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The Danish fishery for northern shrimp (*Pandalus*) in Skagerrak and the Norwegian Deep: Standardisation of LPUE data.

by

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Abstract

The effort data for the Danish shrimp fishery are based on log-book records, which do not provide information of increasing gear efficiency and engine power of the vessels. In order to standardise the Danish LPUE series considering technological developments in terms of vessel and gear developments in the Danish *Pandalus* fleet, the relationship between vessel power and gear size has been taken into account in a GLM standardisation. The standardised LPUEs are compared to the unadjusted LPUEs.

Introduction – background

Historically, the Danish *Pandalus* fishery has targeted both the shrimp stock in the Div. IVa east and Div. IIIa and the stock on Fladen Ground (Fig. 1). In the period 1994 to 1999 the fisheries in the two areas were of about the same size, but since 2000 the Fladen fishery has declined and this fishery came to a stop during 2004. Virtually no shrimp landings have been recorded from Fladen since 2004. At present, all Danish shrimp landings come from IVa east and IIIa. In Table 1 the yearly catch data for the Danish and international Pandalus fishery in IIIa and IVa are given and in Fig. 2 the fluctuations in Danish catch and log-book recorded effort are shown from 1987 to 2006.

In recent years the assessment of the *Pandalus* stock in the Skagerrak (IIIa) and the North Sea (IVa) has been based mainly on LPUE (Landings Per Unit of Effort) series from commercial catch and effort data (ICES 2006).The objective of the analyses presented in this paper is to investigate the possibility to standardise the Danish LPUE series taking into account technological developments, in terms of vessel and gear developments, of the Danish *Pandalus* fleet.

To do this we first scrutinize the developments of two key areas of technology of the fleet by using two data sources: i) vessel power information is obtained from the official Danish register of commercial vessels and ii) gear information is obtained from interviews with the major Danish net manufacturers. We then perform a GLM standardisation of the commercial LPUE series considering the estimated relationship between vessel power and gear size.

Materials and methods

Trends in the Danish *Pandalus* fleet

The vessel composition of the Danish *Pandalus* fleet fishing in divs. IIIa and IVa has been analysed by merging log book data on catch, effort and landing values from all the Danish fishing trips in the period 1987 to 2006 with data on fishing vessels for the same period available in the official Danish vessel register.

The first step was to isolate all *Pandalus* fishing trips to IIIa or IVa taking place from 1987 to 2006 (*Pandalus* trips were defined as any trip where the landing value of *Pandalus* catches was larger than or equal to 50% of the total landing value of the trip) together with the id of the vessels responsible for the trips. This *Pandalus* trip sub-sample of the total logbook data base was then merged by vessel identification number to the more detailed vessel information from the same period held in the official Danish register of vessels.

Subsequently standard vessel characteristics such as length and engine power were scrutinized by year for all vessels having made one or more dedicated *Pandalus* trips in the period.

Trawl development in the Danish *Pandalus* fleet

As part of an EU project on technological developments in commercial fisheries (TECTAC) a series of screening interviews covering all trawl fisheries in Denmark were made with the largest Danish net manufacturers in 2005. Some of the information from these interviews pointed at the twin trawl technology and increasing trawl sizes as the two developments having had largest impact on the gear efficiency in the Danish *Pandalus* fishery.

Following up on the information from the screening interviews an in-depth interview was made with the largest manufacturer of *Pandalus* trawls in Denmark in 2007, with the objective to get details of their trawl production during the last 20 years. A list of *Pandalus* trawls produced from 1982 to 2007 was kindly delivered by the manufacturer. Only trawls designed for Skagerrak and Norwegian deep fishery were included in the list and size/circumference of the trawls in list were plotted on a time scale to allow for evaluation of any trends.

Engine power and trawl size

Based on the information from the trawl survey described above, where also the engine power of the vessel having ordered the trawl was informed, a simple correlation between vessel HP and vessel trawl size/circumference is described. To allow inclusion of both single and twin trawl size in the same plot, the two circumferences of a twin trawl were simply summed. The purpose of the plotted correlation is to allow for an evaluation of whether vesssel engine power is a feasible proxy for vessel trawl size (both single and twin trawls) and consequently whether this approximation allows for an adjustment of the Danish LPUE series for trawl size development.

Influence of vessel and trawl development on LPUE.

Incorporation of steady increases in trawl sizes in the commercial LPUE indices is not straight forward as the official Danish log book records do not provide any information on either trawl sizes or single/twin trawl riggings.

The logbooks in combination with the Danish vessel register do, however, offer detailed information on vessel engine power, and assuming validity of horsepower as a proxy for vessel trawl size (both single and twin trawls) this will allow for adjusting the log book data for increasing trawl size on a single trip basis by a GLM standardisation.

Standardisation of LPUE series by GLM analyses

Catch and effort data from logbooks were analysed with standard linear models (Hvingel et al 2000) to create an annual catch-per-unit-effort (LPUE) index, standardised for variations in vessel trawl size by using engine power (HP) as a proxy for trawl size. A GLM standardisation of the LPUE series was performed with the following model on a basis of ca. 20000 *Pandalus* trips conducted in the examined period :

$$\ln(\text{LPUE}) = \ln(\text{LPUEmean}) + \ln(\text{vessel\_hp}) + \ln(\text{year}) + \ln(\text{area}) + \text{error}$$

Where “vessel_hp” depicts the engine power of the individual vessels in horsepower. The index “year” covers the period 1987-2006. The index “area” covers Norwegian deep and Skagerrak and the variance of the error term is assumed to be normally distributed. The calculations were done using the SAS statistical software (Anon., 1988)

The resulting LPUE index was then plotted with an index of the nominal (un-adjusted) LPUE series to allow for comparison.

Results

Trends in the Danish *Pandalus* fleet

The results of the fleet analyses show that the number of vessels participating in the *Pandalus* Fishery has decreased from 191 vessels in 1987 to only 24 vessels in 2006. It is mainly the smaller vessels which have left the *Pandalus* fishery, and the average vessel length has increased from 20 to 26 m in the period and average horsepower from 415 to 670. Trends in vessel characteristics of the Danish *Pandalus* fleet are shown in Fig. 3.

Analyses of the-log book data also show that the total annual nominal effort (days at sea) of the *Pandalus* fleet has decreased to a level in 2006 which is only around 33 % of the 1987 level (Table 3), and in the same period the number of shrimp vessels decreased by almost 90%. However, the development in engine size and efficiency of the gears of the remaining shrimp vessels has probably compensated for the decrease in number of vessels as is described below.

Trawl size development in the Danish *Pandalus* fleet

The list of Pandalus trawls produced for the Skagerrak and Norwegian deep by the largest Danish net manufacturer from 1982 to 2007 is given in Table 2.

The development in trawl size (number of meshes in trawl circumference) during the examined period is shown in Fig. 4. To allow inclusion of single and twin trawls in the same plot, the two circumferences of a twin trawl were simply summed. Fig. 4 displays a marked linear increasing trend in size of the trawls produced throughout the period, from a circumference of ca. 1200 meshes in the beginning of the eighties to roughly 2500 meshes in 2007, resulting in a trawl size increase of app 100% from 1982 to 2007. Such an increase in the size of the trawl gear deployed in the fishery is bound to have an effect on the fishing mortality resulting from the nominal effort unit of one fishing day. Not taking this development into account when calculating and interpreting commercial LPUE indices may seriously bias results.

Engine power and trawl size

Combining the information from this survey of shrimp gear development with the engine power of the vessels ordering the particular trawls provides information on the relation between vessel HP and vessel trawl size/circumference. Based on the plot in Fig. 5 we found it reasonable to assume proportionality between the two parameters and to use vessel engine power as a proxy for trawl size in a GLM standardisation of the LPUE series.

Standardisation of LPUE series by GLM analyses

An index for the unadjusted Danish LPUE series is plotted together with the index of the estimated standardised LPUE series (Fig 6).

The unadjusted LPUE series shows a clear increasing trend throughout the period as opposed to the standardised index, which fluctuates more, but displays a rather stable /slightly increasing trend during the period. Accepting the validity of the engine power standardisation, the plot gives a very clear impression of the need to take technological development into account when operating with commercial catch and effort data: The observed increased trend in the nominal commercial LPUE series is not to be interpreted as an increase in stock size but rather as bias resulting from a steady increase in vessel size, engine power and gear size of the fleet.

References

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Anon. 1998. SAS/STAT User's Guide, Release 6.03 Edition. Cary, NC: SAS Institute Inc., 1988. 1028

Hvingel, C., Lassen, H. and Parsons, D.G. 2000. A biomass index for northern shrimp (*Pandalus borealis*) in Davis Strait based on multiplicative modelling of commercial catch-per-unit-effort data (1976 - 1997). J. Northw. Atl. Fish. Sci. 26: 25–31.

Table 1. Pandalus catch data by nation from IIIa and IVa in tonnes.

Year	Denmark	Norway	Sweden	Total land.	Estimated discards
1970	1102	1729	2742	5573	
1971	1190	2486	2906	6582	
1972	1017	2477	2524	6018	
1973	755	2333	2130	5218	
1974	530	1809	2003	4342	
1975	817	2339	2003	5159	
1976	1204	3348	2529	7081	
1977	1120	3004	2019	6143	
1978	1459	2440	1609	5508	
1979	1062	3040	1787	5889	
1980	1678	4562	2159	8399	
1981	2593	5183	2241	10017	
1982	3766	5042	1450	10258	
1983	1567	5361	1136	8064	
1984	1800	4783	1022	7605	200
1985	4498	6646	1571	12715	558
1986	4866	6490	1463	12819	414
1987	4488	8343	1322	14153	723
1988	3240	7661	1278	12179	750
1989	3242	6411	1433	11086	1107
1990	2479	6108	1608	10195	1226
1991	3583	6119	1908	11610	497
1992	3725	7136	2154	13015	541
1993	2915	7371	2300	12586	889
1994	2134	6813	2601	11548	214
1995	2460	8095	2882	13437	275
1996	3868	7878	2371	14117	318
1997	3909	8565	2597	15071	1039
1998	3330	9606	2469	15406	348
1999	2072	6739	2445	11256	639
2000	2371	6444	2225	11040	687
2001	1953	7266	2108	11327	701
2002	2466	7703	2301	12470	908
2003	3244	8178	2389	13811	868
2004	3905	9544	2464	15913	1797
2005	2952	8959	2257	14168	1483
2006	3061	8613	2488	14162	1186

*) Swedish landings have been corrected for loss in weight due to boiling.

Table 2. Details of Skagerrak and Norwegian Deep *Pandalus* trawls sold from Cosmos Trawls in the period 1982 - 2007.

Observation	Year	Harbour	HP	Trawl name	Trawl number	Circumference	mm ½ mesh	Fishing area
1	1982	Hirtshals	340	Kalut	1	1244	40	IIIa & IVa
2	1982	Hirtshals	400	Kalut	1	1220	40	IIIa & IVa
3	1983	Hirtshals	475	Kalut	1	1300	40	IIIa & IVa
5	1985	Hirtshals	275	Kalut	1	900	40	IIIa & IVa
6	1986	Hirtshals	600	Shjervø	1	1300	40	IIIa & IVa
7	1987	Hirtshals	340	Sputnik	1	1400	40	IIIa & IVa
8	1990	Hirtshals	400	Sputnik	1	1600	40	IIIa & IVa
9	1991	Hirtshals	340	95 trawl	1	1600	40	IIIa & IVa
10	1991	Hirtshals	477	Cosmos trawl	1	1150	40	IIIa & IVa
11	1992	Hirtshals	370	Sputnik	1	1300	40	IIIa & IVa
12	1992	Hirtshals	300	Sputnik	1	1300	40	IIIa & IVa
13	1996	Skagen	440	Grenadier	1	1600	40	IIIa & IVa
14	1996	Skagen	633	Grenadier	1	1600	40	IIIa & IVa
15	1996	Hirtshals	600	Sputnik	1	1800	40	IIIa & IVa
16	1997	Hirtshals	600	Grenadier	1	2460	40	IIIa & IVa
17	1998	Skagen	616	Grenadier	1	2090	40	IIIa & IVa
18	1998	Hirtshals	540	Grenadier	1	2090	40	IIIa & IVa
19	1999	Hanstolm	880	Grenadier	1	2090	40	IIIa & IVa
20	1999	Hanstolm	607	Grenadier	1	2090	40	IIIa & IVa
21	2000	Skagen	960	Grenadier	1	2090	40	IIIa & IVa
22	2001	Skagen	616	Grenadier	1	2400	40	IIIa & IVa
24	2003	Hirtshals	660	Grenadier	1	2090	40	IIIa & IVa
26	2007	Hirtshals	600	Sputnik	2	1600	40	IIIa & IVa
27	2007	Hirtshals	748	Sputnik	2	1600	40	IIIa & IVa
28	2007	Hirtshals	800	Sputnik	2	1600	40	IIIa & IVa

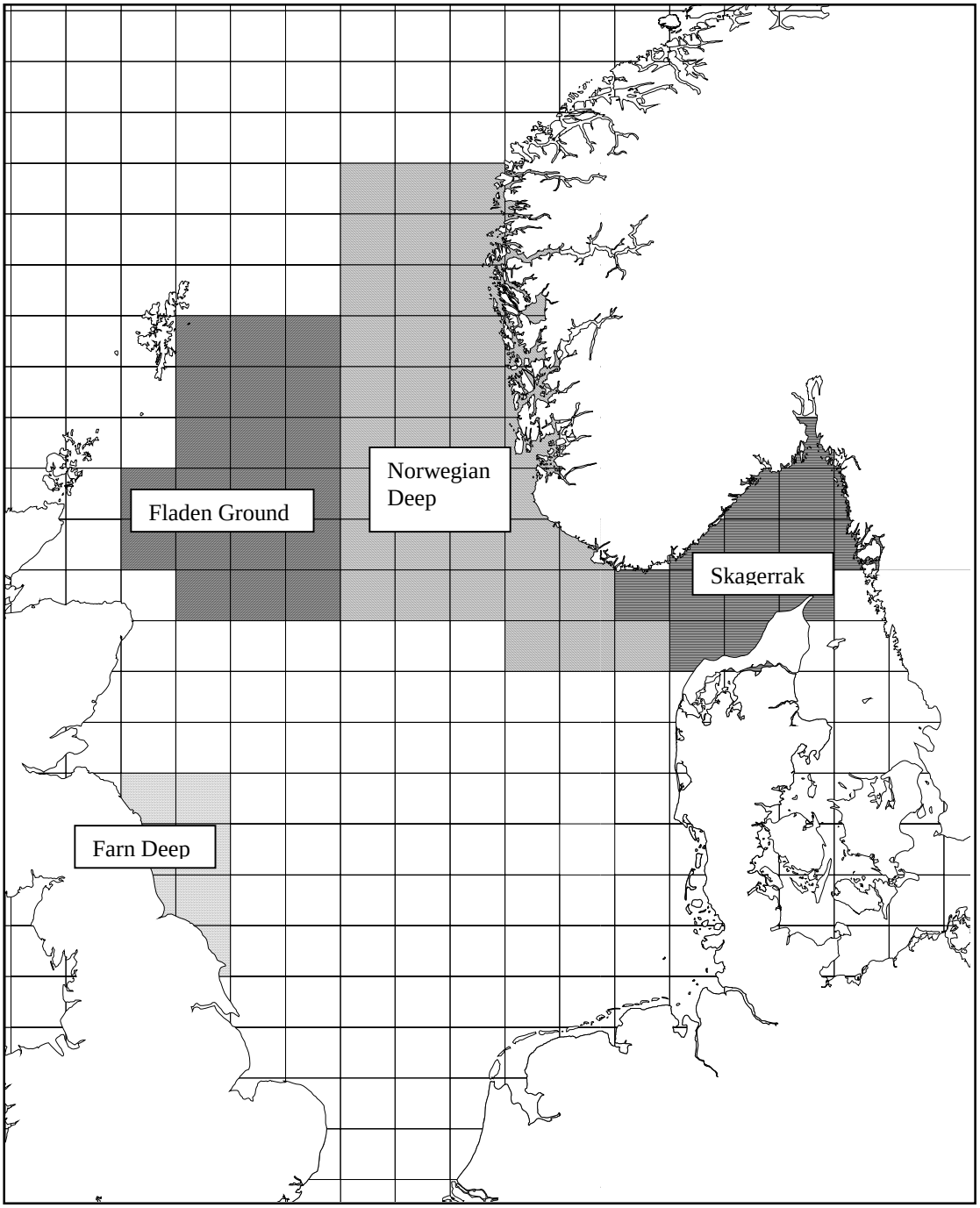
Table 3. Partial model output from Standardisation of the Danish LPUE trend

R-Square	Coeff Var	Root MSE	lncpue Mean
0.201115	11.97483	0.755768	6.311302

Source	DF	Type III SS	Mean Square	F Value	Pr > F
FT_YEAR	19	795.854833	41.887096	73.33	<.0001
hp100	1	1059.343160	1059.343160	1854.64	<.0001
omr	1	222.697974	222.697974	389.89	<.0001

Parameter		Estimate		Standard Error	t Value	Pr > |t|
Intercept		5.711796272	B	0.03309925	172.57	<.0001
FT_YEAR	1987	-0.076226030	B	0.03245060	-2.35	0.0188
FT_YEAR	1988	-0.304642753	B	0.03355131	-9.08	<.0001
FT_YEAR	1989	-0.308804731	B	0.03361371	-9.19	<.0001
FT_YEAR	1990	-0.079179961	B	0.03620668	-2.19	0.0288
FT_YEAR	1991	0.079840597	B	0.03405274	2.34	0.0191
FT_YEAR	1992	0.079579913	B	0.03357282	2.37	0.0178
FT_YEAR	1993	-0.030012761	B	0.03487964	-0.86	0.3895
FT_YEAR	1994	0.102419098	B	0.03911652	2.62	0.0088
FT_YEAR	1995	0.193393503	B	0.03895267	4.96	<.0001
FT_YEAR	1996	0.186825032	B	0.03557628	5.25	<.0001
FT_YEAR	1997	0.463270448	B	0.03696219	12.53	<.0001
FT_YEAR	1998	0.400340708	B	0.03941223	10.16	<.0001
FT_YEAR	1999	0.042957586	B	0.04360077	0.99	0.3245
FT_YEAR	2000	-0.024497340	B	0.03978597	-0.62	0.5381
FT_YEAR	2001	-0.018699331	B	0.04156878	-0.45	0.6528
FT_YEAR	2002	0.111891712	B	0.04061667	2.75	0.0059
FT_YEAR	2003	0.164819477	B	0.03707674	4.45	<.0001
FT_YEAR	2004	0.309609018	B	0.03686706	8.40	<.0001
FT_YEAR	2005	-0.123913085	B	0.03622597	-3.42	0.0006
FT_YEAR	2006	0.000000000	B	.	.	.
hp100		0.124542088		0.00289192	43.07	<.0001
omr	2. Norske rende	-0.291587011	B	0.01476721	-19.75	<.0001
omr	3. Skagerrak	0.000000000	B	.	.	.

Fig.1. The distribution of the *Pandalus* stocks in the North Sea area as defined by the ICES squares.



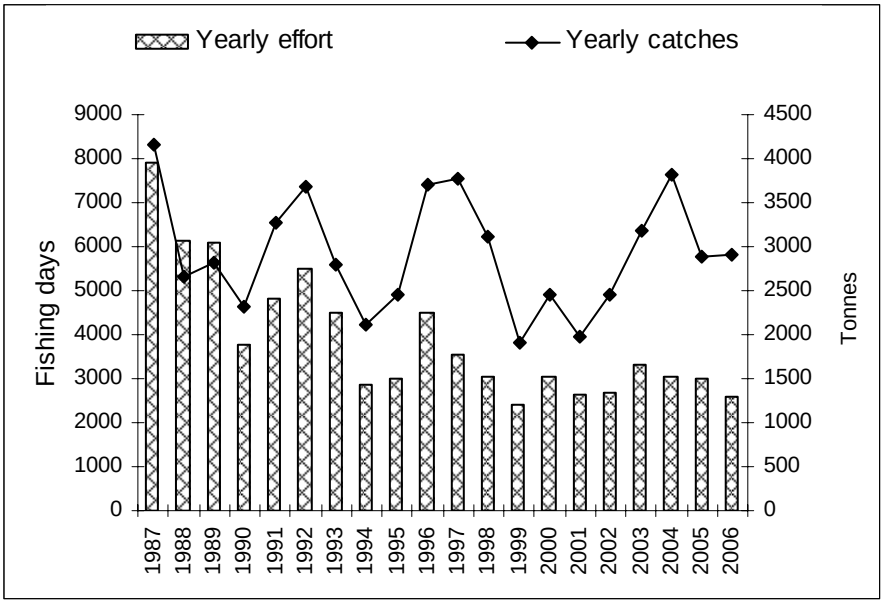


Fig. 2. Catch and effort of the Danish Pandalus fleet in IIIa and IVa.

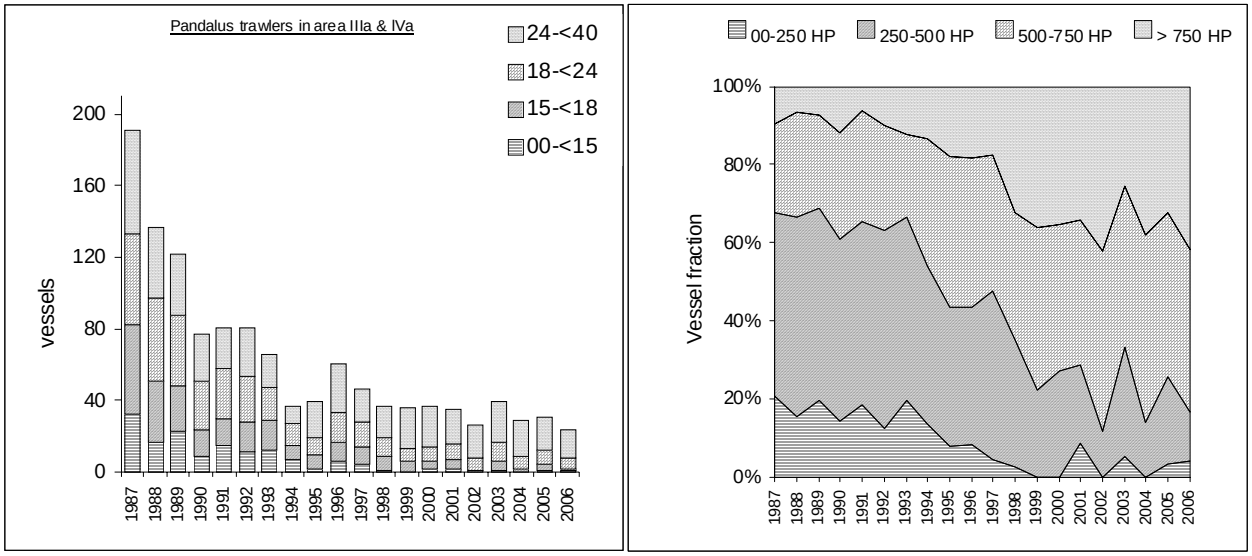


Fig. 3. Trend in numbers (left) and engine power (right) by size groups of Danish trawlers having participated in the *Pandalus* fishery in IIIa and IVa from 1987 to 2006.

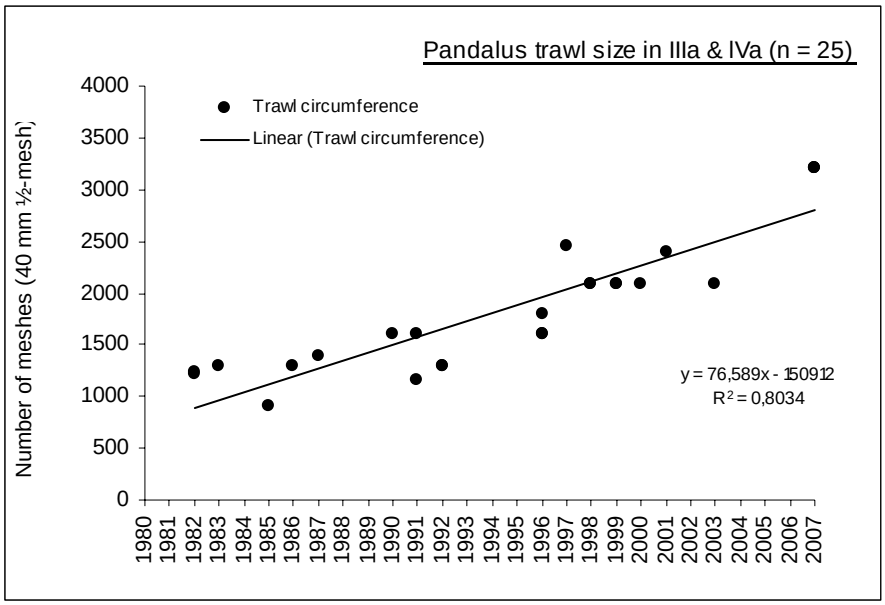


Fig. 4. Development in trawl size (number of meshes in trawl circumference) from 1981 to 2007 of trawls from Cosmos Trawls produced for the *Pandalus* fishery in IIIa IVa

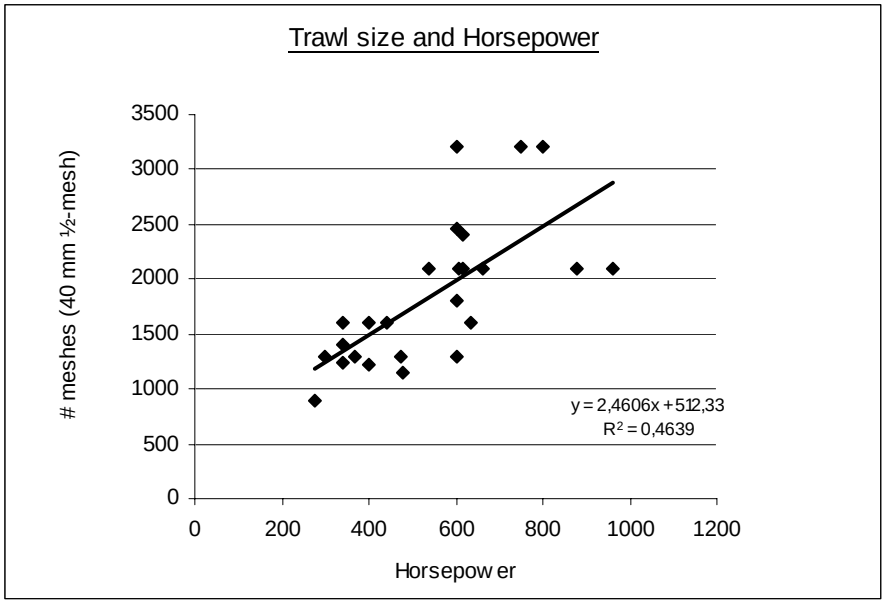


Fig. 5. Trawl size plotted against engine power for paired observations from 25 *pandalus* trawls and vessels in the period 1982 to 2007.

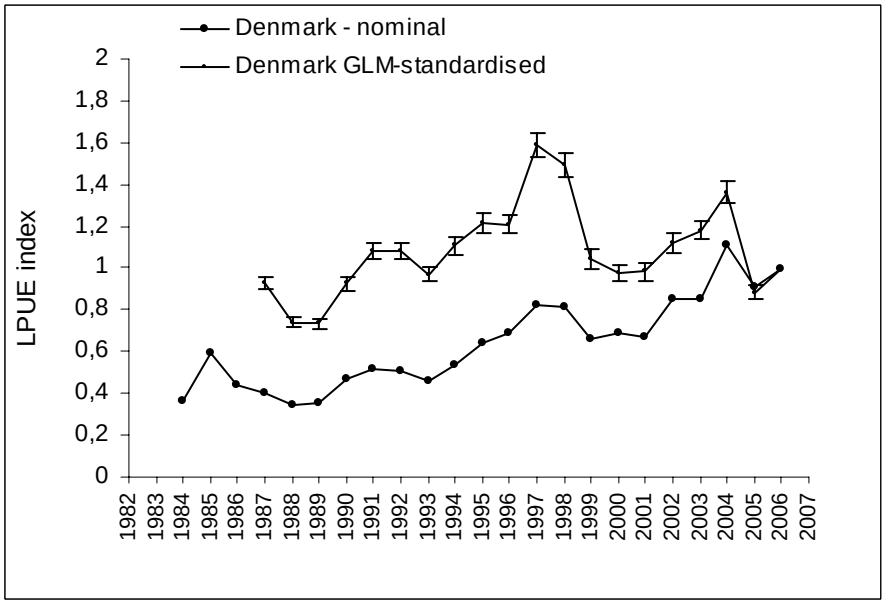


Fig. 6. Comparison of GLM-standardised and unadjusted LPUE time series. Standard errors are given for the Standardised LPUE series.