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Approaches to Assessment of Deepwater Sharks in the Northeast Atlantic
(Elasmobranch Fisheries – Poster)

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Abstract

Deepwater sharks are caught in several fisheries in the northeast Atlantic. Among the most important are the Spanish longline fishery, the Norwegian autoline longline fishery and the mixed-species trawl fishery, mainly prosecuted by French vessels. The main species exploited are *Centrophorus squamosus* and *Centroscymnus coelolepis*. These fisheries are difficult to assess because accurate time series of catch and effort are collected only by France, and in that instance only for both commercial species combined. Two approaches have been taken to stock assessment of these commercial deepwater shark species: Schaefer production model and Leslie depletion model. The deficiencies in the knowledge base are highlighted and future data and model requirements are discussed.

Introduction

There are several fisheries for deepwater sharks in the northeast Atlantic, but most activity takes place in the Rockall Trough, and on the slopes of the Porcupine Bank. Two species of sharks are routinely landed for their flesh and livers; the leafscale gulper shark *Centrophorus squamosus* (Bonnaterre, 1788) and the Portuguese dogfish *Centroscymnus coelolepis* (Bocage and Capello, 1864). These species are collectively called “siki” in French fishery records (Gordon, 1999) though they are marketed elsewhere under this name too. French vessels catch these species in the mixed-species trawl fishery. Spanish longliners target deepwater sharks too (Pineiro *et al*., 2001) but it is difficult to quantify landings as separate statistics for deepwater shark species are not collected from these vessels. More recently, longliners from Norway and Ireland and trawlers from Scotland and Ireland are catching these species. There have been landings of sharks in Sub-area VIII, but the deepwater component is unknown. There are directed gillnet fisheries in this area for sharks also, but little data are available. Table 1 presents landings data for large squalid deepwater sharks, mainly *C. squamosus* and *C. coelolepis* and other sharks, some of which are deepwater species.

Portugal collects species-specific landings data from artisanal longline fisheries in Div. IX a. More details of these fisheries are given by Figueiredo *et al.* (this proceedings). In Sub-area X (Azores, Portugal) there was a directed longline fishery for *D. licha* and details are contained in (Machado *et al*., this proceedings). The present work details results of assessments of the two species that are commercially important in the northern part of the ICES area (Sub-areas V, VI, VII, VIII and XII), *C. squamosus* and *C. coelolepis*.

Stock structure is unclear in these wide-ranging deepwater squalid sharks. Both *C. squamosus* and *C. coelolepis* are present all along the continental margins from Iceland to Portugal and along the Mid-Atlantic Ridge. There is little information on stock discrimination of deep-water sharks, few genetic studies have been carried out, and none in the ICES area. However there are some data that support the view that deep-water sharks are highly migratory. Clark and King (1989) found a cyclical migration around the North Island, New Zealand for the related species, Deania calceus, and showed that breeding aggregations are localised. The continental slopes of Portugal are populated by *Deania calceus* of smaller size (Machado and Figueiredo, 2000) than those present west of Ireland or Scotland (Clarke *et al*., 2002). Gravid female *Centrophorus squamosus* have been recorded in Madeira and continental Portugal. However there are no records of any gravid females from west of Ireland or Scotland despite intensive sampling (Girard, 2000), where only 21% of female *Centrophorus squamosus* were mature.

There are few data to assess stock status. Stock structure is poorly understood, and small specimens are very rarely (*C. coelolepis)* or never (*C. squamosus*) encountered in Sub-areas V, VI, VII, VIII and IX. However, in the absence of information, a single assessment unit of the northeast Atlantic was chosen for these species. A particular problem is the lack of species specific landings data. Biological parameters have been elucidated by several studies, though age estimates for *C. coelolepis* are still not available (Table 2). The present paper aims to present results to date of assessments of the two main commercial species in the northern area, *C. squamosus* and *C. coelolepis*. The deficiencies on the knowledge base are described and recommendations for future research needs are highlighted

Materials and Methods

A series of CPUE from a reference fleet from French trawlers for *Centroscymnus coelolepis* and *Centrophorus squamosus*, for 1990 to 2001, was presented to the ICES Working Group on the Biology and Assessment of Deep-sea Fisheries Resources (Anon., 2002), here termed "WGDEEP" CPUE. This series was calculated from total landings from these vessels and total effort directed at all deepwater species combined. A different CPUE series was presented at the previous meeting of this group (Anon., 2000), here termed "SGDEEP" CPUE. . That series was based on the same fleet of French trawlers, but was calculated from catch by vessel and statistical rectangle directed at squalids. Effort was considered to be directed if it produced more than 10% of total catch or 20% of total annual catch (Lorance and Dupouy, 2001). The two series are described in Anon. (2002). The WGDEEP series produced lower estimates in each case, since it comprises total effort, rather than effort directed at *C. coelolepis* combined with *C. squamosus.*

Survey data were available from Norway (autoline) and Ireland (autoline and trawl) for several years from 1991 to 2000 and were compared with these commercial CPUE data. The Norwegian and Irish surveys (Table 3) are directly comparable, using the same autoline longline gear configurations. Survey CPUE is presented, only for the mid-range of the bathymetric distributions of *C. coelolepis* and *C. squamosus* (1,100-1,600 m) based on the known range of the species (Clarke *et al*., 2001). These data were not directly comparable because the commercial data are for the two species combined, so survey CPUE was pooled for both species, including those catches in the intersections of their bathymetric ranges. There is no evidence of an upward trend in CPUE in Sub-area VI for Portuguese dogfish. Furthermore, the pooled species data, from autoline surveys displayed a downward trend from 1997 to 2000. Thus, survey data do not mirror the upward trend in CPUE from the French commercial fishery. In Sub-areas VII and XII there is some evidence of a decline in CPUE throughout the 1990s.

The WGDEEP CPUE data for "sikis" representing non-directed effort were used as inputs to a Schaefer Production Model which can be defined as;

$$\frac{Db}{Dt} = r\,B\,(1 - B / K) - C$$

Where B = biomass of the stock, r = intrinsic rate of population growth, K = carrying capacity, and C = catch measured as a rate (Hilborn and Walters, 1992). The model was fitted using a non-equilibrium method using the CEDA© package. This model and package were chosen to allow for some comparisons to be made with the previous assessment attempted in 2000. A sensitivity analysis was used to evaluate the effect of error models and ratio of initial to virgin biomass. A time-lag of zero was used, for the same reasons considered by WGDEEP; that the time-series of catch and CPUE were too short to explore the effect of recruitment in this fishery. It was assumed, therefore, that growth rather than recruitment was the main contributor to biomass production. A value of the ratio of initial stock to virgin stock was chosen as 0.7, based on sensitivity analysis. An initial to virgin ratio of 0.9 having been used in Schaefer production models used in SGDEEP (Anon., 2000) because of by-catch in earlier blue ling fisheries. Two combinations of landings data were used, total sharks, including some reported under the "sharks various" category, and deepwater sharks, comprising only sharks that are reported as these two deepwater species.

In addition a Leslie Depletion method, for closed populations was applied, as described in Hilborn and Walters (1992). This is based on the assumption that the population gains no new recruits or immigrants and loses no animals to natural mortality or emigration. The behavior of such populations can be described by the model;

$$N_t = N_1 - K_{t-1}$$

where K_{t-1} is the cumulative catch taken prior to time t.

Based on the assumption that all fish are equally vulnerable to exploitation the population at time t can be described by the Leslie method. Substitution of above equation into observation model y = qN gives;

$$Y_t = qN_t = q(N_1 - K_{t-1}) = qN_1 - qK_{t-1}$$

The last expression is in the form of a linear regression y = a + bx, where the intercept parameter is qN_1, the slope parameter is q, and the regression X is $-K_{t-1.}$ The slope should estimate q and the ratio a/b (intercept of regression line on the abscissa) should estimate N_1. The Leslie method can be conceptualized as a linear regression of relative abundance and cumulative catch and examining the trend to investigate what cumulative catch would result in the relative abundance dropping to zero.

Results

Length frequencies by year from Irish surveys are presented in Fig. 3. Figure 4 shows length frequencies for *C. coelolepis* from exploratory fishing on Hatton Bank, whilst Fig. 5 shows length frequencies and length at maturity as calculated from French commercial samples.

The time series for Sub-area VI, where most effort takes place, both displayed downward trends until 1998. The WGDEEP series did not display the high peak in the SGDEEP series for 1991. However the value for 2001 is the highest since 1994. There is no similar upward trend for the other sub-areas, and it is unclear what the reasons for this trend are. However the series for the Sub-areas combined displayed the same trend, indicating the importance of Sub-area VI effort on these sharks. Indeed the 2001 value is the highest recorded in the combined series. There is no anecdotal evidence from the fishery to suggest that there is an upward trend in abundance in 2000 or 2001 and there is no similar signal in the survey CPUE series (Table 3).

The estimated parameters of the Schaefer model are presented in Table 4. The fit of the model was very poor when all years, except 1990 were included. It was considered reasonable to exclude years 1991-1993 because the fishery was in the learning phase, where catchability was different. The fishery was changing in character and target species at that time. The directed CPUE series (Anon., 2000) displayed a peak in 1991. However non-directed CPUE did not display a first peak until 1993 and this was considered to reflect the targeting of the (now depleted) orange roughy fishery in Sub-area VI at that time. Fisheries independent survey data were considered to be a more reliable indicator of recent abundance and supported the decision to remove years 2000 and 2001 because there was no supporting evidence for an upward trend in stock abundance in these years.

Subsequent runs of the Schaefer model were attempted, excluding 1990, 1992, 2000-2001. The fit of the model was better when these years were excluded. Two scenarios are presented in Table 4, using landings of deep (*C. coelolepis* and *C. squamosus*) + various sharks, and using deep shark landings only. Intrinsic rate of population increase (r) and maximum sustainable yield were poorly estimated, and did not have meaningful confidence intervals. Thus the outputs of these runs should be treated with caution. They should not be considered reliable estimators of stock status. Catchability (q) and carrying capacity (K) were estimated with narrower confidence intervals, however. Runs of the model, after excluding these years were considered to fit the downward trend on abundance quite well, for the years considered (Fig. 6).

Leslie depletion models are presented in Table 5 for two scenarios, representing combinations of total shark and deepwater shark landings. A good degree of fit was obtained (Fig. 7) in each case. Choice of landings data effects the estimate of initial population size.

Discussion

These sharks are by-catch species in mixed-species deepwater fisheries, and by-catch CPUE can be considered useful for assessing them. Results of experimental fishing at Hatton Bank (Fig. 8) show the utility of by-catch CPUE. This is a mixed longline fishery, targeting Greenland halibut *Reinhardtius hippoglossoides*, with by-catches of blue ling *Molva dypterygia*, roughhead grenadier *Macrourus berglax* and *Centroscymnus coelolepis.* When the vessel found good catches of Greenland halibut, a peak in the CPUE for this species was reached. In contrast the CPUE for *Centroscymnus coelolepis*, a by-catch species, remained constant throughout the period. This suggests that that non-directed CPUE for these sharks is a useful indicator of abundance, as it is less susceptible to variation than target CPUE.

These two species have different bathymetric distributions, *C. squamosus* occurring in maximum abundance, shallower at around 800 m whilst *C. coelolepis* is most abundant at a depth of 1,300 m (Clarke *et al*., 2001; Girard, 2000). This combined CPUE series for both species may mask important trends for each species. The deepwater fishery began by targeting species such as blue ling on the upper slopes (Charuau *et al*., 1995) and *C. squamosus* would have been the more dominant species in catches. Later on, targeting of orange roughy at depths of up to 1,800 m would have involved proportionately higher catches of *C. coelolepis*. Girard *et al*. (2000) showed that it is necessary to consider depth when interpreting CPUE in the deepwater fishery. This study compared a commercial skipper's logbook and official CPUE from the national administration. If depth is not considered, variations in CPUE may simply reflect different depths fished, rather than changes in abundance (Girard *et al*., 2000).

CPUE may be considered a useful abundance index for these sharks, provided that catchability is constant. Experience gained by skippers and knowledge shared between boats will have led to some increase in efficiency over time. It is estimated that such experience gained and improvements in technology led to a 10% increase in catch for one deepwater trawler, between 1993 and 1997. The reference fleet of trawlers was considered homogenous over time in terms of power and fishing gear (Lorance and DuPuoy, 2001). The upward trend in CPUE in Sub-area VI in 2000 and 2001 is unexplained. But there is no similar upward trend in longline survey CPUE in 2000. Survey CPUE was considered a more reliable indicator of abundance.

The only parameter of the Schaefer model that appeared to be well estimated was catchability (q). Catchability was considered to be constant during the period, when other years were excluded. Estimates of the carrying capacity K were sensitive to the landings data used as inputs. These landings are either an overestimate (since they represent various sharks and the two case-study species) or an underestimate (only known deepwater landings). Maximum sustainable yield, MSY and intrinsic rate of population increase r are not estimated with meaningful confidence intervals and therefore should not be used. The data used as inputs to this model are poor. They are not species specific, and do not take into account depth-related effects. The output parameters, apart from catchability, are poorly estimated. The Schaefer model does little more than mirror the declining trend in CPUE in the series.

The Leslie depletion model also displayed good estimates of catchability. The assumptions of no recruitment and no inward or outward migrations are almost certainly not met in the case of these species. Stock structure is poorly understood, but the size frequencies indicate that sharks recruit from an area beyond Sub-areas V, VI, VII and XII. Smaller sharks are not present in the area where most fishing activity takes place.

Given the problems with the data and the poor quality of the output parameters, these preliminary assessments are of limited utility. However some general points about the impacts of fishing on these shark populations can be made. A maturity stage segregation according to the depth is a feature of these species. Gravid *C. coelolepis* are found only at the top of the continental slope (Clarke *et al*., 2001; Girard and DuBuit, 1999) so that variation in the fishing strategy can differently impact the stock. The use of a combined series also ignores important aspects of life history in each species. *C. squamosus* may have been subject to exploitation for longer. It has a lower fecundity than *C. coelolepis* (Girard and DuBuit, 1999). However a portion of the stock is not subject to exploitation, gravid females being absent from this area. In contrast, all stages of *C. coelolepis* are present in this area, and this species could be more vulnerable for that reason. Whilst there are no published age estimates for *C. coelolepis*, *C. squamosus* has been estimated to reach ages of 70 years (Clarke *et al*., 2002). These estimates were used to derive an estimate of natural mortality for the latter species of 0.07 (females) and 0.09 (males) (Clarke *et al*., 2001). These values were lower than for any other species taken in the deepwater mixed fishery.

Given the sensitivity of the Schaefer and Leslie models to the landings data used, it should be a cause for concern that species-specific data are not available. The collection of such data should be a priority for future international sampling programmes. It should be pointed out that the estimates of K from the depletion model may be too high, because recruitment was not considered. Further refinement of species-specific catch and effort data, perhaps considering other reference fleets, and taking into account the different fishing strategies with depth in these species, should be carried out. Such work would be particularly valuable in the case of the fisheries that have taken place for the longest periods of time. CPUE data should be collected at a better spatial resolution than at present. Given the differences in their bathymetric distributions, depth-specific data would be very important.

Catch and effort data have only slowly become available for these species, and further work is required in producing new species-specific series of catch and effort. In the meantime alternative approaches should be investigated. Figueiredo *et al*. (this proceedings) presents a life-history approach to assessing one of these species. However there are still gaps in the knowledge base. Age specific natural mortality rates are not available for *C. squamosus*, and there are many uncertainties surrounding age and natural mortality estimates for *C. coelolepis*. Furthermore, the length of gestation is not known for either species. Girard (2000) estimated the duration for both species using Holden's (1974) transformation of the von Bertalanffy growth model and observed length at birth data to derive a range of values between 2.5 years (assuming K = 0.1) and 0.8 years (K = 0.3). This approach depends on an assumption that in utero growth rate is adequately described by the model, which may not be the case. The uncertainties in some important life history parameters have been discussed by Clarke *et al*. (2001). However available data could be used as a first attempt to obtain estimates of vulnerability to exploitation and of recovery times. The ICES Advisory Committee on Fisheries Management ranked all the main deepwater species according to their life history parameters, based on Anon. (2001) and found these sharks to be most vulnerable. Clarke *et al*. (2001) compared vulnerability of a range of deepwater species in comparison with shelf species, and found that whilst deepwater species in general had more conservative life history strategies, the sharks were the most vulnerable to exploitation. Therefore there is an urgent need to improve the scientific basis for management.

There has been great debate both within ICES and European fisheries management agencies on appropriate management measures for deepwater species. The ICES Advisory Committee on Fisheries Management has advised that a range of management measures may be required. The European Commission has proposed a series of TAC's to be introduced in 2002, and later a series of proposals surrounding effort control and licencing of deepwater vessels was brought forward by the Council for the European Union. In June 2002, the Council agreed a series of TAC's for some deepwater species, though not sharks. The Council of the European Union also announced its intention to implement the effort control regime. The debate is now being carried to the Northeast Atlantic Fisheries Commission (NEAFC), which deals with management of fisheries outside coastal jurisdictions in the region. In tandem with this process of developing management measures for deepwater fisheries, the European Commission is in the process of formulating a genera plan for elasmobranch fisheries. This is part of its response to the FAO's invitation to develop such a plan.

Thus there is an impetus to develop a management regime for European deepwater elasmobranch fisheries. Such a management regime will require more data than are currently available. In the northern part of the ICES area, much work has been done on the biological parameters of these sharks (Table 2). Furthermore some attention has been paid to their vulnerability and the possible impacts of the fishery (Anon. 2001; Clarke et al. in press; Clarke *et al*., this proceedings). However before a rational stock assessment is possible the following data requirements will need to be fulfilled:

1. Species specific landings data are required. The collection of such data should be a priority within the EU and other coastal jurisdictions.
2. Catch and effort data are urgently required, by species, but also by depth. These data re required at a higher spatial resolution than ICES Sub-area. However fishing skippers will be reluctant to record latitude and longitude of fishing, for reasons of commercial confidentiality. But depth can be considered more important than fine-scale spatial resolution in interrogating these data.

3. More exploration of existing catch and effort series should be carried out. Species-specific records are known to exist in commercial fishing companies. Means by which to incorporate the knowledge of fishermen into the assessment process may be invaluable.
4. Better knowledge of stock structure is needed. It appears that these species are wide ranging in the NE Atlantic, and some species have been shown to be wide-ranging in the Pacific.
5. Some progress has been made on applying life-history models to deepwater sharks. However further life history data are needed. Foremost among these needs are age estimates (*C. coelolepis*), age specific estimates of natural mortality (all species) and knowledge of gestation period (all species).
6. Programs to improve the knowledge base should be implemented in international waters too; this will involve agreements at regional fisheries bodies such as NEAFC, NAFO and CECAF.

The present data collection program of the EU is tailored to provide data for the routinely assessed teleost and crustacean stocks. Indeed deepwater sharks are not specifically mentioned. It is not well suited to providing the types of data required for deepwater fisheries in general or these shark fisheries in particular. Another flaw in this program is that it does not consider straddling or highly migratory species of sharks in sufficient detail. Elasmobranch stock assessment is subject to many problems, but considerable progress has been made in recent years. The usefulness of the available methodologies has been examined, as discussed by Pastoors (these proceedings), but in most cases the data have not been of sufficient quality to enable strong conclusions being drawn. The next step is to quickly implement enhanced data collection programs to improve the data quality. It is recognised that assembling the data needed for conventional management will take a long time, in fact often longer than a deep-water fishery might be expected to last (Haedrich *et al*., 2001). Much time has been lost in the case of the deepwater shark fisheries, so the emphasis should be placed on collecting the types of data that can be obtained quickly. Such an approach will be necessary before any rational assessments are carried out and rational conclusions drawn about the status of these shark species.

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References

ANON. MS 2000. Report on the working group on the biology and assessment of deep-sea fisheries resources. *ICES CM 2000* /ACFM:8.

ANON. MS 2001. Report on the working group on the biology and assessment of deep-sea fisheries resources. *ICES CM* 2001/ACFM:23.

ANON. MS 2002a. Report on the working group on the biology and assessment of deep-sea fisheries resources. *ICES CM 2002* /ACFM:16.

BOCAGE J.V. & F.B. CAPELLO, 1864. Sur quelques espèces inédites de Squalidae de la tribu Acanthiana, Gray, qui fréquentent les côtes du Portugal. *Proc. Zool. Soc. Lond.*, 24 : 260-263.

BONNATERRE J.P., 1788. Tableau encyclopédique et méthodique des trois règnes de la nature. *Ichthyologie*. Paris, 215p.

CADENAT J. & J. BLACHE, 1981. Requins de Méditerranée et d'Atlantique. Faune Trop. ORSTOM, XXI : 330p.

Charuau, A., H. Dupouy, and P. Lorance, 1995. Deep water fisheries of the north Atlantic slope exploited by French fleets. In *Proceedings of NATO Advanced Research Workshop on deep water fisheries of the north Atlantic slope* (ed., A. L. Hopper), pp. 337-356. Amsterdam, Kluwer Academic Publishers.

Clark, M. R., and King, K. J. 1989. Deepwater fish resources off the North Island, New Zealand: results of a trawl survey, May 1985 to June 1986. Wellington: Ministry of Agriculture and Fisheries. New Zealand Fisheries Technical Report, no. 11.

CLARKE, M.W., P.L.CONNOLLY, and J.J. BRACKEN, 2001. Aspects of reproduction of the deepwater sharks *Centroscymnus coelolepis* and *Centrophorus squamosus* from west of Ireland and Scotland. *J. Mar. Biol. Ass. U.K.*. 81: 1019-1029.

CLARKE, M.W., P.L. CONNOLLY and J.J. BRACKEN, 2002. Age estimation of the exploited deepwater shark *Centrophorus squamosus* from the continental slopes of the Rockall Trough and Porcupine Bank. *J. Fish Biol*., 60: 501-514.

GIRARD M., 2000. Distribution et reproduction de deux espèces de requins de grands fonds, les "sikis", *Centrophorus squamosus* et *Centroscymnus coelolepis*, exploités dans l'Atlantique Nord-Est. *PhD Thesis ENSAR*, 214p.

GIRARD M., 2001. Distribution et reproduction de deux espèces de requins de grands fonds, les "sikis", *Centrophorus squamosus* et *Centroscymnus coelolepis*, exploités dans l'Atlantique Nord-Est. *Bull. Soc. Zool. Fr., 126(3) :291-298.*

GIRARD, M., & M. H. DUBUIT , 1999. Reproductive biology of two deep-water sharks from the British Isles, *Centroscymnus coelolepis* and *Centrophorus squamosus* (Chondrichthyes: Squalidae). *J. Mar. Biol. Ass. U.K.* 79: 923–931.

GIRARD, M., P. LORANCE AND A. BISEAU. 2000. Captures par unite d'effort des especes profindes du talus continental a l'ouest de iles britanniques. *Cybium*. 24(3): 97-104.

GORDON J.D.M., 1999. Management considerations of deep-water shark fisheries. *In* : R. Shotton, ed. Case studies of the management of elsamobranch fisheries. Food and Agricultural Organization of the United Nations, Rome. *FAO Fisheries Technical Paper,* 2, (378) : 774-818.

HAEDRICH, R.L., N.R. MERRETT, and N.R. O'DEA, 2001. Can ecological knowledge catch up with deep-water fishing? A North Atlantic perspective. *Fis. Res*., 51: 113-122.

HILBORN, R. and C. WALTERS. 1992. Quantitative fisheries stock assessment. New York: Chapman Hall.

HOLDEN M.J, 1974. Problems in the rational exploitation of elasmobranch populations and some suggested solutions. *In Sea Fisheries Research Harden Jones ed*. Logo press London, pp 117-138.

LORANCE, P. and H. DUPOUY. 2001. CPUE anundance indices of the main target species of the French deep-water fishery in ICES Sub-areas V-VII. Fisheries Research. 57: 131-149.

MACHADO, P., and I. FIGUEIREDO. 2000. A technique for ageing the birdbeak dogfish (*Deania calcea*, Lowe, 1839) from dorsal spines. *Fisheries Research*, 45, 93-98.

PINEIRO, C.G., M. CASAS, and R. BANON, 2001. The deepwater fisheries exploited by Spanish fleets in the Northeast Atlantic: a review of the current status. *Fis. Res.*, 51: 311-320.

Table 1a. Summary of available landings data (*C. coelolepis* and *C. squamosus* only) by Sub-area. No data were available for VIII from most countries.

	IVa	Va	Vb	VIa	VIb	VI	VII	VIII	IXa	X	XII	**Total**
1990			140	na	na	na	na		475			**615**
1991	3		75	na	na	944	265		1075		1	**2363**
1992	133		123	na	na	1953	878	15	1114		2	**4218**
1993	51		91	na	na	2454	857	9	946		6	**4414**
1994	86		149	na	na	2198	1363	8	1155		8	**4967**
1995	10		262	na	na	1784	991	0	1354		139	**4540**
1996	6		348	na	na	2374	754	1	1189		147	**4819**
1997			261	na	na	2222	571	1	1311		32	**4398**
1998		5	433	na	na	2081	673	13	1220	4	56	**4485**
1999	20		461	1651	472		440	20	972	8	50	**4094**
2000	0		340	2570	470		621	21	1049		809	**5880**
2001p	0		331	2986	801		1032	5	1130		725	**7010**
	309	**5**	**3014**	**7207**	**1743**	**16010**	**8445**	**93**	**12990**	**12**	**1975**	**51803**

P denotes preliminary data.

Table 1b. Total sharks (various, including some deepwater sharks) landings by Sub-areas.

	IVa	Va	Vb	VIa	VIb	VII	VI+VII	VIII + IX	XII	**Total**
1990		3	0	na	na	na	43	0		**46**
1991		133	3	na	na	na	254	2850		**3240**
1992		51	41	na	na	na	639	3740		**4471**
1993		86	387	na	na	na	1392	0		**1865**
1994		10	43	na	na	na	1864	4		**1921**
1995		6	0	na	na	na	2099	39		**2144**
1996		0	32	na	na	na	2176	25		**2233**
1997		0	47	na	na	na	3240	1079		**4366**
1998		20	0	na	na	na	3023	1811		**4854**
1999	53	0	9	136	112	244	1791	476		**2821**
2000	10	0	69	145	420	164	8	228	38	**1082**
2001p	10		212	68	210	315	0	321		**1136**
	73	**306**	**843**	**349**	**742**	**723**	**16486**	**10573**	**38**	**30133**

* Some countries reported data for VI and VII combined, while others reported data separately for each Sub-area. The column for VI and VII combined shows data reported for both Sub-areas combined but does not contain landings for VI and VII reported separately.

Table 2. Available life history information on deepwater squalid sharks *C. squamosus* and *C. coelolepis*.

Parameter	Value	Reference
	Centroscymnus coelolepis	
Ovarian fecundity	8-22 (mean 16)*	Girard & DuBuit, 1999; Girard 2001
Uterine Fecundity	8-19 (mean 14)*	Girard & DuBuit, 1999; Girard, 2001
Length at maturity	86 cm (m), 102 cm (f)	Girard & DuBuit, 1999
	Centrophorus squamosus	
Longevity	53 (m), 70 (f)	Clarke *et al*. 2002
Natural mortality	0.09 (m), 0.07 (f)	Clarke *et al.* 2001
Ovarian fecundity	7-11* (mean = 10)*	Girard & DuBuit, 1999
Uterine Fecundity	6-8*	Cadenat & Blache, 1981
Length at maturity	98 cm (m), 124 cm (f)	Girard & DuBuit, 1999

Table 3. CPUE (kg/1,000 autoline hooks; kg/hour trawled) data from Norwegian and Irish research surveys in the NE Atlantic. Gear configurations were the same for both countries.

Sub Area	Country	Date	Gear	*C. squamosus* 600 - 1,000	*C. coelolepis* 1,100 - 1,600	Combined 600 -1,600
VI	Ireland	1997	Autoline	218	70	133
VI	Norway	1999	Autoline	219	83	178
VI	Norway	2000	Autoline	42	92	86
VI	Ireland	2000	Autoline	24	76	38
VII	Norway	1996	Autoline	221	227	264
VII	Ireland	1997	Autoline	56	158	69
VII	Ireland	1999	Autoline	51	107	61
VII	Ireland	2000	Autoline	73	166	81
XII	Norway	1999	Autoline	100	128	174
XII	Norway	2000	Autoline	78	98	113
XII	Ireland	2000	Autoline	38	19	33
VI	Ireland	1993a	Trawl	55		62
VI	Ireland	1993b	Trawl	63	8	49
VI	Ireland	1995	Trawl	15	11	14
VI	Ireland	1996	Trawl	48	9	37
VI	Ireland	1997	Trawl	24	25	20
VII	Ireland	1993a	Trawl	6		32
VII	Ireland	1995	Trawl		242	197
VII	Ireland	1996	Trawl	30	26	27
VII	Ireland	1997	Trawl	6	15	15

Table 4. Estimated carrying capacity (K), catchability (q), intrinsic rate of population increase (r) and maximum sustainable yield (MSY) from Schaefer production model, using French CPUE data presented to WGDEEP 2002, for Sub-areas V, VI and VII. All scenarios fitted using a least squares error model.

Total landings data used	Points eliminated	Parameter	Estimate	Lower CI	Upper CI
Deep sharks + various	1990 only	Initial ratio	0.7		
		K	34505	9.74E+03	2.62E+05
		q	0.003	4.67E-04	1.28E-02
		r	0.688	1.18E-06	2.41E+00
		MSY	5937	6.27E-02	1.16E+04
		Final Biomass	21625		
		r^2	0.301		
Deep sharks + various	90, 91, 92, 00, 01	Initial ratio	0.7		
		K	62638	1.43E+04	1.16E+05
		q	0.002	1.28E-03	9.41E-03
		r	0.139	1.10E-07	1.41E+00
		MSY	2179	2.86E-03	5.12E+03
		Final Biomass	10939		
		r^2	0.955		
Deep sharks only	90, 91, 92, 00, 01	Initial ratio	0.7		
		K	63982	1.60E+04	7.02E+04
		q	0.003	2.21E-03	9.06E-03
		r	0.000	1.72E-07	6.28E-01
		MSY	0.002	2.77E-03	2.52E+03
		Final Biomass	7928		
		r^2	0.948		

Table 5. Estimates of q and initial biomass (1993) from the Leslie Depletion model for both species combined.

Scenario	Catch data	CPUE data	q	r^2	Biomass in 1993	Estimated CPUE, 1993
1	Total sharks	DWWG	0.0013	0.92	80000	101
2	Deep only	DWWG	0.0021	0.90	47000	102

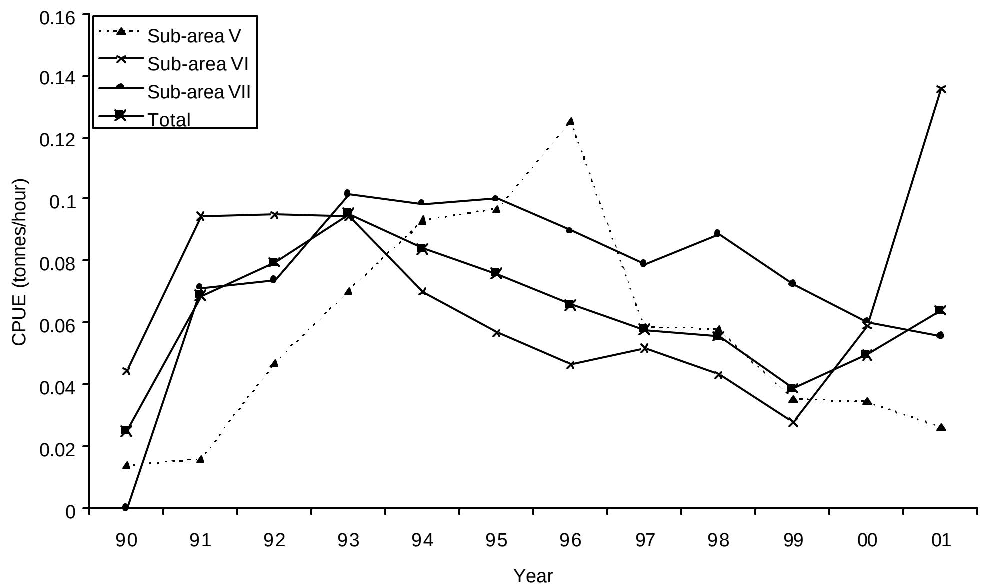


Fig. 1. Total CPUE directed at deepwater fish by reference fleet of large French trawlers in tons per hour in ICES Sub-areas V, VI and VII.

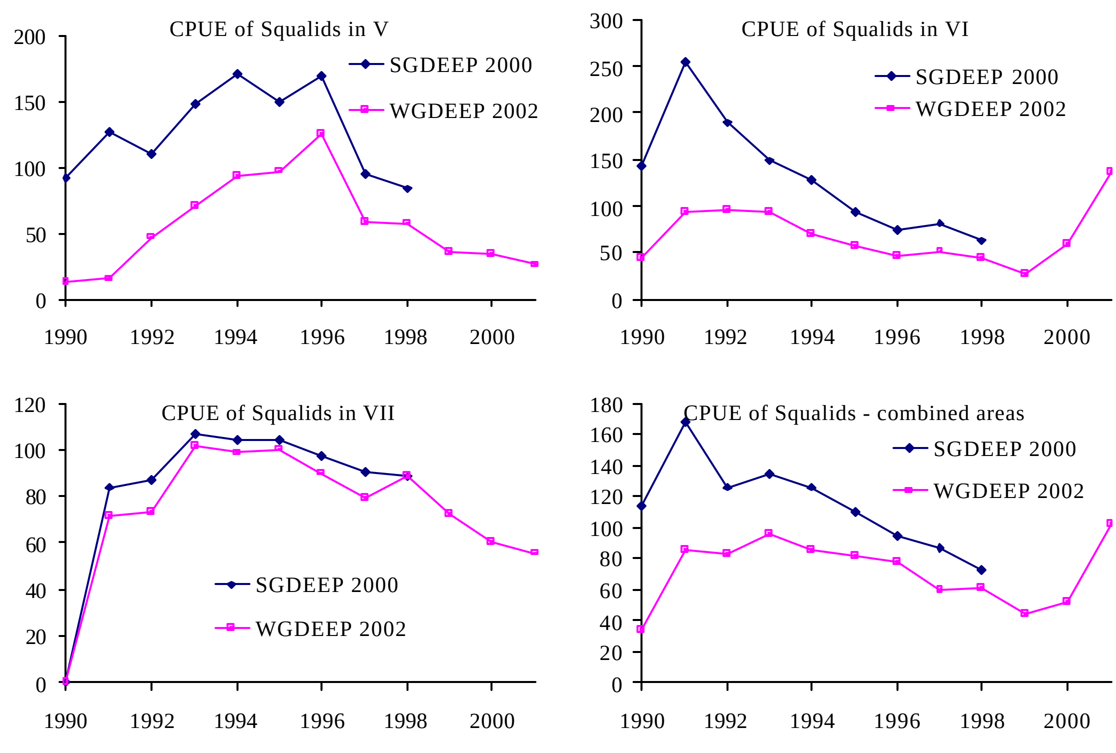


Fig. 2. Comparison of two French time series of catch and effort for *Centrophorus squamosus* and *Centroscymnus coelolepis*. Series 1, 1990 to 1998 represents effort directed at these species. Series 2, 1990 to 2001 represents total effort directed to all deepwater fish species

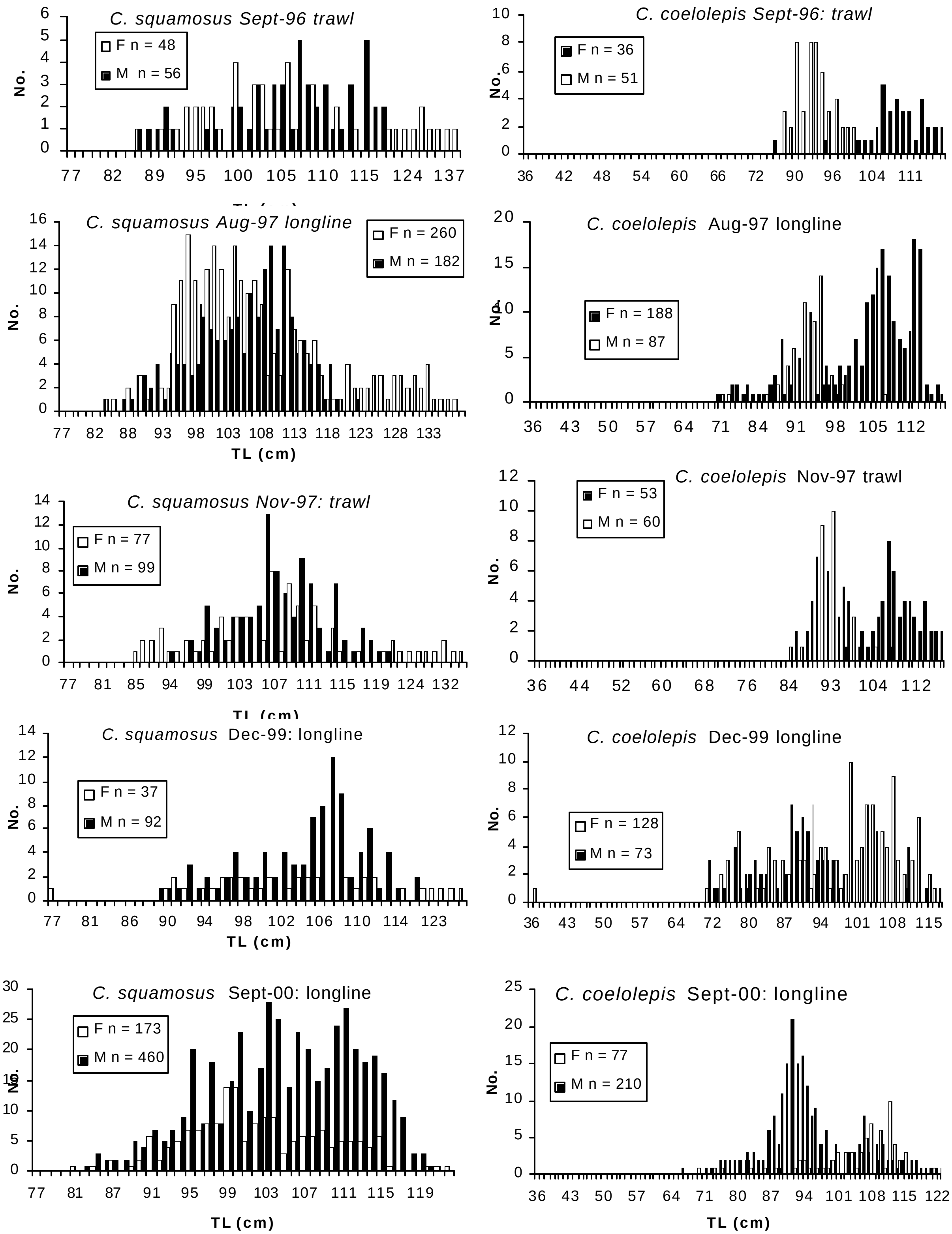


Fig. 3. Length frequency for *Centrophorus squamosus* and *Centroscymnus coelolepis* from Irish research trawl and longline surveys of Sub-areas VI and VII 1996-2000.

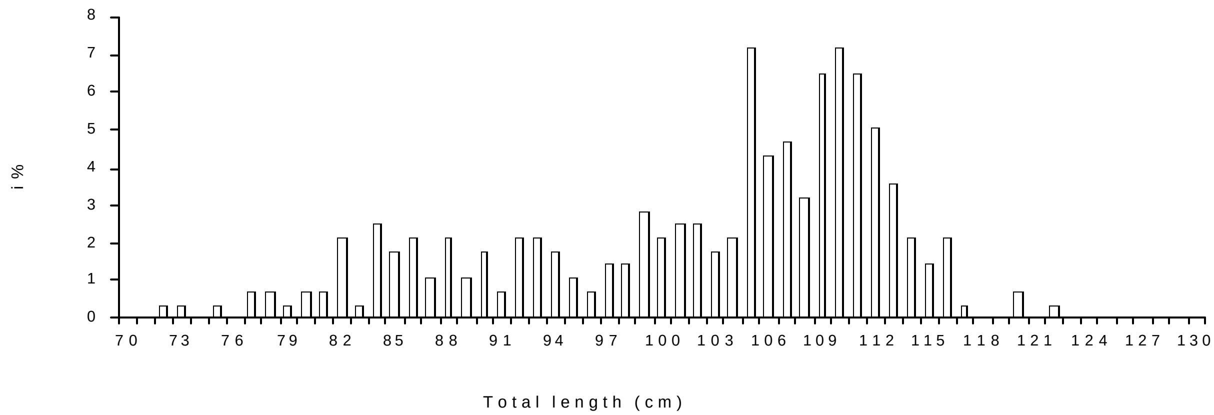


Fig. 4. Length distribution for *Centroscymnus coelolepis* from Norwegian exploratory longline fishing on Hatton Bank (Sub-area XII and Division VI b) in 2001 (n=279).

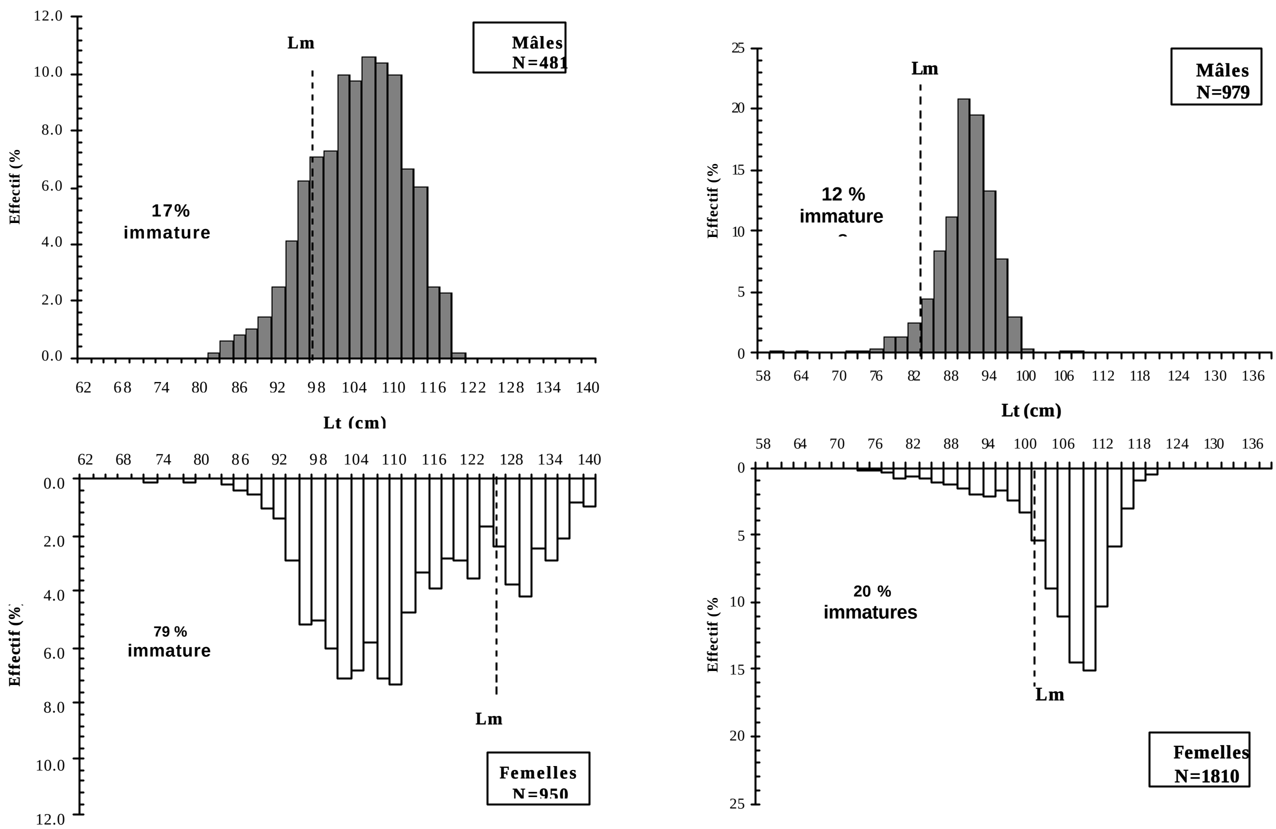


Fig. 5. Length frequency for *Centrophorus squamosus* (left) and *Centroscymnus coelolepis* (righ) from Sub-areas VI and VII, 1995-1999 from French commercial trawl survey (1996-1999).

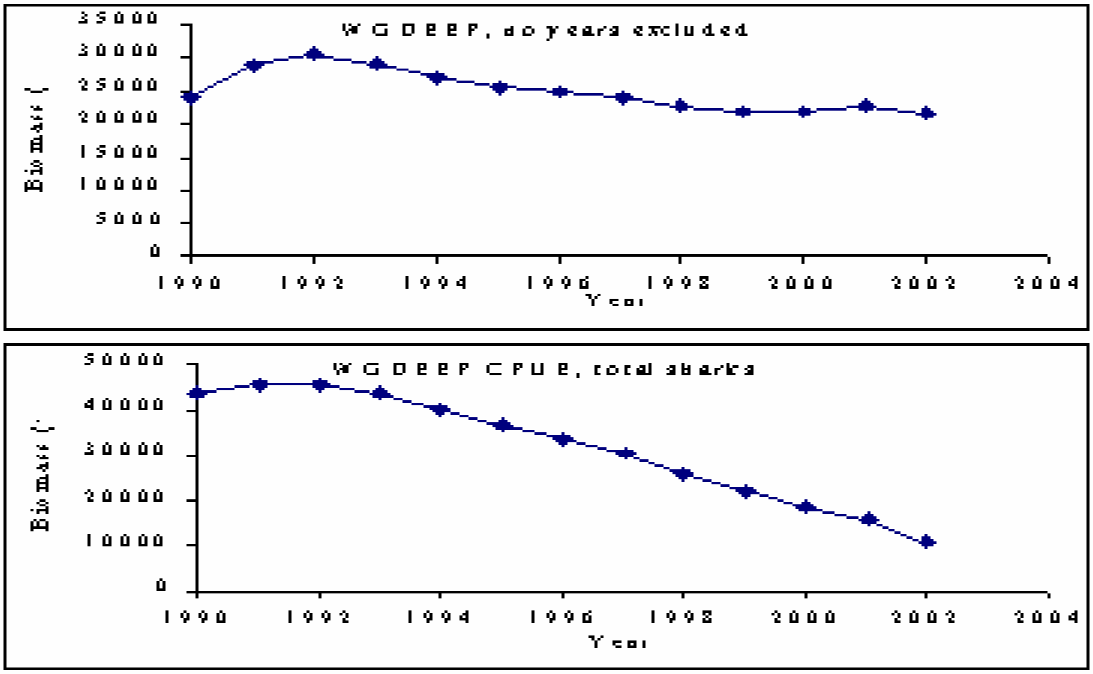
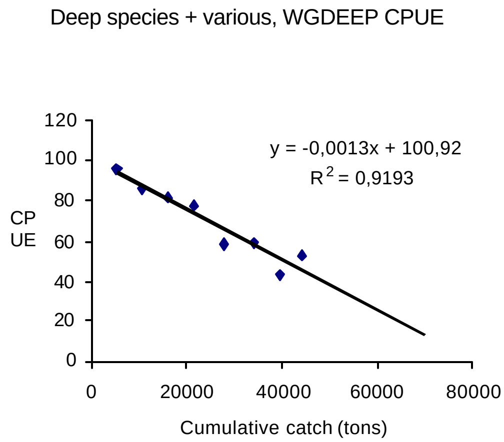


Fig. 6. Biomass trends based on Schaefer production model. CPUE data as inputs are as provided in WGDEEP and recalculated from catch and effort presented in the WGDEEP report, for Sub-areas V, VI and VII. Top plot includes 1991 to 2001 as inputs, bottom show results when 1991, 1992, 2000 and 2001 are excluded.



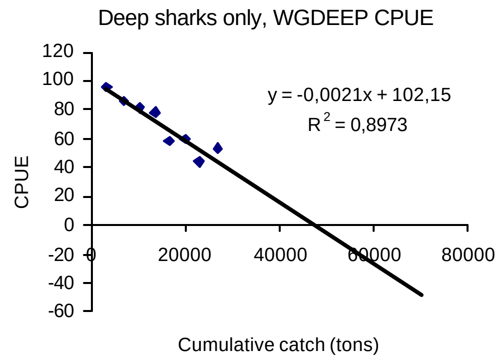


Fig. 7. Closed population estimate of *C. squamosus* and *C. coelolepis* combined Sub-areas V, VI and VII combined, using two combinations of CPUE and landings data as inputs. CPUE data are as presented in Anon. (2002).

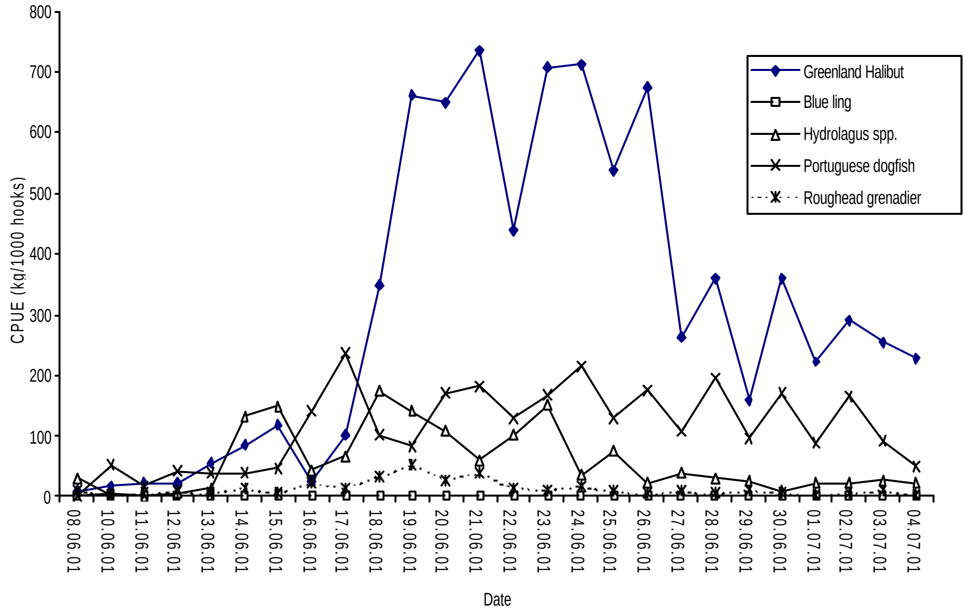


Fig. 8. CPUE for one longline vessel fishing in depths between 1200 and 1600 meters. The period between June 8 and June 17 was used for searching. The vessel found good concentrations of Greenland halibut and fished on these concentrations between June 18 and July 4. The data for *C. coelolepis* suggest that by-catch CPUE is a useful index of stock abundance in this species.