch limits were the best practical method of regulating that fishery.

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BIBLIOGRAPHY

Aasen, O. (1964). The exploitation of the spiny dogfish (*Squalus acanthias* L.) in European waters. *Fisk, Dir. Skr. Serie Havundersokeler* 13:5-16.

Beamish, R. J. and G. A. McFarlane (1985). Annulus development on the second dorsal spine of the spiny dogfish (*Squalus acanthias*) and its validity for age determination. *Can. J. Fish. Aquat. Sci. 42*: 1799-1805.

Fahy, E. (1979). The exploitation of grey mullet *Chelon labrosus*(Risso) in the south east of Ireland. *Ir.Fish.Invests* B (Marine) No. 19:15pp.

Ford, E. (1921). A contribution to our knowledge of the life histories of dogfishes landed at Plymouth. *J. Mar. Biol. Ass. UK, new ser* 12 (3):468-505.

Gauld, J. (1979). Reproduction and fecundity of the Scottish-Norwegian stock of spurdogs, *Squalus acanthias* (L.) ICES CM 1979 H:54:16pp.

Gauld, J. and W. S. MacDonald (1982). The results of tagging experiments on spurdogs *Squalus acanthias* L. around Scotland. ICES CM 1982/H:51.

Gulland, J. A. (1955). Estimation of growth and mortality in commercial fish populations. *Fish. Invest. Lond.* Ser. 2. 18(9):46pp.

Hickling, C. F. (1930). A contribution towards the life history of the spurdog. *J. mar. biol. Ass. UK* 16: 529-576.

Hisau, F. L. and A. Albert (1947). Observations on the reproduction of the spiny dogfish (*Squalus acanthias*) *Biol.Bull (Woods Hole)* 92:187-199.

Holden, M. J. (1965). The stocks of spurdogs (*Squalus acanthias* L.) in British waters and their migrations. *Fish. Invest. Lond.* Ser 2 24(4):20pp.

Holden, M. J. (1968). The rational exploitation of the Scottish-Norwegian stock of spurdogs, *Squalus acanthias* L. *Fishery Invest. Lond.*, Ser 2, 25(8), 27pp.

Holden, M. J. (1973) Are long term sustainable fisheries for Elasmobranchs possible? In Fish stocks and recruitment *Rapp. P.V.Reun. Cons. Int. Explor. Mer.* 164: 360-367.

Holden, M. J. and P.S. Meadows (1962). The structure of the spine of the spur dogfish. (*Squalus acanthias* L.) and its use for age determination *J. mar. biol. Ass. UK.* 42:179-197.

Holden, J. J. and P. S. Meadows (1964). The fecundity of the spurdog (*Squalus acanthias* L.) *J. Cons. perm. int. Explor. Mer.* 28:418-424.

Jones, B. C. and G. H. Geen (1977). Reproduction and embryonic development of spiny dogfish (*Squalus acanthias*) in the Strait of Georgia, *J. Fish. Res. Board. Can.* 34: 1286-1292.

Kaufmann, D. E. (1955). Noteworthy recoveries of tagged dogfish. *Fish. Res. Pap. Wash. Dep. Fish* 1 (3):39-40.

Ketchen, K. S. (1972). Size at maturity, fecundity and embryonic growth of the spiny dogfish (*Squalus acanthias*) in British Columbian waters. *J. Fish. Res. Bd. Can* 29:1717-1723.

McFarlane, G. A. and R. J. Beamish (1985) Validation of the dorsal spine method of age determination for spiny dogfish in *Age and Growth of Fish* eds: Summerfelt, R. C. and G. E. Hall: 287-300. Iowa State University press/Ames.

Satò and Inukai (1934) quoted in Ketchen, 1972.

Templeman, W. (1944). The life history of the spiny dogfish (*Squalus acanthias*) and the vitamin A values of dogfish liver oil. *Res. Bull. Div. Fish. Resour. Newfoundland* No. 15. 102pp.

Templeman, W (1958). Ground bank tagged dogfish moves to Iceland. *Progr.Rep.Atl.biol.Sta* No. 17:28-30.

Wood, C. C., K. S. Ketchen and R. J. Beamish (1979) Population dynamics of spiny dogfish (*Squalus acanthias*) in British Columbia waters *J. Fish. Res. Board Can.* 36: 647-656.

Yamamoto, T. and O. Kibezaki (1958). Studies on the spiny dogfish *Squalus acanthias* L.(1) on the development and maturity of the genital glands and growth. *Hokkaido Reg. Fish. Resour. Res. Rep. 3:* 531-538.

Table 1. Spurdog landings (in metric tonnes) at four ports on the west coast, 1979-1987 inclusive.

	Ports			
Year	Burtonport	Greencastle	Dingle	Rossaveal
1979			19	
1980		13	3	
1981	2	12	71	23
1982	5	859	52	7
1983	110	1,670	251	173
1984	1,299	1,523	353	212
1985	2,248	1,560	730	213
1986	870	727	337	181
1987	1,124	639	1,781	338

Table 2. Details of two consignments of spurdogs, as reported by questionnaire; box weight 45 kg.

Sample 1: Location, Kenmare Bay, Eyeries — Ardgroom; Gear: gill nets (GN).

Contents of boxes	females	males
1	14	0
2	13	5
3	14	5
Totals	41	10 (19.6%)
Average Wt.	2.6kg	

Sample 2. Location, North west of the Sceligs; Gear: Trawl (OTB)

Contents of boxes	females	males
1	3	29
2	1	27
3	4	25
Totals	8 (9.0%)	81
Average Wt.	1.5kg	

Table 3. Summary of exercise to standardise interpretations of spurdog spines: Reader 1 was J. Gauld, Reader 2, E. Fahy.

Number of spines read	Age determined by Reader 1	Percentage of readings coinciding exactly	Mean ages of spines determined by Reader 2
4	8	50	8.0
8	9	50	10.0
7	10	43	10.4
6	11	33	12.3
11	12	18	11.7
8	13	50	13.3
14	14	21	13.9
10	15	40	15.5
7	16	19	16.6
20	17	25	16.3
16	18	31	18.6
9	20	33	19.0
9	20	22	20.9
4	21	50	20.3
11	22	18	22.1
9	23	44	22.8
3	24	0	25.7
7	25	29	24.1
5	26	0	26.0
2	27	0	26.0
1	28	100	28.0
1	30	100	30.0
Total 172			

Table 4. Percentages of male and female spurdogs taken in gill nets and otter trawls, April 1987 to March 1988 inclusive.

	Sex	
Gear	Females	Males
GN	74.7	25.3 (N=2,714)
OTB	36.3	63.7 (N=2,572)

Table 5. Average weights (kg) of male and female spurdogs in gill nets and otter trawls, April 1987 to March 1988 inclusive.

Gear	Sex: Females	Sex: Males
GN	2.20	1.51
OTB	1.89	1.35

Table 6. Some characteristics of the 26 samples investigated in greatest detail, arranged by type of gear and date (GN = gill net, OTB = bottom trawl and LL = long line).

No.	Date	Where landed	Gear	Numbers	AvLt, all	AvLt, m	AvLt, f	AvWt, m	AvWt, f	AvAge, m	AvAge, f	% f	Mature f, %
1	87.04.02	Carrigaholt	GN	190	77.5	71.6	78.5	1,422	2,046	18.6	19.6	86	86
2	87.05.05	Dingle	GN	75	81.5	72.6	81.0	1,335	2,049	17.4	19.9	87	86
3	87.06.09	Dingle	GN	152	77.5	71.6	79.0	1,386	2,075	14.7	17.6	90	39
4	87.06.09	Dingle	GN	153	77.3	71.6	79.0	1,398	2,075	14.7	17.5	90	56
5	87.07.14	Dingle	GN	37	80.3		80.3		2,163		19.7	100	86
6	87.07.17	Carrigaholt	GN	147	73.7	73.3	74.8	1,404	1,885	17.8	18.6	24	53
7	87.08.05	Dingle	GN	200	81.9	75.1	82.3			15.1	18.0	94	
8	87.08.15	Dingle	GN	102	83.8	74.6	86.0			19.7	21.4	80	
9	87.08.18	Fenit	GN	89	81.6		81.6		2,281		18.8	99	84
10	87.08.19	Fenit	GN	99	75.2	74.0	75.8			15.0	15.7	98	
11	87.09.22	Dingle	GN	75	89.8		89.8		3,257		24.2	99	
12	87.09.23	Dingle	GN	59	83.5		83.5				21.6	100	
13	87.12.10	Dingle	GN	220	76.9	75.6	82.3	1.549	2,318	22.4	22.5	18	81
14	88.01.27	Carrigaholt	GN	115	76.9		76.9			17.3	20.0	97	60
15	88.01.28	Dingle	GN	147	74.2	72.2	74.9	1,343	1,801	17.6	16.3	73	80
16	88.02.20	Dingle	GN	76	78.4		78.4		2,076		18.9	100	21
17	88.03.23	Carrigaholt	GN	106	83.1		83.1		2,556		21.8	99	
		Averages			79.6	73.2	80.4	1,405	2,215	17.3	19.5	84.4	66.6
18	87.05.15	Dingle	OTB	95	63.2	65.6	61.0	931	792	13.7	11.3	52	11
19	87.05.07	Rossaveal	OTB	99	70.1	65.7	72.4	1,058	1,605	13.3	15.2	66	53
20	87.07.17	Rossaveal	OTB	206	72.9	72.8	73.2	1,476	1,686	18.1	16.4	36	
21	87.07.22	Dingle	OTB	93	73.3	73.2	73.7			16.2	15.4	24	
22	87.08.19	Dingle	OTB	88	72.7	72.2	73.5	1,364	1,694	17.2	15.4	38	23
23	87.10.20	Dingle	OTB	106	73.0	72.3	74.2	1,467	1,710	21.9	17.4	19	50
24	87.10.21	Rossaveal	OTB	173	65.9	67.8	61.5	1,194	949	16.4	12.0	2	31
25	87.11.25	Rossaveal	OTB	169	72.3	72.0	74.3	1,373	1,863	17.2	18.3	13	56
		Averages			70.4	70.2	70.5	1,266	1,471	16.8	15.2	31.3	37.3
26	87.04.03	Carrigaholt	LL	191	76.4	71.1	78.9	1,281	2,030	17.7	19.6	68	82
Total	3,262												

7. Aspects of spurdog fecundity regressed on length (cm), by linear and multiplicative correlation.

Linear, y = a + bx: Intercept, a	Slope, b	Correlation coeff.	Multiplicative, y = a x^b: Intercept, a*,	Slope, b	Correlation coeff.	d.f.
Number of ovarian Ova, threshold 5q						
—8.8483	0.1886	0.7082	—8.0841	2.2560	0.6725	201
Number of ovarian ova, threshold 16g						
—10.0157	0.2013	0.7615	—8.7277	2.3959	0.7181	94
Numbers of candled ova						
—13.1970	0.2323	0.6880	—10.2925	2.7223	0.5834	121
Embryo number						
—6.1045	0.1342	0.4959	—7.7152	2.0936	0.3900	168

*log a.

Table 8. Calculated numbers of ova and embryos at three parent lengths — various sources

Criterion	Source	Regression	Parent lengths 80	90	100cm
Ovarian ova, small	S.W. Ireland — this work	Linear	6.23	8.12	10.00
Ovarian ova, large	S.W. Ireland — this work	Linear	6.09	8.10	10.10
Ovarian ova, large	North Sea —Gauld, 1979	Linear	6.58	8.96	11.33
ovarian ova, large	North Sea — Holden & Meadows (1964)	Logarithmic	4.31	6.25	8.71
Candled ova	S.W. ireland — this work	Linear	5.39	7.71	10.00
Candled ova	S.W. Ireland — this work	Multiplicative	5.14	7.08	9.43
Candled ova	North sea — Gauld 1979	Linear	6.10	8.92	11.74
Free embryo	S.W. Ireland, this work	Linear	4.63	5.97	7.32

Table 9. Life table for female spurdogs off south west Ireland. Size of cohort in year 0, 10,000; coefficient of natural mortality M = 0.10 in years 1-6; coefficient of total mortality (Z) rising annually from year 7 to year 16 to reflect increasing recruitment and from year 17 = 0.2433. Percentage mature from Fig 7. Whelps per year from linear regression of candled ova on length (x0.25).

Age	Average lt, cm	% mature	Numbers surviving	Numbers mature	Female whelps/ female year	Total female whelps
12	69.70	2	2,441	49	.75	37
13	72.20	20	2,080	416	.89	370
14	74.50	55	1,738	956	1.03	985
15	76.60	67	1,451	972	1.15	1,118
16	78.50	77	1,188	915	1.25	1,153
17	80.20	80	932	746	1.36	1.015
18	81.80	82	731	599	1.45	869
19	83.30	90	573	516	1.54	795
20	84.60	92	449	413	1.61	665
21	85.80	100	352	352	1.68	591
22	87.00	100	276	276	1.75	483
23	88.00	100	216	216	1.81	391
24	88.90	100	170	170	1.86	316
25	89.80	100	133	133	1.92	255
26	90.50	100	104	104	1.96	204
27	91.20	100	82	82	2.00	164
28	91.90	100	64	64	2.04	131
29	92.50	100	50	50	2.07	104
30	93.00	100	39	39	2.10	82
31	93.50	100	31	31	2.13	66
32	94.00	100	24	24	2.16	52
33	94.40	100	19	19	2.18	41
34	94.80	100	15	15	2.21	33
35	95.10	100	12	12	2.22	27
36	95.40	100	9	9	2.24	20
37	95.70	100	7	7	2.26	16
38	96.00	100	6	6	2.28	14
39	96.20	100	4	4	2.29	9
40	96.50	100	3	3	2.30	7
					Total	10,013

Table 10. Alternative life table for female spurdogs in the south west Ireland fishery. M marks the mode.

Age 1	% mature (Curve B Fig 9) 2	Numbers surviving to start of age class (Curve A Fig 9) 3	Numbers breeding (Columns 2 x 3) 4	Numbers breeding (Column 4 as % mode at age 15) kx 5	Numbers surviving (Column 3 as % mode in col. 4 x 2)* lx 6	Embryos per breeding female (line C, Fig 9) 7	Female embryos/ breeding female /year (Columns 7 x 2 x 0.25)** mx 8	Total female embryos (Columns 6 x 8) lxmx 9
11	0	2,865	0	.00	5.90	.00	.00	.00
12	2	2,441	49	.05	5.02	3.00	.02	.10
13	20	2,080	416	.43	4.28	3.56	.18	.77
14	55	1,738	956	.98	3.58	4.12	.57	2.04
15	67	1,451	M972	1.00	2.99	4.60	.77	2.30
16	77	1,188	915	.94	2.44	5.04	.97	2.37
17	80	932	746	.77	1.92	5.44	1.09	2.09
18	82	731	599	.62	1.50	5.80	1.19	1.79
19	90	573	516	.53	1.18	6.16	1.39	1.64
20	92	449	413	.42	.92	6.44	1.48	1.36
21	100	352	352	.36	.72	6.72	1.68	1.21
22	100	276	276	.28	.57	7.00	1.75	1.00
23	100	216	216	.22	.44	7.24	1.81	.80
24	100	170	170	.17	.35	7.44	1.86	.65
25	100	133	133	.14	.27	7.68	1.92	.52
26	100	104	104	.11	.21	7.84	1.96	.41
27	100	82	82	.08	.17	8.00	2.00	.34
28	100	64	64	.07	.13	8.16	2.04	.27
29	100	50	50	.05	.10	8.28	2.06	.21
30	100	39	39	.04	.08	8.40	2.10	.17
31	100	31	31	.03	.06	8.52	2.13	.13
32	100	24	24	.02	.05	8.64	2.16	.11
33	100	19	19	.02	.04	8.72	2.18	.09
34	100	15	15	.02	.03	8.84	2.21	.07
35	100	12	12	.01	.02	8.88	2.22	.04
36	100	9	9	.01	.02	8.96	2.24	.04
37	100	7	7	.01	.01	9.04	2.26	.02
38	100	6	6	.01	.01	9.12	2.28	.02
39	100	4	4	.00	.01	9.16	2.29	.02
40	100	3	3	.00	.00	9.20	2.30	.00
			Totals	7.39				20.58

*breeding every other year.

**Sex ratio at birth 50:50; breeding every other year, therefore annual production of female embryos = X 0.25 candled ova on length regression.

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