C.M.1975/K:2
Shellfish and Benthos Committee

REPORT OF THE WORKING GROUP ON NEPHROPS STOCKS

Charlottenlund, 21-23 January 1975

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1. Introduction

1.1 The Working Group on Nephrops Stocks met at Charlottenlund, 21-23 January 1975, with the following terms of reference (C.Res.1974/2:11):

"It was decided, that

a Working Group should be set up to meet for three days (21-23 January 1975) in Copenhagen to evaluate the state of the Nephrops stocks and the effects of changes in management, particularly in relation to NEAFC Recommendations 2 and 4, on the fisheries for Nephrops and associated by-catch species. The Group, to be convened by Dr. H J Thomas, will report to the Liaison Committee and to the 1975 Statutory Meeting".

1.2 The following scientists participated:

Dr O Bagge	Denmark
Dr R Boddeke	Netherlands
M A Charuau	France
M J Dardignac	France
Dr B I Dybern	Sweden
Dr E Edwards	U.K.
Mr H Eiríksson	Iceland
Dr J M de Figueiredo	Portugal
Mr K Gundersen	Norway
Dr J P Hillis	Ireland
Dr R Meixner	Germany, F.R.
Mr S Munch-Petersen	Denmark
Dr H J Thomas (Chairman)	U.K.

Mr David Griffith, ICES Statistician, also attended the meeting.

2. Biology

2.1 Catch composition

2.1.1 Values of the ratio (No. of females/100 males)are well under 100 for most of the year, but peak values usually exceed 100, or sometimes 200. Peak values occur in June-August off Scotland and Ireland, but in some northerly areas (north-east England, Skagerak and Iceland) two peaks are found - one in February-April and another in October-December. High female/male ratios are believed to be due to heavy fishing causing a greater increase in adult male mortality than in adult females. These data are modified by the presence of juveniles, among which the sex ratio remains closer to unity.

2.1.2 Off the United Kingdom, Ireland and Portugal the maximum percentage of recently spawned externally borne eggs occurs in August-October, in the Bay of Biscay in June-July, but in Icelandic waters it occurs in May-June. The eggs are borne externally for an incubation period which varies with latitude - six to seven months off Portugal to twelve months in Icelandic waters.

2.1.3 The 50% maturity size varies from country to country, the highest values having been found in Portuguese and Swedish waters, both at about 32 mm carapace length. Around Iceland and Ireland this size is rather constant from 23-25 mm carapace length. The size of the smallest berried females also varies accordingly, ranging from 18 mm to 22 mm carapace length in Irish and Icelandic waters and 26 mm and 27 mm respectively for Portugal and Sweden.

	50% maturity size (carapace length, mm)	Minimum maturity size (carapace length, mm)
Iceland	25	22
Sweden	32	27
Scotland	23	20
Northern Ireland	23	18-19
Ireland	24	21
Bay of Biscay	24-25	22
Portugal	32	26

2.2 Growth

Aquarium data support those of field studies on modal distribution. Irish Sea data give December carapace-length modal values of 18 mm, 23 mm, 28 mm, and 33 mm approximately. Around Iceland, tagging data for *Nephrops* averaging 45 mm carapace length give an average increment of 3 mm over a 7-month period for 50% of *Nephrops* moulting from September to April. Data for the Bay of Biscay taken in November, show modes at 15 mm and 24 mm carapace length, and the progression of the lowest mode through 12 months suggests that this is annual growth.

2.3 Recruitment

No data are available on the annual recruitment to catchable stocks. Around the United Kingdom *Nephrops* first appear in the catch at a carapace length of 16 mm - 18 mm between June and September. Work in the Irish Sea suggests that these belong to age group I. In the Bay of Biscay recruitment to the catchable stock occurs in November at a carapace length of 14 mm - 16 mm.

2.4 Mortality

Mark-recapture experiments have not provided any reliable mortality data. On the basis of an assessment using the method of Jones (1974), assuming that $M \leq 1$, that $K_{females} = 0.06$ and that $K_{males} = 0.1$, the total mortality coefficient Z may be given as 0.5. (An application of Jones' method to the Firth of Forth stock of *Nephrops* may be found as an Appendix to this Report). Calculations on Irish Sea data, however, based on the numerical strength of assumed age groups ($\log_e N_{t>1} - \log_e N_{t+1>2} = Z$) suggest that Z is close to 1.0 for this range of age groups.

2.5 Survival of discards

Work in the northern Irish Sea has shown that 70% of *Nephrops* caught survived on deck for 15 minutes and 40% survived for 3 hours. Icelandic work has shown that about 60% survived after 0-2 hours on deck with no variation in survival with varying exposure time (up to 2 hours). Recent work by Loew (1974), however, shows that permanent blindness results from 2 hours exposure to daylight. These factors and the uncertainty of surviving *Nephrops* finding a suitable substrate, will combine to give a generally low survival rate of discards.

3. The Fisheries

3.1 Nominal catch and fishing effort

3.1.1 Tables 1 and 2 give a breakdown of the annual catches of Nephrops for the years 1950, 1955 and 1960-1973. In the period 1960-1973, marked increases (by factors of 2.5 to 15.0) have occurred in ICES fishing areas IVa, IVb, VIa, VIIa and VIII. In fishing areas IIIa, Va, VIIb,c, VIIg-k and IX, catches have fluctuated throughout this period.

3.1.2 In the waters around the United Kingdom and Ireland, the greatest increase in effort was seen prior to 1960. Since then, the effort has increased further, as it also has in most other areas (Table 3).

3.1.3 The catch per unit of effort since 1960 has fluctuated widely without any obvious trend (Table 4), although around Iceland - where data are available from the commencement of the fishery - catch per unit of effort has shown a downward trend since 1960.

3.1.4 In those areas where data are available, there has been a decrease in the mean carapace length of Nephrops since 1960 (Table 5).

3.1.5 In ICES statistical Divisions IIIa, IVa, IVb, Va, VIa and VIIa, fishing for Nephrops is mainly carried out within 3-12 miles of the coast. In Division VII g-k and in the Bay of Biscay (Sub-area VIII) fishing takes place more than 12 miles offshore. In Sub-area IX, trawling is forbidden within 6 miles of the coast of Portugal.

3.2 The nature of the fisheries

The following summary of national fisheries describes,for each country, the types of boats and gear in use (all mesh sizes stated refer to stretched mesh), the nature of the fishery (directed or mixed) and the constituant species of the by-catch of Nephrops-directed fisheries.

3.2.1 Belgium

Nephrops constitute a by-catch in fisheries mainly directed at other species, principally the sole. Such vessels are between 200 BHP and 500 BHP.

3.2.2 Denmark

Most of the vessels are of less than 30 GRT, and are the same as those used for other trawl fisheries in Danish waters. The principal part of the Nephrops catch arises from a specialised Nephrops fishery using a Nephrops trawl. A small part of the landings is derived from a shrimp fishery using shrimp gear. Nephrops are also landed by vessels engaged in a Pandalus fishery and in an industrial fishery. The Nephrops-directed fishery is located in the Kattegat, whereas the mixed fisheries are located in the Skagerak-North Sea. In general, cod ends of 35 mm mesh are used in the Nephrops fishery. There is a minimum legal landing size for Nephrops of 130 mm total length (= 40 mm carapace length) or 72 mm for tails. (The minimum size in the Faroes is 150 mm total length). In the central and southern part of the Kattegat Nephrops is the primary species taken, using 35 mm mesh nets. Tables 6 and 7 present data on the proportion of various fish species in the Nephrops-directed fisheries in these areas. The main protected species caught are cod, plaice and sole and these form a valuable by-catch.

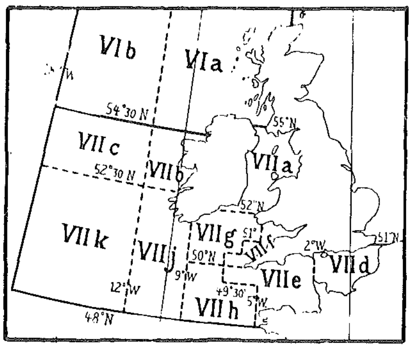
3.2.3 France

There is an important primary fishery undertaken by smaller vessels fishing in the Bay of Biscay, but the Nephrops landings derive in part also from the fishery for whitefish. Vessels are of three classes:

Small "artisan" trawlers of about 28 GRT, 15 m long and of 150-200 BHP fishing in the Bay of Biscay (statistical Sub-area VIII);

Large "artisan" trawlers of about 50-75 GRT, 19 m long and of 300-400 BHP fishing in the Celtic Sea and off southwest Ireland (statistical Divisions VIIe,f,g and j - see small chart below*);

"Semi-industrial" trawlers of about 126 GRT, 25 m long and of 440 BHP. These fish in statistical Divisions VIIa,b and g. While Nephrops are an important part of their catches, whitefish are equally as important. Nets used in this fishery have cod ends of 50 mm and below.



The artisan fishery in the northern half of the Bay of Biscay is primarily directed at Nephrops. Nevertheless, other species - mainly young hake - are caught in large quantities and greatly contribute to the value of the catch (Tables 8 and 17). A variable, but very large proportion of hake caught (40% - 95% by number), is undersized and is discarded.

In the Celtic Sea the by-catch of demersal species (hake, whiting) is in general more important.

In the Irish Sea, the fishery by "semi-industrial" trawlers is a mixed one, more directed at demersal species (whiting, cod, hake) than at Nephrops.

There is a minimum legal landing size for Nephrops of 80 mm total length.

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* The divisions of statistical Sub-area VII shown here are used only in the domestic fishery statistics of France. The ICES statistical programme continues to use the divisional breakdown indicated in "Bulletin Statistique", namely VIIa, VIIb,c, VIId,e, VIIf, VIIg-k.

3.2.4 Germany (Federal Republic of)

The Nephrops catch constitutes a small by-catch in fisheries mainly directed at other species and the gears employed are dictated by these types of fisheries.

3.2.5 Iceland

The fishery is mainly by side trawlers. The average size of boats has increased in recent years, as has the engine power (51 GRT in 1964 to 80 GRT in 1971). The Nephrops trawl has long wings and a wire foot rope. The average headline length is 41 m. Mean mesh size in the cod end has increased from about 75 mm in 1967 to the regulated 80 mm minimum mesh size in the last few years. The majority of landings derive from a specialised Nephrops fishery, by vessels using a Nephrops trawl. There is also a small fishery off the southwest of Iceland for Pandalus, in which Nephrops is an important by-catch. Table 9 shows the average Icelandic by-catch of the Nephrops fishery during 1960-73. Main species taken are cod, haddock, ling and redfish. In recent years there has been an increase in the catch of ling, redfish and coalfish which can be partly attributed to the Nephrops boats fishing further offshore.

3.2.6 Ireland

The fishery is mainly Nephrops -directed and is undertaken by trawlers of 15 m - 21 m with engines generally between 90 BHP and 250 BHP. The nets have cod end mesh sizes of 40 mm - 45 mm. A small proportion of landings is by-catch from demersal fisheries. In the Irish Sea Nephrops fishery, whiting forms the most important by-catch and fairly large amounts of small whiting are caught (Table 10).

3.2.7 Netherlands

Nephrops are caught incidentally by cutters fishing for flatfish (sole and plaice). They fish with a motor power of 500-2000 BHP and beam trawls with up to 16 tickler chains. The net opening of each trawl is about 10 m - 12 m.

3.2.8 Norway

The fishery is a mixed fishery, in which Pandalus plays an important part. The gear used is a Pandalus otter trawl of 35 mm mesh size, by boats of up to 21 m with 100 BHP - 400 BHP engines. Sometimes a Danish Nephrops trawl is used, but not often due to the loss of Pandalus which results. There is a minimum legal landing size for Nephrops of 130 mm total length (= 40 mm carapace length).

3.2.9 Portugal

The fishery is mainly a mixed fishery, undertaken in coastal waters by trawlers of 50 GRT - 200 GRT and of 150 BHP - 800 BHP. Hake is the main associated species. The nets are of 60 mm - 70 mm mesh in accordance with NEAFC Recommendation 1, but they are mainly 65 mm. Nephrops is also taken in a bottom tangle net fishery for other crustacean species by boats of up to 50 GRT and of 40 BHP - 400 BHP.

3.2.10 Spain

Nephrops constitutes a by-catch in trawl fisheries for other species.

3.2.11 Sweden

The Nephrops are caught by trawlers of 30 GRT to 60 GRT with engines generally from 100 BHP to 250 BHP. Most boats use fish trawls with a mesh size of 70 mm in the cod end. Some boats are allowed to fish in specified areas inside territorial limits using 60 mm - 65 mm meshes. The fishery may be classed as principally a mixed fishery (main by-catch species: cod, haddock, whiting and plaice) although especially during the months of July-September Nephrops is the most important species on most grounds. A very small part of the landings derives from a Pandalus fishery. There is a minimum legal landing size for Nephrops of 130 mm total length (= 40 mm carapace length).

3.2.12 United Kingdom

The main fishery is Nephrops-directed, and is undertaken by trawlers of 12 m - 20 m with engines generally of 60 BHP - 250 BHP, using the Nephrops trawl. In this fishery the legal minimum mesh size for Nephrops trawls is 70 mm except in the Irish Sea where nets of up to 50 mm mesh are permitted for vessels fishing wholly for Nephrops, and of 60 mm and upwards for certain vessels fishing for whiting in the northwest Irish Sea. There is also a creel fishery for Nephrops on the west coast of Scotland by boats 9 m - 12 m with engines of 50 BHP - 80 BHP. Table 11 shows the species composition of the by-catch for Nephrops trawlers landing at North Shields (NE England) during the months of 1969. Cod, haddock and whiting, with dogfish to a lesser extent, form the main species. Total weights for the period 1967-73 are shown in Table 12.

The principal by-catch species in the Scottish Nephrops fishery are whiting, long rough dab, hake, dogfish and haddock in that numerical order.

In the Irish Sea various species of fish occur on the same fishing grounds as Nephrops, whiting being the main protected species of fish in the by-catch, followed by cod (Table 13). Large numbers are undersized.

3.3 Market limitations

3.3.1 In France the market limitation for ports in south Brittany is 100 mm total length for Nephrops taken north of 48°N.

3.3.2 In Ireland and the United Kingdom merchants do not usually accept Nephrops under 24 mm - 25 mm carapace length.

4. Selection

4.1 A review of the available data on mesh selection carried out by Garrod (unpubl.) showed that:

4.1.1 Selection varies with mesh size through the trawl.

4.1.2 Diurnal and seasonal factors affect selection characteristics.

4.1.3 The length range over which selection occurs is wide and the proportion retained at different lengths is variable. This makes conventional assessment of the effect of a change in mesh size difficult. Even the largest mesh in use will retain some small Nephrops.

4.1.4 One may reasonably establish carapace lengths above which escape is impossible (i.e. 100% selection points) for different mesh sizes. The 100% point for 30 mm carapace length occurs with a uniform 50 mm mesh. Thus a trawl containing any meshes exceeding 50 mm will release some Nephrops of up to 30 mm carapace length.

4.1.5 Previous comparative fishing trials are inadequate to assess differences in fishing power between different gear. This is necessary in order to determine the effect on catch rates of a change in gear.

4.2 In experiments in the Irish Sea in September 1974, various trawls were compared under commercial fishing conditions. Parallel hauls were made using similar commercial vessels comparing (a) dual purpose trawls with meshes of 70 mm and 40 mm respectively in the cod end and (b) the latter with a prawn trawl of 40 mm mesh throughout. Table 14 gives the results as landed catches and catch per unit of effort for both Nephrops and whiting.

4.3 The results (Table 15) showed that the use of 70 mm meshes as compared with 40 mm in the cod end of a dual purpose trawl gave a 25% reduction in the catch rate of marketable Nephrops on grounds adjacent to the coast. A long-winged prawn trawl of 40 mm mesh throughout increased the catch rate by 6% for marketable prawns. All nets retained a high proportion of undersized whiting (85% - 99%) under commercial fishing conditions. This was within the average for the season and the area fished.

4.4 Figure 1 shows the selection lines derived by Garrod for 40 mm and 70 mm mesh (lines a and b). If there is no difference due to selection the line c applies. Taking 27 mm carapace length as the minimum marketable size, the difference between the case of selection and no selection is given by the areas marked d. If there is no selection then an increase in mesh size from 40 mm to 70 mm will result in a decrease in F by 25%, because of decreased fishing power. If selection is taking place then the proportion retained at each age can be calculated and a mesh assessment carried out. The parameters used for such an assessment are shown in Table 16.

4.5 French work (Abbes et Warluzel, 1970) has examined selectivity in the cod end on Nephrops fishing grounds in the Bay of Biscay. The work showed the relative importance of the wings and belly in the selection of Nephrops, and confirms Cole's and Simpson's (1965) results which showed that selection occurred in other parts of the net as well as the cod end. They concluded that previous work based on cod end selectivity alone was inadequate, and suggested further work using commercial fishing vessels.

4.6 Rather limited work has also been carried out by Iceland. The 50% rejection length in the 80 mm mesh trawls appears to be about 39 mm carapace length. Fishing experiments with trawls of 42 m headline length compared with those of 50 m length showed 12% - 13% higher catches of the latter.

4.7 Some Swedish data are available on mesh selection and discards (all Nephrops less than 130 mm total length have to be discarded). Figure 2 shows the large proportion of small Nephrops taken in nets of various mesh sizes.

4.8 Various species of whitefish occur on the same fishing grounds as Nephrops and are therefore captured by the small meshed Nephrops trawls. Thomas (1965) showed that whiting (Merlangius merlangus) were among the most common whitefish by-catch off the coast of Scotland, and the catch of undersized whiting was greater in small-meshed Nephrops trawls than in the 70 mm trawls.

4.9 Watson and Parsons (1974) reported that a figure of over 70% of undersized whiting is rejected at sea when cod ends of 40 mm - 50 mm are used in the Irish Nephrops fishery. French data, in general, show that there is a similar problem in that large numbers of small hake are also taken mainly in the Smalls area and the Bay of Biscay.

4.10 Unlike fish, the selection range for Nephrops is wide because of the animal's structure and its behaviour. Nevertheless, available evidence indicates that catch rates of marketable Nephrops are reduced when larger-meshed nets are used.

5. Conservation Measures

5.1 Restriction of grounds

The closing of an area can be beneficial if the area is overfished. Such a closure should be associated with measures to prevent the diversion of effort to other areas where an increase in fishing effort might be detrimental to the stocks. Iceland restricted certain grounds for part of the 1973 season, but this no longer applies. Fishing off Iceland is, however, restricted by law to depths of 60 fathoms and more.

5.2 Restriction of vessels and gears

A restriction of vessels or size of gear is only beneficial to a heavily fished stock when it results in a reduction in total effort. Iceland introduced a size limit of 100 GRT and/or 400 BHP for *Nephrops* boats in 1974 in order to limit effort. In the Faroe Islands, the number of boats trawling for *Nephrops* is regulated annually by licence, and only boats of 40 BHP or less are allowed. In 1973, only 3 boats were so licensed.

5.3 Total allowable catch limitation

The imposition of total allowable catches (TACs) are effective in controlling levels of F, and in restricting the diversion of effort. Increased catches per unit of effort may also result. In Iceland, TACs for 1973 and 1974 were set at 3 000 tons and 2 000 tons respectively, and a fishing log is required to be maintained by each vessel.

5.4 Closed seasons

Closed seasons may be effective in protecting certain classes of the stock and associated species, and in reducing total fishing effort. The Icelandic *Nephrops* fishery is closed from 15 August to 25 May, and the Faroese fishery from 16 July to 14 June.

5.5 Mesh regulation

This seems to be the most important way of protecting the stock, at least in the fisheries where *Nephrops* catches are important and where overfishing is likely to occur. The minimum size to be recommended may vary from one fishing ground to another but accurate assessments of the conservation effects of particular mesh sizes in different parts of a trawl are not possible at present. The general opinion of the Working Group, however, was that a minimum mesh size of 70 mm throughout the trawl would be beneficial. Mesh size is specified as 50 mm for boats engaged in the French *Nephrops* fisheries, and in Iceland there is a minimum legal mesh size of 80 mm. In Sweden, mesh size must not be below 70 mm (same as for white fish): in certain territorial waters (inside the trawling border) a mesh size down to 60 mm is permitted under certain circumstances, and vessels must maintain a fishing log. In United Kingdom waters, except in the Irish Sea, regulations specify a 70 mm minimum mesh size: in the Irish Sea, the relevant NEAFC Recommendations apply.

5.6 Minimum legal landing size

Although the survival of discards seems to be low, at least a few of the discarded animals survive. To this extent, a minimum size can help to maintain the stock. A legal minimum size could, however, be a support for mesh size regulations. The following minimum size regulations are at present in force (total length regulations are based on the length from the tip of the rostrum to the end of the telson with the tail fan extended, excluding the setae):

Denmark:	130 mm total length, or 72 mm tail length
Faroes:	150 mm total length
France:	80 mm total length
Iceland:	70 mm tail length or 10 g tail weight
Norway:	130 mm total length
Sweden:	130 mm total length.

5.7 Protection of berried females

Although no legislation protecting berried females is presently in force, the protection of berried females is sometimes practised, for example in Iceland. The usefulness of this measure is not known. Various opinions are held on its effectiveness in fisheries for *Homarus*.

6. Effects of Regulations on the By-Catch and the Conservation of the Protected Species

6.1 The Group agreed that only a limited amount of data was available on the size composition of the by-catch, particularly the undersized proportion of the protected species. Watson and Parsons (1974) have reported that the increased intensity of *Nephrops* trawling in the Irish Sea with nets containing meshes under 50 mm has inevitably increased mortality of small whiting. Estimates of rejection at sea of undersized (less than 25 cm length) whiting, based on data collected at sea and from recorded total numbers of trawlers fishing for *Nephrops*, vary between 9 and 35 million fish in any one year during the period 1968-73 inclusive. The effects of this mortality on the whiting fishery in the Irish Sea may be considerable.

6.2 Similarly all French data available show that the age composition of hake landings from the Bay of Biscay and the southern Celtic Sea is mainly of small fish in the age groups II and III. These stocks are mainly exploited by small "artisan" vessels using small-meshed nets. Observations have shown that in addition to the hake landed, a larger proportion of the hake taken in the trawl (40-90% by numbers) are undersized and are discarded at sea (Table 17). In recent years this inshore artisan fleet has expanded considerably and this substantial increase in effort (about 80% between 1961-73) may have contributed to the decline of the offshore fishery for hake in the Bay of Biscay and the Celtic Sea.

6.3 Thomas (1965) also showed that small mesh nets took large numbers of undersized fish of the protected species, and presented some data on length composition of the by-catch. Results from experimental hauls varied seasonally as did the proportion of undersized protected species in the catches. Data gathered in July 1962 compared the catches of a 70 mm trawl and a small-meshed *Nephrops* trawl. A summary of the proportion of undersized fish taken is shown below for the main species:

	Whiting	Hake	Haddock
70 mm trawl	18%	60%	47%
Nephrops trawl	47%	73%	58%

These results support the view that small meshed nets take a higher proportion of small fish. Similar results are available from Danish research vessel cruises where a high proportion of undersized fish of various species were taken with small meshed (35 mm) nets (Table 18).

7. Estimates of Future Catches

7.1 The current management objective in the Icelandic fishery is to stabilise the annual yield at 3 600 tons from 1976 onwards. (A total allowable catch is enforced in this fishery at present - see Section 5.3). The Faroese trawl fishery is regulated by licence (see Section 5.2), and the yield of both the trap fishery and the trawl fishery is expected to increase only slowly from its present level.

7.2 There is considerable difficulty in estimating future catches for most countries. The general opinion of the Working Group was that the Nephrops fisheries cannot expand very much in future, and that further protection of the stocks is, in general, desirable.

8. Conclusions

8.1 The Nephrops fisheries are now of such importance as to merit conservation in their own right.

8.2 Further conservation measures, beyond those presently applicable, would be beneficial for the optimum exploitation of the Nephrops stocks.

8.3 The regulation of mesh size appears to be the most practicable means of conservation presently available.

8.4 There may possibly be advantages for the enforcement of mesh regulations in having an associated minimum legal landing size.

8.5 The introduction of mesh regulations for Nephrops fishing could assist in the conservation of associated species such as whiting and hake.

8.6 The removal of Nephrops from the species listed under Recommendation 2 would result in an increase in the minimum mesh size. Except for Iceland, for which an inappropriately large mesh, at least 120 mm, would apply (special exemption would be required), the increase should have long-term benefits. The immediate losses of Nephrops and associated species could, however, be considerable in some areas. It was not possible for this meeting of the Working Group to make assessments of the magnitude of the immediate losses involved.

8.7 The inclusion of Nephrops in the species listed under Recommendation 4 should be considered only in the event of it being removed from the species listed under Recommendation 2. The Working Group was of the opinion that the imposition of a minimum legal landing size may be of assistance in enforcing a minimum mesh size. It was nevertheless of the opinion that a general application of a minimum legal landing size was of questionable value.

9. References

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Table 1. Annual catch of Nephrops in the ICES area 1950, and 1954 - 1973

Country	1950	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973
Belgium	311	456	441	374	649	831	970	788	895	668	766	789	536	705	477	456	468	479	378	299	392
Denmark	633	521	1 014	1 470	1 638	1 678	1 530	2 236	1 452	1 666	1 752	2 243	1 744	1 152	1 495	1 737	1 176	1 244	1 233	2 096	1 339
Faroe Islands	-	3	2	2	51	91	96	73	35	39	78	54	49	43	36	23	23	-	38	31	43
France	2 454	4 928	5 136	5 574	7 440	6 604	7 213	8 188	8 410	8 244	8 706	9 644	7 783	7 325	7 703	8 310	11 227	10 022	9 025	9 581	12 098
Germany, Federal Republic of	49	57	75	75	58	94	97	117	110	91	109	145	57	26	65	65	29	6	3	2	3
Iceland	-	-	-	-	-	-	1 434	2 081	1 490	2 662	5 550	3 487	3 706	3 465	2 731	2 489	3 512	4 026	4 657	4 321	2 791
Ireland	-	52	209	206	340	599	736	397	715	840	1 491	1 016	801	1 251	878	1 493	1 372	2 019	1 775	1 823	2 150
Netherlands	+	+	+	+	+	+	+	20	11	4	11	-	-	-	-	-	-	-	-	-	-
Norway	-	19	121	72	189	88	66	69	58	50	15	102	161	36	15	84	74	18	52	29	37
Portugal	94	74	112	53	29	64	97	85	77	68	71	170	214	205	321	246	261	210	120	72	72
Spain	2 065	1 667	1 963	1 716	1 742	1 701	1 749	1 697	2 192	1 626	1 710	2 468	3 065	3 576	4 109	4 047	4 237	3 234	3 231	3 759	4 046
Sweden	616	584	651	722	834	679	654	716	691	511	560	782	550	436	554	613	431	335	373	468	452
England/ Wales	79	252	279	220	277	395	326	431	770	325	297	356	396	1 064	768	983	859	612	1 044	948	814
N. Ireland	-	167	397	534	600	845	750	495	926	749	1 329	1 282	931	1 393	2 029	1 915	2 663	2 809	2 920	3 997	3 643
Scotland	-	575	1 084	1 058	1 374	1 144	2 163	1 969	2 920	3 482	3 708	4 940	5 244	6 344	6 687	7 203	8 189	8 179	9 029	10 780	9 780
All countries	6 301	9 361	11 484	12 076	15 223	15 813	17 881	19 362	20 752	21 025	26 153	27 478	25 237	27 021	27 868	29 664	34 521	33 193	33 878	38 206	37 660

Table 2. Annual catch of Nephrops (in metric tons) by country and by fishing areas 1950, 1955 and 1960 - 1973

	Va				Vb_1	IIa	IIIa					III b,c	IVa						IVb							IVc			VIa				
	Belgium	Iceland	Others	TOTAL	Faroes	TOTAL	Denmark	Germany F.R.	Norway	Sweden	TOTAL	TOTAL	Belgium	France b)	Germany F.R.	Norway c)	Scotland	TOTAL	Belgium	Denmark d)	Germany F.R.	Netherlands	England/ Wales	Scotland	TOTAL	Belgium	Others	TOTAL	France	Ireland	Scotland	Others	TOTAL
1950	15	-	1	16	-	-	633	34	-	615	1282	1 a)	...	91	...	-	-	91	183	-	14	+	-	-	197	...	-	...	-	-	-	1	1
1955	203	-	-	203	2	-	1013	70	119	651	1853	1	...	70	...	2	1014	1086	190	-	5	+	34	...	229	...	-	...	150 f)	-	70 g)	-	220
1960	451	2081	+	2532	73	-	2228	115	68	716	3127	1	5	-	2	1	539	567 e)	121	7	...	...	270	498	896	32	...	32	178	2	931	1	1112
1961	322	1490	+	1812	35	-	1446	110	57	691	2304	-	8	89	-	1	765	863	372	6	-	11	582	590	1561	75	1	76	147	11	1554	-	1712
1962	154	2662	-	2816	39	-	1660	88	-	511	2259	1	2	24	3	-	899	928	390	5	-	4	175	632	1206	62	...	62	149	1	1950	2	2102
1963	510	5550	2	6062	79 h)	-	1746	109	12	560	2427	1	8	24	+	3	932	967	151	5	+	7	198	685	1046	39	4	43	105	-	2087	3	2195
1964	586	3487	-	4073	54	-	2228	138	102	782	3250	1	21	12	1	+	1387	1421	107	14	4	-	234	907	1266	17	-	17	367	32	2645	3	3047
1965	409	3706	-	4115	49	-	1731	57	142	550	2480	+	2	2	-	19	1029	1052	86	13	-	-	293	1052	1444	10	-	10	367	1	3147	-	3515
1966	546	3465	-	4011	43	-	1140	22	17	436	1615	+	4	9	-	19	1432	1464	112	12	4	-	828	1964	2920	22	1	23	-	5	2945	-	2950
1967	208	2731	-	2939	36	1 i)	1458	60	15	554	2087	1	1	5	-	+	1386	1392	242	36	5	-	699	1451	2433	23	...	23	315	2	3849	+	4166
1968	157	2489	-	2646	23	-	1711	-	83	613	2407	-	2	-	+	1	1496	1499	249	26	65	-	894	1135	2374 j)	46	...	46	315	11	4571	-	4897
1969	188	3512	1	3701	23	-	1151	23	74	431	1679	5 k)	+	-	1	-	1575	1576	230	25	-	-	688	1113	2056	45	-	45	224	6	5494	-	5724
1970	119	4026	-	4145	-	-	1232	6	18	335	1591	-	3	-	-	-	1092	1095	330	12	-	-	419	1654	2415	19	-	19	-	-	5431	-	5431
1971	155	4657	-	4812	38	30 l)	1214	2	18	373	1607	-	2	-	-	4	1638	1644	215	19	1	-	702	1412	2349	5	-	5	200	-	5972	+	6172
1972	82	4321	178 m)	4581	31	-	2085	1	24	468	2578	-	1	-	-	5	1304	1310	213	11	1	-	827	1904	2956	3	-	3	108	-	7556	-	7664
1973	5	2791	-	2796	43	-	1336	2	28	452	1818	-	+	-	-	9	1566	1575	358	3	1	-	446	1754	2562	29	-	29	-	2	6422	-	6424

a) Sweden 1. b) France 1960-1966 IVa includes IVb,c. c) Norway IVa includes IVb,c. d) Denmark IVb includes IVa. e) 1960 Total includes Netherlands 20 tons. f) France 150 allocated to IVb. g) Scotland 70 in VIa includes VIb. h) Faroes 78, Scotland 1. i) France 1. j) 1968 Total includes France 5 tons. k) Denmark +, Germany F.R. 5. l) Norway 30. m) France 178.

	VIIa							VIIb, c			VIId,e			VIIf				VIIg-k					VIII			IX			X	Un-known	TOTAL All Areas
	Belgium n)	France	Ireland	England/ Wales	N. Ireland	Scotland	TOTAL n)	France	Ireland	TOTAL	France	Others	TOTAL	Belgium n)	France	Others	TOTAL n)	Belgium	France	Ireland	England/ Wales	TOTAL	France	Spain	TOTAL	Portugal	Spain	TOTAL	Portugal	TOTAL p)	
1950	20	-	-	-	-	-	20	-	-	-	7	9	16	...	-	-	...	83	976	-	-	1059	1380	28	1408	94	1232	1326	-	884	6 301
1955	10	-	209	204	397	-	820	-	-	-	-	1	1	...	-	...	...	37	2426	-	41	2504	2490	180	2670	112	1783	1895	-	-	11 484
1960	178	133	392	-	495	1	1199	191	3	218 o)	-	3	3	...	...	-	...	-	4085	-	134	4219	3524	577	4101	84	1120	1204	1	77	19 362
1961	11	139	688	179	926	11	1954	151	3	154	2	9	11	...	...	-	...	106	4258	13	-	4377	3607	744	4351	73	1448	1521	4	17	20 752
1962	3	140	649	67	749	1	1609	171	2	173	4	-	4	8	...	1	9	47	4708	188	82	5025	3042	768	3810	62	858	920	6	56	21 025
1963	1	449	1059	24	1329	1	2863	588	2	590	-	3	3	14	...	-	14	37	3500	430	75	4042	4040	1053	5093	67	657	724	4	-	26 153
1964	29	652	539	34	1282	1	2537	493	80	573	-	2	2	4	...	-	4	22	3522	365	88	3997	4596	1278	5874	166	1190	1356	4	2	27 478
1965	8	489	557	35	931	16	2036	514	80	594	24	1	25	+	...	6	6	20	2946	163	62	3191	3441	1721	5162	210	1344	1554	4	-	25 237
1966	1	... q)	886	193	1393	3	2476	... q)	87	87	-	-	-	1	... q)	-	1	19	3459 q)	273	42	3793	3857	2038	5895	201	1538	1739	4	-	27 021
1967	2	1122	731	49	2029	1	3934	441	49	490	-	-	-	-	84	-	84	1	2488	96	20	2605	3245	2574	5819	317	1535	1852	4	2	27 868
1968	+	981	906	72	1915	1	3875	441	17	458	5	-	5	-	55	-	55	2	2649	559	17	3227	3859	2814	6673	242	1233	1475	4	-	29 664
1969	3	762	941	161	2663	6	4536	609	3	612	26	+	26	+	10	-	10	2	4786	422	10	5220	4810	2734	7544	257	1503	1760	4	-	34 521
1970	7	547	1258	192	2809	2	4815	256	18	274	64	+	64	+	2	-	2	1	3699	743	1	4444	5454	2278	7732	207	956	1163	3	-	33 193
1971	1	305	1415	342	2920	7	4990	500	1	501	20	-	20	-	10	-	10	-	4000	359	-	4359	3990	... r)	3990	120	... r)	120	... s)	-	33 878 t)
1972	-	7	1626	121	3997	16	5767	-	46	46	55	-	55	+	190	-	190	-	3518	151	-	3669	5525	3166	8691	72	593	665	... s)	-	38 206
1973	-	-	1862	368	3643	38	5911	811	35	846	297	+	297	+	21	-	21	-	3929	251	-	4180	7040	3560	10600	72	486	558	... s)	-	37 660

n) Dots (...) in VIIf signify that the catches have been included in VIIa. o) 1960 Total includes England/Wales 24 tons. p) 1950 Others 884; 1962 France 6, Norway 50; figures for other years refer to France. q) France 1966 VIIg-k includes VIIa, VIIb,c, VIIf. r) Area breakdown not available; the total Nephrops catch by Spain in 1971, however, was 3231 tons. s) Details not available. t) Includes 3231 tons caught by Spain, not broken down by area.

Table 2a. Alternative breakdown of catches of *Nephrops* by French fishing vessels in 1973 (metric tons)

Port of landing	Fishing area		Total
	North of 48°N	South of 48°N	
Douarnenez	928	-	928
St. Guénolé	1 691	107	1 798
Le Guilvinec	292	1 125	1 417
Lesconil	-	898	898
Loctudy	630	916	1 546
Concarneau	228	368	596
Lorient	1 084	903	1 987
St. Nazaire	-	755	755
St. Gilles	-	64	64
Les Sables d'Olonne	146	658	804
La Rochelle	247	42	289
Other ports	-	94	94
Total	5 246	5 930	11 176

Table 3. Fishing effort, 1960 - 1973

	Scotland		England (NE)	Ireland	France		Denmark	Faroe Islands	Iceland
	Hours fishing Anstruther	Hours fishing Buckie	Hours fishing	Hours fishingxBHPx10^{-2} (Skerries, May-October)	Total power (<50 GRT) x10^{-3}	Lesconil Days fishingxBHPx10^{-2}	Gilleleje (October) Hours fishing	Hours fishing	Hours fishing
1960	-	-						3 721	25 223
1961	-	-		7 380	91.3			2 876	-
1962	-	28 290	9 487	6 651	94.9			1 633	34 756
1963	7 268	24 685	6 465	7 326	103.9			2 538	63 350
1964	7 102	41 869	7 309	6 336	108.6		716		53 265
1965	9 090	-	9 994	6 120	116.6		291		57 816
1966	22 027	-	18 490	6 831	124.6	10 941	1 341		56 342
1967	18 155	26 031	22 380	8 145	119.5	9 296	803		65 492
1968	14 493	29 046	22 195	8 973	121.1	9 958	2 223		84 373
1969	14 589	28 115	23 165	9 909	130.6	10 912	822		90 502
1970	19 001	17 528	12 653		144.4	11 259			100 125
1971	18 199	19 470	22 522		148.9	12 049			96 219
1972	22 096	18 307	18 641		159.3	11 011			114 682
1973	30 817	26 791	16 436		170.9	12 774			89 169

Table 4. Catch per unit of effort
(Catch in kg per hour fishing unless otherwise stated)

Year	Scotland Anstruther	Scotland Buckie	England (NE)	Ireland* Skerries	France* Lesconil VIII	France* Lesconil VIIg	France* La Rochelle Art.[1] VIII	France* La Rochelle S.I.[2] VIIg	Denmark Gilleleje (October)	Faroe Islands	Iceland
1960										19.6	82.5
1961				43.61						12.2	
1962		16.8	13.5*	39.28						23.2	76.6
1963	27.2	21.1	21.8	71.98						30.5	87.6
1964	25.4	16.3	22.5	27.17					11.0		66.1
1965	36.6	-	22.6	36.62					7.7		64.1
1966	37.6	-	24.1	55.86	51.5				4.5		61.5
1967	24.4	27.4	17.0	30.34	39.4				8.0		41.7
1968	20.3	18.8	21.0	37.44	50.1				7.2		29.5
1969	23.9	17.8	17.5	47.45	62.7	89	5	39	10.1		38.8
1970	31.5	22.9	18.6		45.5	86	4	36			40.2
1971	25.4	29.0	15.7		44.7	67	1	35			48.4
1972	29.0	27.9	21.4		53.1	92	2	31			37.7
1973	22.4	29.5	14.0		70.3	60	2	26			31.3

1) Artisans
2) Semi-industrial

* France - kg per day. Adjusted to standard 100 BHP vessel
Ireland - adjusted to standard 100 BHP vessel
England - 1962 figure based on 6 months only

Table 5. Mean carapace lengths, males, 1958 - 1974 (mm).

Year	Scotland FF	Scotland MF	Scotland NM	Scotland FC	Ireland Skerries, summer (Median)	Iceland
1958	-	-	-	-	29.9	-
1959	-	-	-	-	30.2	-
1960	47	38	44	37	26.2	51.2
1961	40	-	-	-	29.8	52.4
1962	38	32	40	34	30.4	46.6
1963	36	32	37	30	-	49.2
1964	36	29	36	30	27.6	50.9
1965	39	35	37	35	-	50.4
1966	36	-	-	-	28.7	46.5
1967	34	29	39	34	28.8	44.1
1968	33	-	-	-	25.3	44.2
1969	34	-	49	33	26.8	42.5
1970	31	32	43	35	28.3	43.0
1971	35	34	-	39	27.2	44.7
1972	32	31	34	34	25.9	43.0
1973	31	27	33	34	25.3	42.3
1974	30	28	38	31	-	44.8

FF = Firth of Forth

MF = Moray Firth

NM = North Minch

FC = Firth of Clyde

Table 6. Percentage distribution of species by weight per month of catch in *Nephrops* trawl during 1964 - 1969. Kattegat. (Data based on landings in the port of Gilleleje.)

Month	Nephrops	Plaice	Cod	Dab	Whiting	Sole	Saithe	Various	Mink-food
Jan.	18.9	7.1	38.7	1.3	6.4	4.4	1.8	21.4	-
Aug.	53.3	5.4	34.7	0.2	0.2	-	0.1	6.1	0.3
Sep.	38.8	5.1	35.1	0.1	1.0	0.2	0.4	2.4	16.9
Oct.	48.7	8.7	30.8	0.2	1.4	2.8	0.9	2.4	4.3
Nov.	16.7	13.2	35.1	0.4	6.1	8.0	1.7	3.0	16.3

Table 7. Percentage distribution of species by weight per month of catch in Nephrops trawl in 1973. Kattegat. (Data based on landings in the ports of Skagen, Grenå and Anholt.)

Month	Nephrops	Plaice	Cod	Dab	Whiting	Sole	Haddock	Norway Pout	Blue Whiting	Pandalus
Jan.	15.56	20.87	12.89	0.83	1.03	33.46	0.83	14.43	0.1	-
Feb.	29.60	11.05	35.6	2.2	2.95	8.25	1.75	8.05	-	1.4
Mar.	22.13	20.0	39.23	2.77	1.33	11.13	1.0	-	-	1.77
Apr.	17.03	10.87	32.83	22.77	2.13	11.17	1.73	-	-	1.47
May	51.85	4.55	7.8	10.55	-	7.5	0.25	16.5	-	1.0
June	76.83	10.6	10.17	1.93	-	0.13	-	-	-	0.3
July	69.90	7.05	7.95	1.0	-	0.05	-	-	14.1	-
Aug.	88.57	4.93	6.47	0.03	-	0.03	-	-	-	-
Sep.	79.53	4.9	15.1	0.13	0.33	0.07	-	-	-	-
Oct.	36.27	14.4	21.73	0.2	1.5	5.23	-	-	20.1	-
Nov.	100.0	-	-	-	-	-	-	-	-	-
Dec.	100.0	-	-	-	-	-	-	-	-	-
Mean:	57.27	9.10	15.03	3.53	0.77	6.42	0.46	3.25	2.86	0.5

Table 8. France. Weight of landed hake for 100 kg landed *Nephrops*.

Year	Lesconil VIIIa	Loctudy VII + VIII	Lorient VIIa	Lorient VIIIa	St. Nazaire VIIIa	St. Gilles VIIIa	Les Sables d'Olonne VII + VIII	La Rochelle VIIa	La Rochelle VIIg	La Rochelle VIIIa
1966	-	75.8	-	-	-	-	-	-	-	-
1967	56.3	83.0	-	-	-	-	-	-	-	-
1968	39.4	73.4	-	-	-	-	-	-	-	-
1969	59.8	74.6	-	-	-	-	-	-	-	-
1970	123.3	120.4	-	-	-	-	-	-	-	-
1971	63.6	100.1	-	-	-	-	-	-	-	-
1972	48.5	62.0	24.8	45.3	-	-	-	-	-	-
1973	38.2	52.4	-	-	32.7	301.6	123.3	23.5	28.3	115.2
1974	-	-	-	-	30.1	282.8	65.2	-	-	-

Table 9. Iceland. Catch (kg/hour) of *Nephrops* and the main by-catch species.

Year	*Nephrops*	Cod	Haddock	Ling	Coalfish	Redfish	Monk	Others
1960	83	43	35	13	1	19	-	55
1962	77	21	29	14	1	15	-	29
1963	88	13	24	8	1	19	3	22
1964	66	28	15	10	1	24	4	36
1965	64	21	12	15	1	18	6	35
1966	62	13	16	19	1	17	7	30
1967	42	14	9	33	2	24	9	20
1968	30	25	5	34	3	26	7	13
1969	39	26	4	33	4	29	8	17
1970	40	18	6	27	4	13	5	18
1971	48	16	4	29	5	12	5	18
1972	38	13	5	16	5	11	3	12
1973	31							

Table 10. Ireland. Numbers and weights of marketable Nephrops (carapace length > 24.50 mm), and numbers and weights per standard amount of marketable Nephrops of undersized Nephrops and by-catch species, summer 1973.

Sample	Amount of marketable Nephrops (N)	Amount of other types of fish per standard amount of marketable Nephrops N per 100					
		Nephrops undersized	(1) Whiting 0	(1) Whiting I	(2) Poor Cod	(3) Norway Pout	(4) Common Dab
A	169	49	1	27	24	25	16
B	413	69	-	15	25	38	10
C	328	180	169	10	5	8	-
D	459	141	2	5	3	8	1
Mean (unweighted)	-	110	43	14	14	20	7
Total N	1 369	1 605	562	165	176	261	74
	Wt. (kg)	Wt. (kg) per 100 kg					
A	1.81	0.25	+	1.75	0.68	0.64	0.70
B	5.68	0.27	-	0.11	0.59	0.75	0.20
C	4.00	0.32	0.63	0.74	0.17	0.16	0.02
D	5.98	0.54	+	0.31	0.08	0.21	0.02
Mean (unweighted)	-	0.47	0.16	0.73	0.38	0.44	0.23
Total Wt.	25.94	8.47	2.56	14.32	5.69	7.30	2.50

(1) Merlangius merlangus (age groups 0 and I)

(2) Trisopterus minutus

(3) Trisopterus esmarkii

(4) Limanda limanda

Table 11. U.K. (England). Monthly landings in 1969 of Nephrops and the by-catch, together with the species composition of the by-catch, for Nephrops trawlers landing at North Shields. (- = no landings). No landings in June, July or August.

	Jan	Feb	Mar	Apr	May	Sep	Oct	Nov	Dec
Nephrops (metric tons)	58.6	7.0	21.3	6.1	0.1	53.5	114.5	94.2	49.7
By-catch (metric tons)	155.4	29.7	52.3	26.3	1.0	105.3	179.6	94.5	153.8
Species composition (kg/100 kg Nephrops)									
Cod	67.7	43.8	34.3	262.0	500.0	18.3	6.8	2.2	44.0
Haddock	64.2	110.2	42.6	24.8	200.0	93.0	64.3	52.2	137.2
Whiting	55.4	100.7	41.0	-	-	29.2	19.0	21.6	52.1
Plaice	26.9	79.6	54.8	28.9	50.0	10.0	7.4	2.0	24.9
Lemon sole	6.6	32.8	28.1	38.8	100.0	1.0	0.9	-	1.0
Skate/ray	14.0	14.6	9.5	18.2	-	0.4	0.8	0.4	2.2
Dogfish	-	-	-	-	-	12.0	30.0	0.2	4.5
Unspecified	30.5	41.6	34.8	55.4	150.0	32.5	27.2	21.8	43.3
Total pelagic	-	-	-	-	-	0.1	0.4	-	-
Pandalus borealis	-	3.6	-	-	-	-	0.1	-	-
Total by-catch	265.3	426.9	245.1	428.1	1000.0	196.5	156.9	100.4	309.2

Table 12. U.K. (England & Wales). Nephrops catch and by-catch of protected (Recommendation 4) species (metric tons) taken by small-meshed nets (Recommendation 2) in VIIa.

Source: Mixed fishery data submitted to Liaison Committee

Year	Nephrops	By-catch	Kg. by-catch per ton Nephrops
1967	432	329	762
1968	1 408	1 306	928
1969	1 838	1 522	828
1970	...	...	...
1971	...	...	...
1972	2 956	1 042	353
1973	2 704	939	347

Table 13. U.K. (Northern Ireland). M[illegible]n catch-per-unit-effort (kg landed/h[illegible]urs fishing) of Nephrops and by-catch based on data from 22 one-day trips on board vessels using "small mesh" nets, 1971-1974. The data is expressed seasonally and overall

Period	Total hours fishing	Kg. landed per hr. fishing							Total By-Catch Fish
		Nephrops*	Whiting	Cod	Coalfish	Monk	Hake	Others	
Jan-Mar	50.0	42.7	33.5	39.5	15.0	5.0	1.6	9.9	104.5
Apr-Jun	60.7	32.4	6.8	2.0	1.9	1.4	1.3	2.2	15.7
Jul-Sep	57.7	46.6	7.3	2.9	1.1	1.8	1.0	4.7	18.8
Oct-Dec	56.6	33.5	18.7	8.2	2.1	3.0	0.6	6.1	38.7
Overall	225.0	38.6	15.8	12.1	4.7	2.7	1.1	5.5	42.0

* Nephrops are normally landed as tails only. The weights given above refer to whole prawns. (1 kg. tails = 4 kg. whole prawns). Cod and coalfish are normally landed gutted, the remainder of the fish caught being landed whole.

Table 14. Irish Sea, September 1974. Landed catches and catch-per-unit-effort of Nephrops and whiting from various trawls.

Dates	Number of comparable hauls	Number of comparable hours fishing	Landed Catches		Catch-per-unit-effort		Gear
			Nephrops[1]	Whiting[2]	Nephrops[3]	Whiting[4]	
9-13 Sep. 1974	12	38.8	1 252	641	32.3	16.5	Dual-purpose trawl with 70 mm cod-end
9-13 Sep. 1974	12	38.8	1 662	600	42.8	15.5	Dual-purpose trawl with 40 mm cod-end
16-20 Sep. 1974	13	38.2	1 194	236	31.3	6.2	Dual-purpose trawl with 40 mm cod-end
16-20 Sep. 1974	13	35.8	1 194	311	33.3	8.7	Prawn trawl of 40 mm throughout

1. Kg. whole prawns
2. Kg. whole fish
3. Kg. landed/hour fishing
4. Kg. landed/hour fishing

Table 15. Irish Sea. Parallel haul trials.

Carapace length (mm)	Total numbers		Total numbers		70/40	Total weight (g)		70/40
	40 mm P.T.	40 mm Gundry	40 mm Gundry	70 mm Gundry		40 mm Gundry	70 mm Gundry	
12-14			16	12	0.75	10.4	7.8	
15-17	32	34	15	29	1.93	15	29	
18-20	650	850	239	172	0.72	368	265	
21-23	2 179	3 185	1 243	618	0.50	2 847	1 415	
24-26	1 809	2 872	1 148	604	0.53	3 800	1 999	
27-29	1 049	1 672	538	267	0.43	2 496	1 239	
30-32	529	803	313	136	0.43	1 981	861	
33-35	255	408	129	88	0.68	1 085	740	
36-38	106	216	73	63	0.86	799	689	
39-41	30	72	45	55	1.22	629	768	
42-44	38	50	20	24	1.20	351	421	
45-47	13	6	12	10	0.83	261	217	
48-50			7	7	1.00	186	186	
Total	6 589	10 080	3 785	2 058	0.54	14 828	8 837	0.60
Total >30	712	1 190	463	322	0.69	5 292	3 882	0.73

P.T.: Uniform 40 mm prawn trawl made by Gourock.

Gundry: Standard Gundry prawn trawl, 20 fm courlene, wings 89 mm, belly + batings 56 mm.

Table 16. Irish Sea *Nephrops*. Selection by 40 mm and 70 mm mesh.

Age		1	2	3	4	5	6	7	8	9	10
Carapace length mm	♂	14.0	21.0	26.0	31.0	34.0	38.0	41.0	(45)	(48)	(50)
	♀	14.0	21.0	23.0	25.0	27.0	30.0	32.0	(34)	(36)	(38)
Tail weight gms	♂	0.7	2.0	3.4	5.5	8.3	11.7	15.0	18.0	20.6	22.5
	♀	0.3	1.2	2.2	3.2	4.4	5.7	6.9	8.1	9.0	9.6
% retained 40 mm	♂	70.0	91.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
	♀	70.0	91.0	97.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
% retained 70 mm	♂	12.0	33.0	48.0	60.0	72.0	83.0	93.0	100.0	100.0	100.0
	♀	12.0	33.0	39.0	45.0	51.0	60.0	66.0	72.0	77.0	82.0

Table 17. Size composition of hake catches of the small trawlers of Lorient working 47°30'N 3°30'W Jan.-Apr. and June-Aug. 1973.

cm	Number per 10 hours fishing						
	January	February	March	April	June	July	August
10			9				
11			10				
12			29	5	5	3	
13			58	65	2	6	
14			60	165	91	5	
15		20	91	431	245	5	
16		10	68	845	371	6	
17		15	75	774	589	5	
18		19	89	593	520	5	
19		35	72	462	425	5	
20		42	72	315	320	20	
21		55	68	170	158	29	
22		71	65	52	130	25	
23		75	40	30	75	31	
24		81	35	28	40	28	
25		70	30	25	38	20	5
26	5	69	25	10	10	17	10
27	11	51	20	12	7	30	20
28	21	42	15	10	10	20	35
29	35	21	10	7	1	15	61
30	59	18	5	6	5	20	122
31	120	5	5	5	5	10	159
32	160	5	5	6	1	7	155
33	155	1	1	2	5		148
34	151	1		1	5		130
35	129	1		1	1		75
36	75	1		1			60
37	60			1			40
38	41			1			19
39	22			1			9
40	12			1			18
41	20			1			5
42	5			1			5
43	5			1			5
44	4						

Table 18. Denmark (Southern Kattegat). Catch per 1 hour (brought on board).

Gear: *Nephrops* trawl

Mesh size: 35 mm

(Data based on trawling with the research vessel "Havfisken"
July - November 1971 - 1974)

Species	Weight (kg)	% According to weight	Number	Number of undersized
Nephrops	11.88	21.12		
Cod	9.98	17.74	44.6	32.38
Whiting	6.4	11.37	58.43	13.83
Haddock	0.4	0.71	3.1	1.18
Hake	0.1	0.20	1.33	1.33
Plaice	1.78	3.16	5.13	0.45
Dab	7.83	13.92	97.23	94.15
Sole	0.88	1.56	2.68	0.15
Lemon sole	0.05	0.08	0.08	-
Turbot	0.08	0.14	0.08	-
Brill	0.03	0.05	0.08	-
Unprotected species*	16.83	29.92		
Total	56.24	99.97		

* Mainly Long Rough Dab

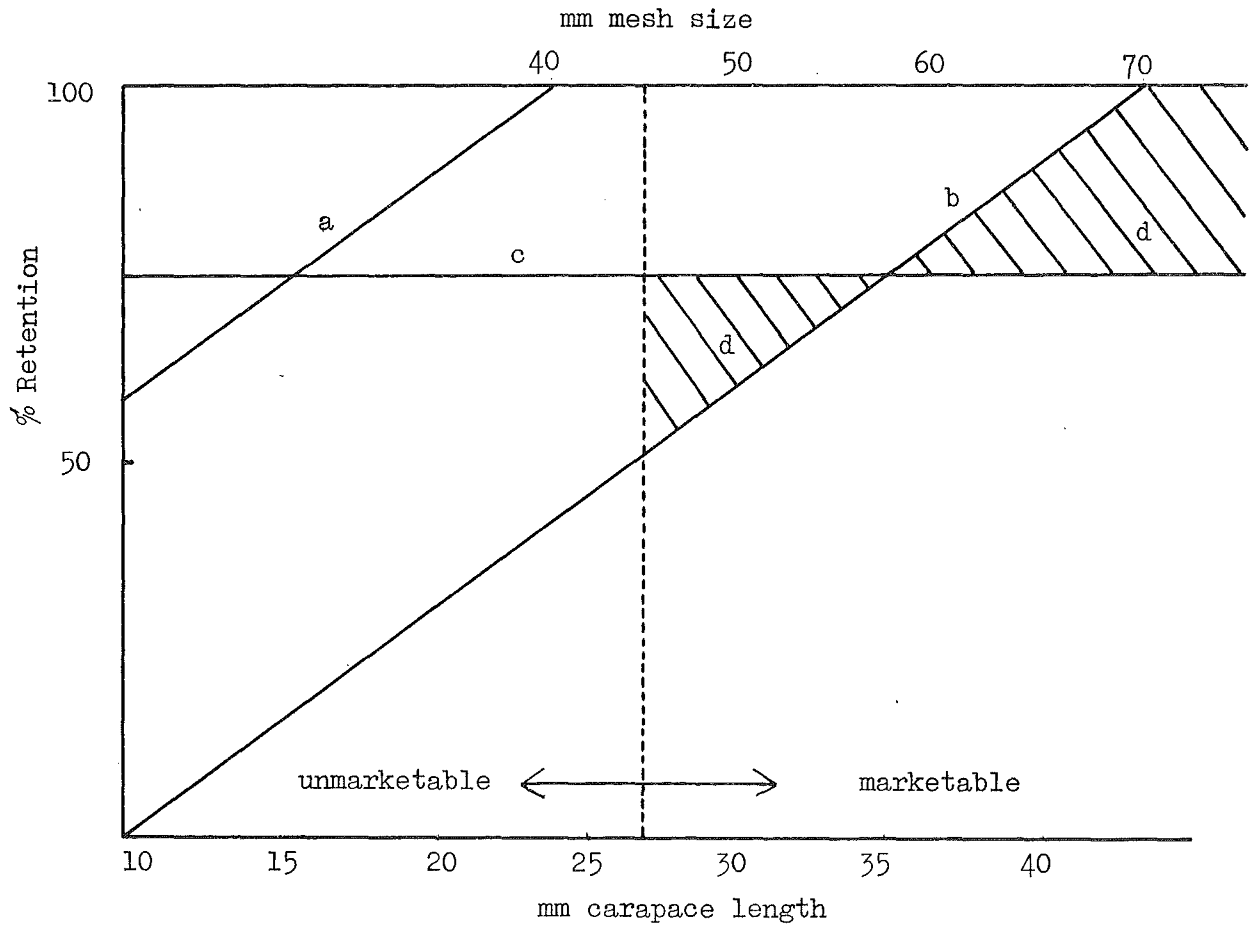

Figure 1. Selection lines derived from 40 mm and 70 mm meshes.

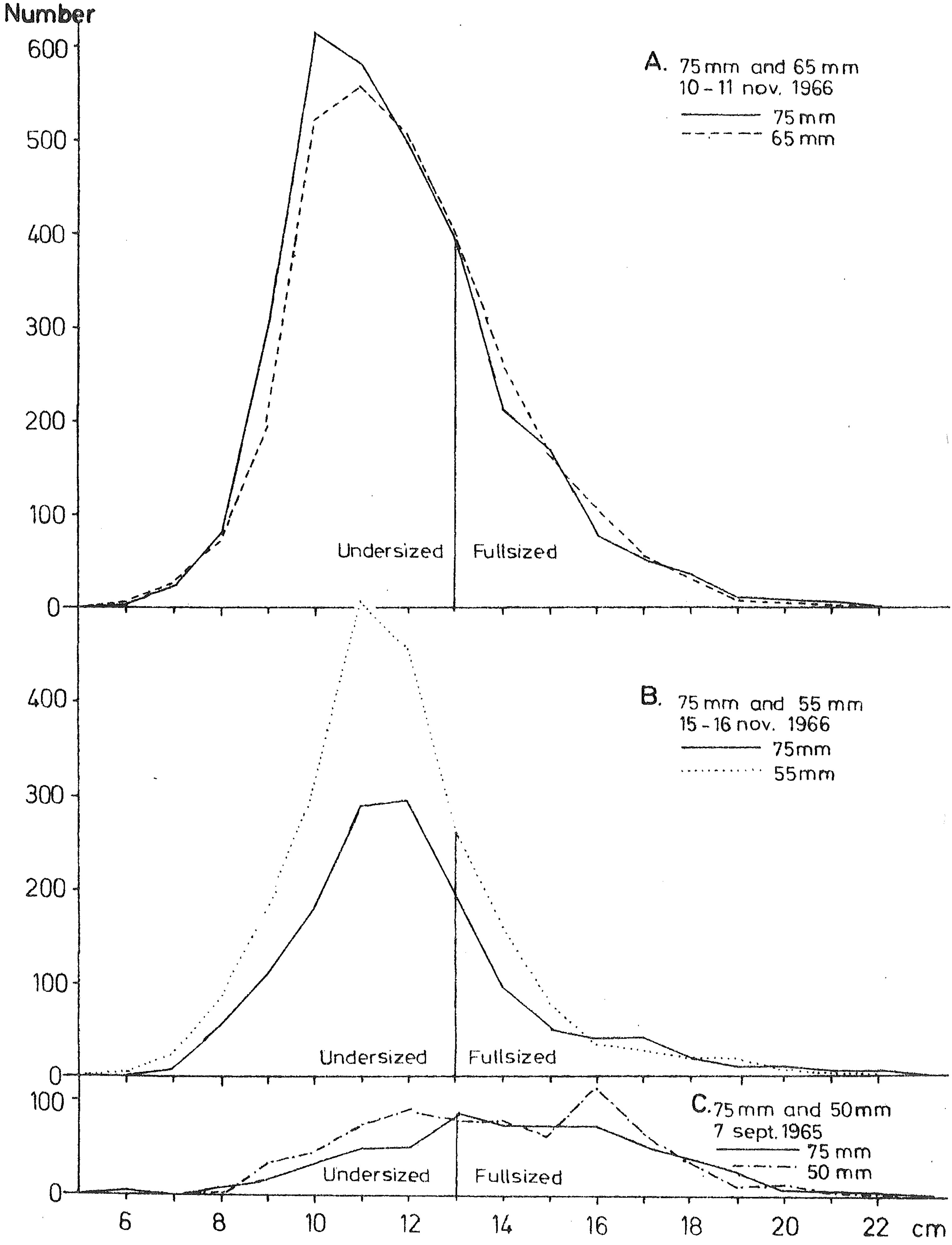

Figure 2. Nephrops: size distribution. Comparison between different mesh sizes. (Sweden).

A PRELIMINARY ASSESSMENT OF THE FIRTH OF FORTH STOCK OF NEPHROPS

by

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Nephrops is a species that cannot be aged and for this reason a stock assessment method not requiring age data has been applied. In this paper an attempt has been made to assess the Firth of Forth stock of *Nephrops* using length composition data using a method described by Jones (1974). The assessments are of the effects on the yield per recruit of changes in effort and mesh size.

Basic Data

Nephrops landings (in tons) from the Firth of Forth at the ports of Leith, Anstruther and Eyemouth are shown in Table 1. The data are for the period 1954-73. During this period, landings increased from 228 tons in 1954 to a peak of 1 903 tons in 1966. During the period 1967-73 landings averaged 1 432 tons, and in 1973 the landings were 1 697 tons. It appears that after a period of increasing landings, landings levelled off to fluctuate about a more or less constant level.

Because of the nature of the fishery in this region, no effort data are available for making reliable comparisons of changes in fishing effort.

Length compositions of *Nephrops* taken in the commercial fishery have been made by observers on board commercial vessels. Data are available for 1956 and for each of the years from 1966-73. These data have provided length compositions of males and females caught. They have also provided estimates of the proportions rejected at various lengths from which it has been possible to determine length compositions of the landings.

Table 2 shows the percentages of *Nephrops* rejected at various lengths based on samples taken on board Anstruther vessels during the period January - August 1966. From these samples it appears that the 50% rejection length occurs at a carapace length of approximately 31 mm.

Numbers landed

Estimates of the numbers landed at various lengths have been made using the length composition data taken on board commercial vessels. As an example a worksheet showing the estimation of the numbers landed in 1973 is given in Table 3.

Columns A and B show the number of males and females at each length per 100 individuals sampled in the catch. In this particular year, the sex ratio was almost equal. There were 50.2% males and 49.8% females.

By making use of the percentages rejected given in Table 2 it is possible to determine the numbers landed in each length group per 100 individuals actually captured. This information is given in columns C and D.

In order to relate the numbers landed to the weight landed it is necessary to convert numbers to weights. This has been done using mean weight at length data given by Pope and Thomas (1967). The relationship used is intermediate between the relationships given by these authors for each sex separately, i.e.

$$W = 0.00055 L^3$$

where W = total body weight in grams

L = carapace length in mm.

The mean weights are shown in column E. They have been multiplied by the numbers landed in columns C and D to give estimates of the weights landed in the various length groups per 100 individuals caught. This information is shown in columns F and G. The aggregate total of columns F and G for both sexes is 1337.1 g i.e. for every 100 individuals in the catch it is estimated that 1337.1 g of Nephrops are landed. In 1973 the total weight landed (in units of whole body weight) by Anstruther vessels was 690 tons. This gives a raising factor of

$$690/1.337 = 516$$

Using the raising factor of 516 for all data in columns A-D, columns H-L have been derived. Columns H and J show the numbers landed (in thousands of individuals), columns K and L show the corresponding numbers caught. In 1973, it is estimated that Anstruther boats took 51.6 million individuals of which 25.3 millions were landed. Since the total landings in 1973 by vessels landing at Leith, Anstruther and Eyemouth amounted to 1 697 tons the values in Table 3 can be further raised by a factor of

$$1697/690 = 2.46$$

to determine total landings for the district. Using this factor it is estimated that total landings amounted to 126.9 million individuals of which 62.2 millions were landed.

In order to estimate the relatively small proportion of individuals caught at very small and very large lengths, actual computations were carried out using more significant figures than those shown in Table 3. In this way, estimates similar to those in Table 3 have been obtained for each of the years 1967-73. The mean of these estimates of the numbers (in thousands) of Nephrops caught annually by Anstruther boats for the period 1967-73 is shown in Table 4. During the period 1967-73 Anstruther vessels caught 29.4 million individuals annually and landed 16.1 million individuals annually. If it is assumed that the length composition of Nephrops taken by vessels landing at Leith and Eyemouth is the same as at Anstruther, then estimates of the total numbers landed from the whole Firth of Forth fishery can be determined by a simple proportion. Thus during the period 1967-73 the landings by Anstruther vessels averaged 498 tons compared with an average annual landing of 1 430 tons by Leith, Anstruther and Eyemouth vessels combined. Using a raising factor of

$$1430/498 = 2.87$$

gives an estimated annual catch for the entire fishery from the period 1967-73 of 84 million individuals. The corresponding annual landing is 46 million individuals.

Cohort Analysis

Cohort analyses of the length composition data in Table 4 have been carried out using the method described by Jones (1974). For each analysis, a pair of values of L_∞ and M/K is required and calculations have been done for various combinations of these parameters. For each combination of the values of L_∞ and K it is possible to obtain values of the rate of exploitation (F/Z), and the annual recruitment. It is also possible to estimate the effect on the yield per recruit of changes in fishing effort and mesh size. A worksheet is given in the Annex (p.40) illustrating the application of the cohort analysis to the length composition data for males.

The effect of changes in fishing effort and mesh size

Each cohort analysis provides, along with other estimates, estimates of FDT for each length group. Each of these is an estimate of the instantaneous rate of fishing mortality (F), times DT, the time required for a fish to grow from the lower to the upper limit, of the length group in question. Given values of FDT for each length group, it is possible to determine the effect on the yield per recruit of a change in fishing effort or mesh size (Jones, 1974).

Investigations showed that for small values of M/K, yield/recruit ought to increase if fishing effort were decreased or mesh size increased. For large values of M/K the opposite result was obtained.

The first step therefore was to calculate the critical values of M/K at which the transition took place from one kind of result to the other. The results are shown in Table 5. Calculations were done for males and females separately and for values of L_∞ = 70 mm and 100 mm.

For males, it was found that the yield/recruit should increase if fishing effort was decreased, or mesh size increased, provided M/K did not exceed 2 (if L_∞ = 70 mm) or 4 (if L_∞ = 100 mm).

For females the critical values of M/K were about 2 (if L_∞ = 70 mm) or 6 (if L_∞ = 100 mm) Some examples of actual changes in the yield/recruit are given in Tables 6 and 7. Table 6 shows the effect of various changes in fishing effort using the current mesh size.

Table 7 shows the effect of various changes in mesh size using the current level of fishing effort. The current mesh size is 70 mm and calculations were made for increases in mesh size of 20, 40 and 60 mm. According to Pope (personal comm.) the selection factor for Nephrops is about 0.3 and this value was used in the calculations.

These calculations were made using the length composition of the catch. Since many small Nephrops are discarded, increases in mesh size should benefit landings more than is suggested by the values in Table 7.

Estimates of the rate of exploitation

Values of the rate of exploitation (F/Z) have been determined for both sexes assuming L_∞ = 70 mm and 100 mm. Various values of M/K have been adopted and some results are shown in Tables 8 and 9. All calculations were done assuming that the rate of exploitation for the largest individuals was 0.7.

In general the estimates of the rate of exploitation increased with L_∞ and decreased with M/K.

Annual recruitment

Estimates of the numbers (millions) attaining a length of 10 mm each year are given in Table 10. These numbers refer to the numbers of individuals attaining a length of 10 mm each year, irrespective of how many year classes they might come from. To a first approximation, it may be supposed that the number attaining a particular length each year out of all year classes combined, will be equal to the total number in any one year class i.e. to a first approximation, the annual recruitment of individuals of 10 mm length should be equivalent to the annual recruitment of a year class at a mean age corresponding to a length of 10 mm.

For both sexes, estimates increase with the value of M/K and decrease with the value of L_∞.

Further assessments

By making one further assumption (i.e. about the value of M) it is possible to estimate the actual size of the stock and also values of Z and DT. An example of the computational procedure is shown in the Annex.

No values of M are available for this species. However values, consistent with the values of M/K adopted can be determined by first making estimates of the likely magnitude of K from observations on the growth of Nephrops.

Growth of Nephrops

No information is available on the growth of Nephrops under natural conditions, but aquarium observations have been made. (Thomas, 1965).

For males, the growth increments on moulting tended to be constant for individuals ranging from 20-45 mm in length. The mean growth increment on moulting averaged 2.7 mm.

For females there was a well defined trend showing an increase with size in the growth increment on moulting. For *Nephrops* of 22 mm the average increment was $1\frac{1}{2}$ mm. For individuals of 42 mm the average increment was 4.0 mm.

This information alone is not sufficient for constructing growth curves since it is also necessary to know the frequency of moulting. In the aquarium experiments the duration of the inter-moult interval for males was approximately $6\frac{1}{2}$ months. There was no discernible trend with size of individuals and this value is applicable to individuals of 20-45 mm in length. To a first approximation the aquarium results suggested that males moult twice per year and that the growth should therefore be about 5.4 mm per year.

For females, the tendency for the growth increment to increase with body size suggests a curved growth curve that would tend to infinity if extrapolated. The results for males seem to suggest a linear growth curve and this also would tend to infinity if extrapolated.

In reality, both of these implications are improbable. Instead, it is more realistic to suppose that the frequency of moulting decreases as the individuals grow, so that size, for both sexes, tends towards an asymptote and growth eventually ceases.

One assumption is that the growth curve is of the von Bertalanffy type. In that case, it is possible to determine a value of K, for any given value of L_∞ provided at least one annual increment is known. For this purpose, it will be assumed that only the smallest individuals moult twice a year, i.e. for males, it will be supposed that an annual increment of 5.4 mm is applicable only to individuals of 20 mm.

Values of K can then be determined by noting that the slope of a Ford/Walford plot is e^{-K}.

Thus for males, if a 20 mm individual grows to 25 mm in one year, these values provide one point on a Ford/Walford plot. To draw a complete line, only one other point is required, and a value of L_∞ is sufficient for this purpose.

For example suppose L_∞ = 70 mm then the slope becomes:-

$$(70 - 25)/(70 - 20) = 0.90$$

From this it follows that K = 0.11.

Similarly if L_∞ = 100 mm, K = 0.065.

For females the smallest individuals examined were 22 mm long and these grew $1\frac{1}{2}$ mm on moulting. Since this size of individual is likely to be immature, it is possible that it could moult twice in one year giving an annual increment of 3 mm.

Values of K can then be calculated as for males, giving

if L_∞ = 70 mm, K = 0.065

L_∞ =100 mm, K = 0.039.

Estimates of natural mortality

Given the values of K above, values of M can be obtained corresponding to the various values adopted for M/K. This has been done, and some values are shown in Table 11.

Stock size

Given combinations of L_∞, M/K, and M, values of the actual size of the stock can be calculated by the method described in the Annex. Some results are given in Table 12.

For males, if L_∞ = 70 mm and M/K is less than 2.0 (Table 5) then the upper limit to the population would be 174 million individuals.

If L_∞ = 100 mm and M/K is less than 4.0 (Table 5) then the population should be no greater than 187 million individuals.

For females if M/K is no greater than 2.0 (if L_∞ = 70 mm) or 6.0 (if L_∞ = 100 mm) (Table 5), the upper limit to population size should be about 300 million individuals.

Density of the stock

Anstruther boats fish the northern half of the Firth of Forth from Methil to a point about $5\frac{1}{2}$ miles east of May Island. The total area fished by these boats is approximately 100 square miles. If it is assumed that 80% of this is suitable for Nephrops it means that the individuals taken by Anstruther vessels come from an area of about 80 square miles or 274 million m^2.

If the upper limits of the population estimates for males and females are adopted, this would suggest to a first approximation a density of about 0.7 males and 1.1 females per m^2. Vessels landing at Leith and Eyemouth also fish to a certain extent in or near the Firth of Forth. Eyemouth vessels operate mainly off the mouth of the Forth in the vicinity of Eyemouth and scarcely overlap the grounds fished by Anstruther vessels. Leith vessels fish primarily on the south side of the Forth but also fish to some extent on the grounds fished by Anstruther boats. To a first approximation it will be assumed that a quarter of the landings by Leith vessels come from the region fished by Anstruther boats. To allow for this it is necessary to increase the values in Tables 10 and 12 by a factor of about 30%. If this is done, the density of Nephrops in the northern half of the Firth of Forth would be about 0.9 per m^2 for males and 1.4 per m^2 for females.

Estimates of the density of Nephrops in the Firth of Forth have been made by Chapman (personal comm.) from UW television photography. He obtained provisional estimates of 0.5 Nephrops burrows/m^2 giving an upper limit to the population density of 0.5/m^2.

This is lower than the upper limits to density obtained above by a factor of about 5. If it is assumed that the density of male and female Nephrops is no greater than 0.25/m^2 for each sex, the calculations suggest the upper limits to the values of M/K should be considerably smaller than those shown in Table 5.

It is concluded therefore that it should be possible to increase the yield/recruit of Nephrops by decreasing fishing effort or by increasing mesh size.

Total yields

It should be noted that the conclusions reached in this paper are quite tentative and based on a number of assumptions which have yet to be verified. It is hoped to carry out a more exhaustive study when further data have been collected.

Summary

In this paper the method described by Jones (1974) for assessing the effects of changes in fishing effort and mesh size using length composition data has been applied to Nephrops in the Firth of Forth. For this analysis, values of L_∞ and M/K are required for each sex. Preliminary analyses of the data were carried out using various combinations of L_∞ and M/K.

For both sexes, it was found that it should be possible to increase yield/recruit by decreasing fishing effort or increasing mesh size provided values of M/K did not exceed certain critical values. The critical values obtained are shown for each sex and for two values of L_∞ (70 mm and 100 mm) in Table 5.

Further investigations were carried out to determine possible combinations of values of the von Bertalanffy growth parameters L_∞ and K that were likely to be consistent with growth observations obtained in the aquarium. With the estimates of K that were obtained it was possible to calculate a value of M for each value of M/K (Table 11).

Given this additional information, estimates were also made of stock size and stock density. The estimates of stock density were then compared with a provisional estimate obtained by Chapman (personal comm.) based on the number of Nephrops burrows visible from UW television photography.

In this way, it was possible to determine a different set of upper limits for M/K, such that the theoretical estimates of density were no greater than the value obtained by Chapman.

Since these estimates are considerably lower than the critical values shown in Table 5, it was concluded that it should be possible to increase the yield/recruit by decreasing effort or increasing mesh size.

It was noted however that a number of assumptions had had to be made in order to reach this conclusion and it is recommended that further investigations should be carried out once more data have been collected. For this purpose, further direct estimates of the densities of male and female Nephrops should prove particularly useful.

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Table 1. Nephrops: Landings (tonnes) by districts.

	Eyemouth	Leith	Anstruther	Total
1954	59.8	11.8	156.0	227.6
1955	43.9	329.5	430.0	803.5
1956	39.2	306.8	317.3	663.3
1957	54.6	446.7	481.4	982.8
1958	21.5	421.7	241.6	684.8
1959	40.5	405.0	383.8	829.4
1960	43.9	227.5	227.0	498.5
1961	74.6	290.8	223.0	588.4
1962	94.9	232.9	303.2	630.9
1963	41.3	280.2	362.9	684.3
1964	67.7	518.9	318.3	904.8
1965	147.3	419.4	478.9	1 045.6
1966	286.9	668.3	947.8	1 902.9
1967	216.9	687.6	443.7	1 348.2
1968	237.3	510.9	299.4	1 047.6
1969	165.4	576.5	348.8	1 090.7
1970	252.2	759.3	601.3	1 612.8
1971	212.5	680.0	464.1	1 356.7
1972	455.5	776.4	637.7	1 869.6
1973	296.5	710.6	689.5	1 696.6

Table 2. Percentages of Nephrops rejected at various lengths based on Anstruther samples taken January-August 1966.

Length (mm)	% Rejected
22	100
23	100
24	99
25	99
26	96
27	94
28	88
29	79
30	65
31	51
32	39
33	18
34	8
35	5
36	2
37	1

Table 3. Worksheet showing estimation of numbers landed in 1973.

	A	B	C	D	E	F	G	H	J	K	L
	Catch (%)		Landings (%)			Catch	Weight	Landings (thousands)		Catch (thousands)	
Length (L)	♂	♀	♂	♀	Mean Wt g	♂	♀	♂	♀	♂	♀
10-14	-	-	-	-	-	-	-	-	-	-	-
15-19	0.3	0.3	-	-	-	-	-	-	-	155	155
20-24	4.1	5.4	-	-	-	-	-	-	-	2 116	2 786
25-29	18.7	17.0	1.87	1.70	11.4	21.3	19.4	965	877	9 649	8 772
30-34	14.9	14.2	10.43	9.94	18.9	197.1	187.9	5 382	5 129	7 688	7 327
35-39	7.5	8.8	7.46	8.76	29.0	216.3	254.0	3 849	4 520	3 870	4 541
40-44	2.6	3.6	2.6	3.6	42.2	109.7	151.9	1 342	1 858	1 342	1 858
45-49	1.2	0.5	1.2	0.5	59.0	70.8	29.5	619	258	619	258
50-54	0.6	-	0.6	-	79.6	47.8	-	310	-	310	-
55-59	0.3	-	0.3	-	104.6	31.4	-	155	-	155	-
60-64	-	-	-	-	-	-	-	-	-	-	-
65-69	-	-	-	-	-	-	-	-	-	-	-
Total	50.2	49.8	24.46	24.50		694.4	642.7	12 622	12 642	25 904	25 697
	100		48.96			1 337.1		25 264		51 601	

A & B Numbers at each length per 100 individuals in the catch.
C & D Numbers landed at each length per 100 individuals caught.
E Mean body weight calculated from $W = 0.00055L^3$.
F & G Weights landed (g) per 100 individuals caught.
H & J Numbers landed (thousands) for an observed landing of 690 tons.
K & L Numbers caught (thousands) for an observed landing of 690 tons.

(raising factor 690/1.337 = 516 for columns H - L).

Table 4. Numbers (thousands) of *Nephrops* caught annually at Anstruther.
Mean for the period 1967-1973.

Length	♂	♀
10-14	1	2
15-19	163	155
20-24	1 391	1 512
25-29	4 120	3 660
30-34	4 729	4 027
35-39	3 040	2 593
40-44	1 650	963
45-49	827	164
50-54	312	6
55-59	94	0.3
60-64	10	-
65-69	3	-
Total	16 340	13 082
	29 422	

Table 5. Maximum values of M/K such that provided these are not exceeded, the yield/recruit should Benefit from a decrease in fishing effort or an increase in mesh size.

L_∞ (mm)	Males	Females
70	2	2
100	4	6

Table 6. Nephrops: optimum change in fishing effort with current mesh size.

L_∞	M/K	% Change in Effort	% Change in Yield/Recruit
Males			
70	0.4	-70	+65.6
	1.0	-60	+17.0
	2.0	+20	+ 0.6
	3.0	+90	+23.4
100	1.0	-70	+67.8
	2.0	-70	+29.3
	3.0	-50	+ 8.6
	4.0	-20	+ 3.1
	5.0	+60	+ 2.7
Females			
70	0.6	-80	+81.9
	1.0	-70	+47.8
	3.0	+10	+ 1.5
	5.0	+90	+ 2.1
100	3.0	-70	+26.3
	5.0	-40	+ 1.6
	7.0	+90	+ 5.3

Table 7. Nephrops: optimum increases in mesh size with current level of fishing effort.

L_∞	M/K	Change in Mesh Size	% Change in Catch/Recruit
		Males	
70	(0.4	+60 mm[1]	+73.2
	(1.0	+60 mm[1]	+40.6
	(2.0	+40 mm	+ 5.5
	(3.0	no increase	-
100	(1.0	+60 mm[1]	+68.1
	(2.0	+60 mm[1]	+42.9
	(3.0	+60 mm[1]	+22.6
	(4.0	+40 mm	+ 6.9
	(5.0	+20 mm	
		Females	
70	(0.6	+60 mm[1]	+71.1
	(1.0	+60 mm[1]	+52.6
	(3.0	+20 mm	+ 1.7
	(5.0	no increase	-
100	(3.0	+60 mm[1]	+31.7
	(5.0	+40 mm	+ 4.1
	(7.0	no increase	-

(1) No greater mesh increases considered.

Table 8. Male *Nephrops*.
Values of the rate of exploitation (F/Z) using length composition for the period 1967-1973.

Assuming L_∞ = 70 mm

M/K Length	0.6	0.8	1.0	2.0	3.0
10-15	0.001	0.001	-	-	-
15-20	0.12	0.09	0.06	0.02	0.01
20-25	0.54	0.45	0.38	0.16	0.07
25-30	0.80	0.74	0.68	0.42	0.22
30-35	0.86	0.82	0.77	0.54	0.32
35-40	0.87	0.82	0.78	0.56	0.34
40-45	0.86	0.82	0.77	0.55	0.33
45-50	0.87	0.82	0.78	0.55	0.33
50-55	0.86	0.81	0.76	0.53	0.31
55-60	0.84	0.79	0.74	0.50	0.29
60-65	0.69	0.61	0.54	0.30	0.17

Assuming L_∞ = 100 mm

M/K Length	1.0	2.0	3.0	4.0	5.0
10-15	0.001	-	-	-	-
15-20	0.12	0.05	0.03	0.02	-
20-25	0.54	0.32	0.21	0.14	0.03
25-30	0.80	0.64	0.50	0.38	0.14
30-35	0.87	0.75	0.64	0.53	0.28
35-40	0.89	0.78	0.67	0.57	0.37
40-45	0.89	0.79	0.69	0.60	0.47
45-50	0.91	0.81	0.73	0.64	0.64
50-55	0.91	0.83	0.75	0.67	0.85
55-60	0.92	0.85	0.78	0.72	1.31
60-65	0.88	0.78	0.70	0.62	0.92

Table 9. Female Nephrops.
Values of the rate of exploitation using length composition for the period 1967-1973.

Assuming L_∞ = 70 mm

M/K / Length	0.6	0.8	1.0	2.0	3.0
10-15	-	-	-	-	-
15-20	0.14	0.11	0.08	0.03	0.01
20-25	0.63	0.54	0.48	0.25	0.14
25-30	0.83	0.78	0.73	0.52	0.36
30-35	0.89	0.85	0.82	0.66	0.51
35-40	0.92	0.89	0.86	0.73	0.61
40-45	0.93	0.90	0.88	0.77	0.66
45-50	0.93	0.91	0.88	0.78	0.69
50-55	0.91	0.88	0.85	0.72	0.61

Assuming L_∞ = 100 mm

M/K / Length	2.0	3.0	5.0	7.0
10-15	-	-	-	-
15-20	0.06	0.03	0.01	0.01
20-25	0.42	0.29	0.15	0.08
25-30	0.69	0.57	0.38	0.25
30-35	0.80	0.71	0.55	0.42
35-40	0.86	0.79	0.66	0.54
40-45	0.89	0.83	0.73	0.64
45-50	0.90	0.86	0.77	0.69
50-55	0.89	0.84	0.74	0.66

Table 10. Nephrops.
Estimates of numbers (millions) attaining a length of 10 mm each year, for various assumptions about L_∞ and M/K - using length composition for the period 1967 - 1973 Anstruther boats only.

Males

M/K / L_∞	0.2	0.6	1.0	2.0	3.0	4.0	5.0
70	18	23	28	54	124	408	2 270
100	17	20	22	31	44	64	95

Females

M/K / L_∞	0.2	0.6	1.0	2.0	3.0	5.0	7.0
70	14	17	21	35	60	200	793
100	14	16	17	23	31	59	115

Table 11. Showing possible values of M for various values of L_∞ and M/K.

Male				Female	
L_∞	M/K	K	M	K	M
70	0.2	0.11	0.022	0.065	0.013
	0.6		0.066		0.039
	1.0		0.11		0.065
	2.0		0.22		0.13
	3.0		0.33		0.20
	4.0		0.44		0.26
	5.0		0.55		0.32
	7.0		0.77		0.46
100	0.2	0.065	0.013	0.039	0.008
	0.6		0.039		0.023
	1.0		0.065		0.039
	2.0		0.13		0.078
	3.0		0.20		0.11
	4.0		0.260		0.16
	5.0		0.32		0.20
	7.0		0.46		0.27

Table 12. Nephrops.
Estimates of numbers (millions) in the sea, for the combinations of L_∞, M/K and M using length composition for the period 1967-1973 Anstruther boats only.

Males L_∞ \ M/K	0.2	0.6	1.0	2.0	3.0	4.0	5.0
70	83	93	111	174	327	891	4 110
100	80	89	93	117	145	187	246
Females L_∞ \ M/K	0.2	0.6	1.0	2.0	3.0	5.0	7.0
70	98	110	123	169	242	576	1 716
100	94	105	110	131	159	235	372

ANNEX

Worksheet Showing Sample Cohort Analysis of Length Composition Data
(Period 1967-1973).

Males Only.

LINFINITY = 70.0 M/K = 0.400 FINAL F/Z = .70 M = 0.20

LENGTH GROUP mm	NUMBER(1) LANDED thousands	NUMBER (2) IN SEA thousands	MEAN NUMBER(3) IN SEA thousands	F/Z	ZDT(4)	FDT(4)	Z	DT
65---- 70	0.300E+01	0.429E+01						
60---- 65	0.100E+02	0.171E+02	0.143E+02	0.778	1.386	1.078	0.900	1.540
55---- 60	0.940E+02	0.122E+03	0.548E+02	0.896	1.963	1.758	1.916	1.025
50---- 55	0.312E+03	0.467E+03	0.167E+03	0.903	1.342	1.213	2.070	0.649
45---- 50	0.827E+03	0.138E+04	0.407E+03	0.910	1.079	0.983	2.232	0.484
40---- 45	0.165E+04	0.319E+04	0.827E+03	0.909	0.841	0.765	2.196	0.383
35---- 40	0.304E+04	0.653E+04	0.149E+04	0.911	0.716	0.652	2.239	0.320
30---- 35	0.473E+04	0.117E+05	0.243E+04	0.907	0.587	0.532	2.145	0.274
25---- 30	0.412E+04	0.165E+05	0.332E+04	0.861	0.342	0.294	1.439	0.237
20---- 25	0.139E+04	0.187E+05	0.371E+04	0.652	0.121	0.079	0.575	0.211
15---- 20	0.163E+03	0.196E+05	0.364E+04	0.183	0.047	0.009	0.245	0.191
10---- 15	0.100E+01	0.202E+05	0.346E+04	0.001	0.035	0.000	0.200	0.174
TOTAL	0.163E+05		0.195E+05					

(1) Length composition of landings from Table 4.

(2) Estimate of number attaining the lower limit of each length group (i.e. 122 000 attain a length of 55 mm).

(3) Mean numbers in the sea in each length group at any one time.

(4) Values of Z (and F) multiplied by DT, the time required to grow from the beginning to the end of each length group.

Computational Procedure

1. Calculate the first value of column (2) from

(Number landed)/(final F/Z)

ie 0.3/0.7 = 4.29

2. Calculate a value of "X_L" for each length group

eg for the 60-65 mm length group

$$X_L = \left(\frac{L_\infty - 60}{L_\infty - 65}\right)^{\frac{M}{2K}} = \left(\frac{10}{5}\right)^{0.2} = 1.15$$

3. Calculate successive values of N_L (ie column 2) from

$N_L = (N_{L+\Delta L} X_L + C_L) X_L$

where C_L is the number caught in the length group

L to L + ΔL

ie for the 60 - 65 mm length group

the number attaining 60 mm is given by:-

[4.29(1.15) + 10] 1.15 = 17.17 ($\times 10^3$)

(Note that the values shown in the table were calculated using more significant figures.)

4. Calculate values of F/Z from the relationship

F/Z = (number caught)/(number dying)

eg for the 60-65 mm length group

F/Z = 10/(17.17 - 4.29) = 0.78

5. Calculate ZDT from the relationship

$\exp -ZDT = (N_{L+\Delta L})/N_L$

eg for the 60-65 mm group

exp -ZDT = 4.29/17.17 = 0.249

so that ZDT = 1.39

6. Calculate FDT from

$FDT = ZDT\ (F/Z)$

eg for the 60-65 mm group

$FDT = 1.386(0.778) = 1.078$

In order to calculate columns (3), Z and DT a value of M is required. Here a value of 0.2 has been assumed.

7. Calculate Z from

$Z = M/(1 - F/Z)$

eg for the 60-65 mm group

$Z = 0.2/(1-0.778) = 0.90$

8. Calculate DT from

$DT = ZDT/Z$

eg for the 60-65 mm group

$DT = 1.386/0.90 = 1.54$

9. Calculate col (3) from

mean number in sea $= (N_L - N_{L+\Delta L})/Z$

eg for the 60-65 mm group

$(17.1 - 4.29)/0.90$

$= 14.23\ (x10^3)$