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LPUE standardisation of The Danish *Pandalus* fishery in Skagerrak and the Norwegian Deep

by

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Introduction

The current assessment of the *Pandalus* stock in the Skagerrak (IIIa) and the Nowegian Deep (IVa east) the assessment is based mainly on LPUE (Landings Per Unit of Effort) series from commercial catch and effort data (ICES 2006). The purpose of the analyses presented in this paper is to standardise the currently used Danish LPUE series taking into account technological developments, in terms of vessel and gear developments, of the Danish shrimp fleet.

To do this we first scrutinise the development 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. A GLM standardisation of the commercial LPUE time series is made according to the results and the standardised LPUE time series is compared to the nominal LPUE series.

Background

The Danish *Pandalus* fishery in Skagerrak and Norwegian Deep

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 ended 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. Annual Danish Landings of Pandalus have varied between 2000 – 3000 tons. In Fig. 2 the yearly catch and effort of all designated Pandalus fishing trips are shown from 1987 to 2007 (*Pandalus* trips were defined as any fishing trip where the landing value of *Pandalus* catches was larger than or equal to 50% of the total landing value of the trip – see section below).

Materials and methods

Trends in the Danish *Pandalus* fleet

The vessel composition of the Danish *Pandalus* fleet fishing in areas 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 2007 to vessel information from the same period held in the official Danish vessel register.

First step was to isolate all Pandalus fishing trips to IIIa or IVa taking place from 1987 to 2007 (*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. Trip definitions with thresholds of 10% and 30% of total landing value, and with kilo instead of catch value, were also tried. These showed only small deviations from the 50% catch value definition in resulting number of trips for the 22 year period (10% definition=21447 *Pandalus* trips, 30% definition=21283 trips, and 50% definition=20539 trips). The choice of the 50% threshold is made to ensure of exclusion of trips, where *Pandalus* landings can be considered as by catch rather than target species.

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 scrutinised 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 the largest impact on the catch 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 the list were plotted on a time scale to allow for evaluation of any trends.

Engine power and trawl size

Based on the information on trawl development described above, where also the engine power of the vessel having ordered the trawl was informed, a simple correlation between vessel HP and trawl size/circumference is achieved. 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 vessel engine power (HP) 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 continuous increases in trawl size 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 engine HP as a proxy for vessel trawl size (both single and twin trawls) will allow for adjusting the log book data for increasing trawl size on a single trip basis by a GLM standardisation using the SAS statistical software.

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 20.539 *Pandalus* trips conducted in the period 1987-2007:

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

Where “vessel_kw” denotes the engine power of the individual vessels in kilo*Watt. The index “year” covers the period 1987-2007. 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)

Following the 2006 recommendations from the WG, that inclusion of some seasonal factor might reduce unaccounted variability of model results, the model above (1) was expanded to include also a seasonal factor in terms of quarters 1 to 4:

(2) $\ln(LPUE) = \ln(LPUEmean) + \ln(vessel\_hp) + \ln(year) + \ln(quarter) + \ln(area) + error$

The standardised LPUE indices resulting from model (1) and three model (2) versions with 10%, 30% and 50% trip definitions are plotted together to allow for comparison (Fig 6).

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 12 vessels in 2007. It is mainly the smaller vessels which have left the *Pandalus* fishery, and the average vessel length has increased from 20 to 26 m during 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 nominal total yearly effort (fishing days with registered catch of *Pandalus*) of the *Pandalus* fleet has decreased to a level in 2007 which is only around 20 % of the 1987 level (Fig. 2), and in the same period the number of shrimp vessels decreased by almost 90% (Fig. 3). However, the development in engine size and efficiency of the gears of the remaining shrimp vessels has probably compensated to a large degree 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 1. The development in trawl size (number of meshes in trawl circumference) during the investigated 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 gear size (incl. twin trawls) deployed in the fishery is bound to compensate for the decrease in "nominal effort" (fishing days). 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 on 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

The output from model (2) with the 50% is shown in Table 2. All the variables significantly influence CPUE. Engine power (vessel_hp) is by far the strongest explanatory variable and gives an app. 12% increase in LPUE by each 100 hp increase (Table 2), followed by area (Skagerrak LPUEs are averagely ca. 25% higher than comparable Norwegian Deep LPUEs) fishing year, and fishing season. According to the model no long term annual trend exist in the time series (Fig. 6) and the seasonal differences are also marginal even though LPUE values are app. 10% higher in quarter 3 (Table 2) compared to the other three quarters.

An index for the nominal Danish LPUE series is plotted together with an index of the GLM standardised LPUE series (model (2)) in Fig. 7. The nominal LPUE series shows an increasing trend during the period as opposed to the standardised index, which fluctuates more but displays a rather stable overall trend.

The inclusion of a seasonal factor in the GLM standardisation (2) has practically no effect on the resulting LPUE index when compared to model (1) (Fig. 6) and R values of the two model runs only differ marginally (model (1)

R=0,194 and model (2) R=0,196. Nevertheless the R value is slightly higher for model (2) and standardisation of the commercial Danish LPUE using this model version is recommended because it allows for the inclusion of data from the current year (January to October 2008). Unfortunately it was not possible to include data from 2008 into the standardisation. The model runs with different trip definition thresholds display no visible differences in resulting year effects (Fig. 6).

The generally high levels of unaccounted model variability (R=0,21) in LPUE values between trips are confirmed by the industry. The explanation from the fishery itself is very fluctuating catchability of the shrimp influenced by e.g. turbidity and currents.

Accepting the validity of the engine power standardisation, the plot in Fig. 7 gives a very clear impression of the need to take technological development into account when operating with commercial catch and effort data; The observed long term increase in nominal commercial LPUE series is not to be interpreted as an increase in stock size but rather as bias resulting from a running increase in vessel size, engine power and gear size of the fleet as accounted for in the standardised index..

ICES 2006. Report of the Pandalus assessment working group 2005. ICES CM 2006/ACFM:10. ref G. 72 pp.

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. 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 2. Model (2) output from the GLM Standardisation of the Danish LPUE trend

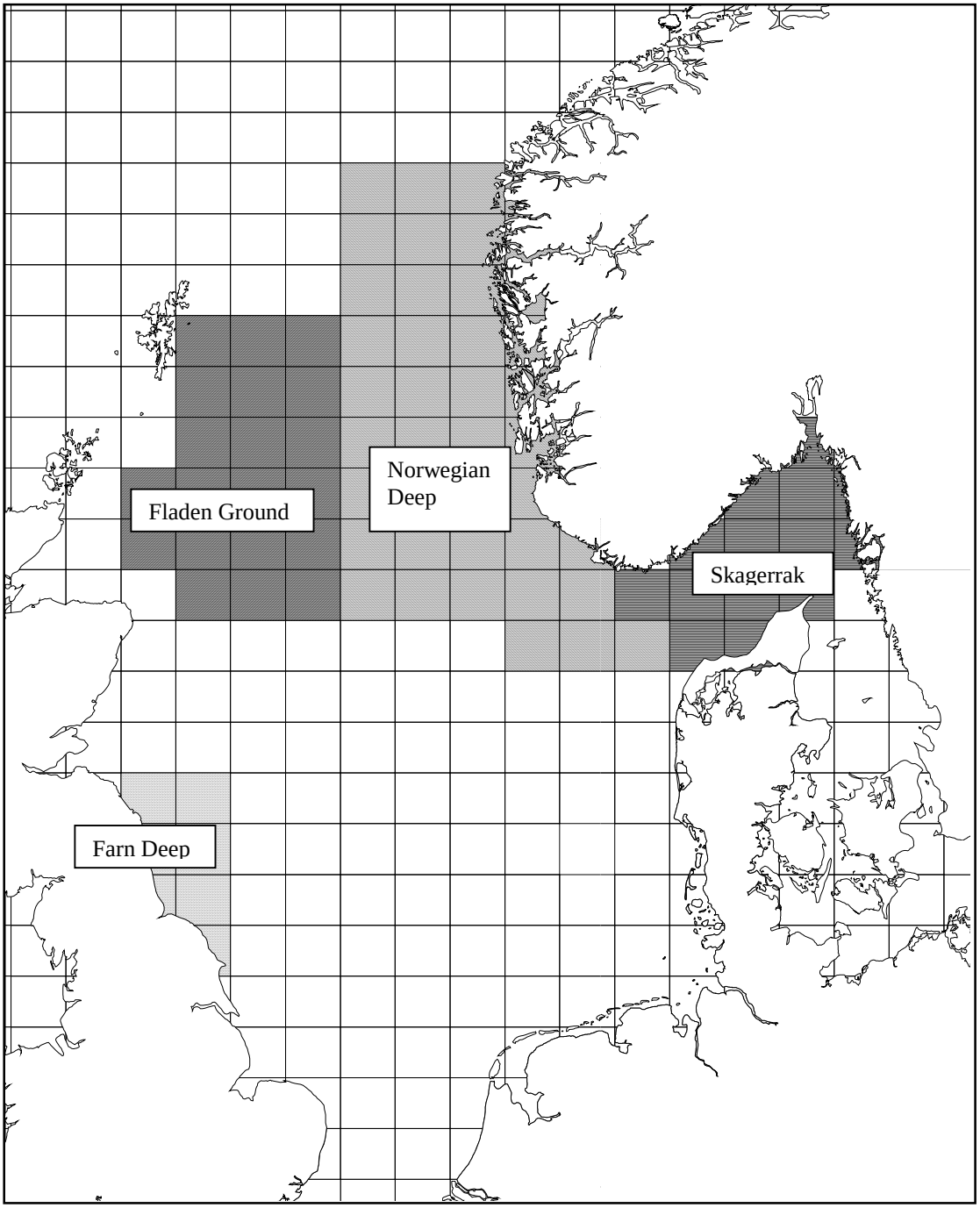
Source	*DF*	*sum of Squares*	*Mean Square*	*F Value*	*Pr > F*
Model	25	2827,64222	113,10569	200,10	<,0001
Error	20513	11595,12303	0,56526		
Corrected Total	20538	14422,76526			

R-Square	*Coeff Var*	*Root MSE*	*lncpue Mean*
0,196054	11,85390	0,751836	6,342519

Source	*DF*	*Type III SS*	*Mean Square*	*F Value*	*Pr > F*
VE_HP	1	1031,727445	1031,727445	1825,24	<,0001
omr	1	116,495273	116,495273	206,09	<,0001
FT_YEAR	20	785,369568	39,268478	69,47	<,0001
kvartal	3	33,399126	11,133042	19,70	<,0001

Parameter		*Estimate*	*std.Error*	*t Value*	*Pr > |t|*
Intercept		5,836936353 B	0,03856639	151,35	<,0001
VE_HP		0,001222799	0,00002862	42,72	<,0001
omr	2, Norske rende	-0,220797694 B	0,01538025	-14,36	<,0001
omr	3, Skagerrak	0,000000000 B	,	,	,
FT_YEAR	1987	-0,226404948 B	0,03608460	-6,27	<,0001
FT_YEAR	1988	-0,446791609 B	0,03713550	-12,03	<,0001
FT_YEAR	1989	-0,441742821 B	0,03720633	-11,87	<,0001
FT_YEAR	1990	-0,216313975 B	0,03951658	-5,47	<,0001
FT_YEAR	1991	-0,060212004 B	0,03752239	-1,60	0,1086
FT_YEAR	1992	-0,065058158 B	0,03709997	-1,75	0,0795
FT_YEAR	1993	-0,176499499 B	0,03828109	-4,61	<,0001
FT_YEAR	1994	-0,037688831 B	0,04214368	-0,89	0,3712
FT_YEAR	1995	0,056724676 B	0,04197407	1,35	0,1766
FT_YEAR	1996	0,040464897 B	0,03887241	1,04	0,2979
FT_YEAR	1997	0,316761437 B	0,04013634	7,89	<,0001
FT_YEAR	1998	0,247932923 B	0,04239865	5,85	<,0001
FT_YEAR	1999	-0,093598333 B	0,04645455	-2,01	0,0439
FT_YEAR	2000	-0,177717768 B	0,04281152	-4,15	<,0001
FT_YEAR	2001	-0,182841876 B	0,04447466	-4,11	<,0001
FT_YEAR	2002	-0,027680290 B	0,04359384	-0,63	0,5255
FT_YEAR	2003	0,022346031 B	0,04023465	0,56	0,5786
FT_YEAR	2004	0,180266224 B	0,04008360	4,50	<,0001
FT_YEAR	2005	-0,267058926 B	0,03941409	-6,78	<,0001
FT_YEAR	2006	-0,122475387 B	0,04049573	-3,02	0,0025
FT_YEAR	2007	0,000000000 B	,	,	,
kvartal	1	0,049052983 B	0,01603165	3,06	0,0022
kvartal	2	-0,002919303 B	0,01547548	-0,19	0,8504
kvartal	3	0,096550923 B	0,01592226	6,06	<,0001
kvartal	4	0,000000000 B	,		

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



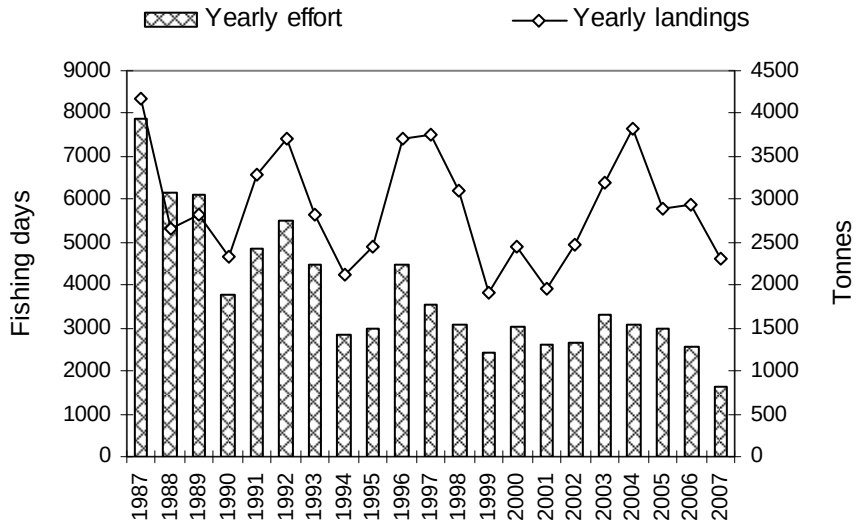


Fig. 2. Catch and nominal effort trends of the Danish Pandalus fleet in IIIa and IVa. Only data from designated *Pandalus* trips (*Pandalus* catches larger than or equal to 50% of the total landing value of the trip) are included in the Fig..

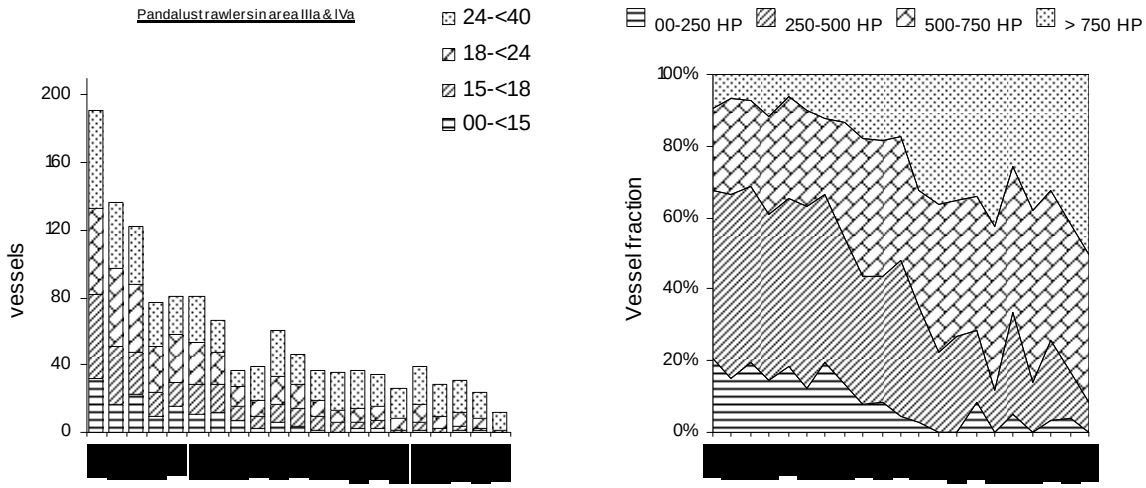


Fig. 3. Trend in numbers (left) and engine power (right) by size groups of Danish trawlers having participated in the *Pandalus* fishery in IIIa and IVa from 1987 to 2007.

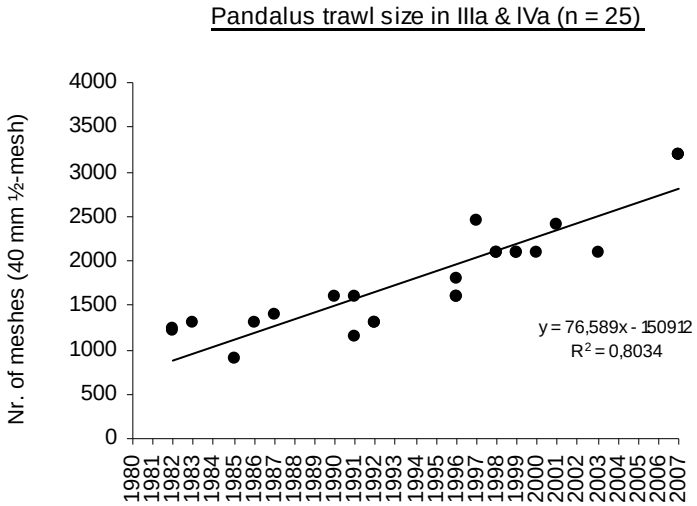


Fig. 4. Development in trawl size (number of meshes in trawl circumference) from 1981 to 2007 of trawls from Cosmos Trawls produced for the *Pandalus* fishery in IIIa IVa

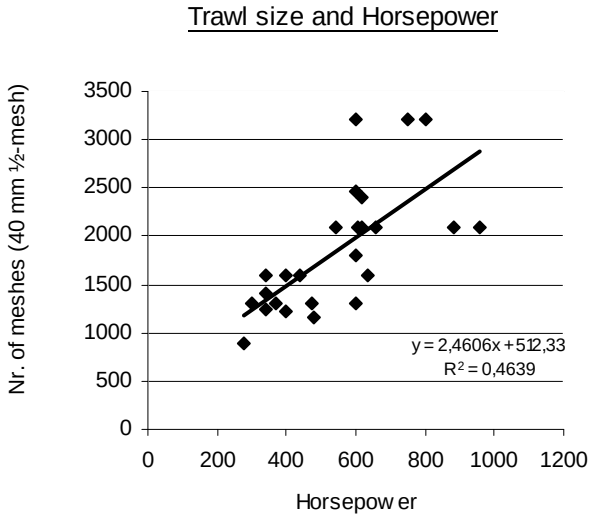


Fig. 5. Trawl size plotted against engine power for paired observations from 25 *pandalus* trawls and vessels in the period 1982 to 2007.

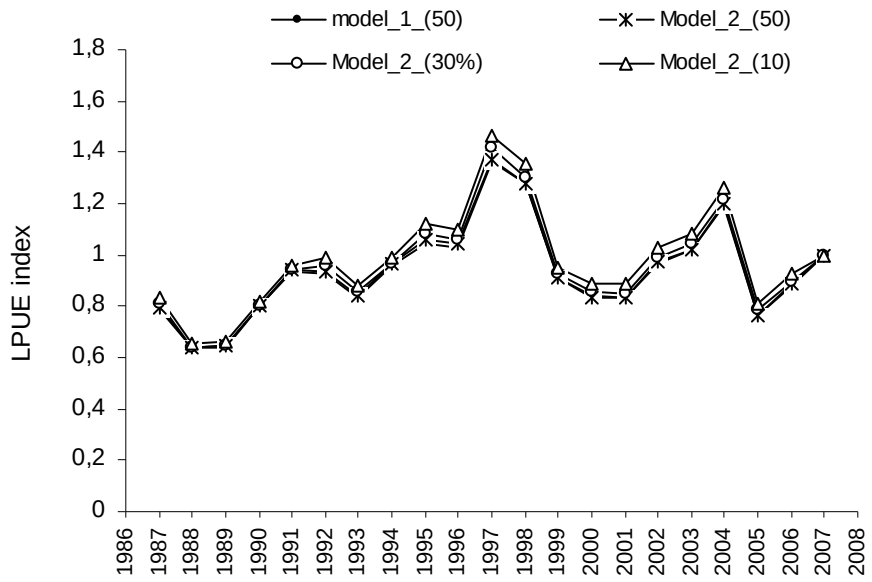


Fig. 6. Comparsion of GLM standardised indices with (model-2) and without(model-1) seasonal components and with three different Pandalus trip definitions (10, 30, and 50% tresholds).

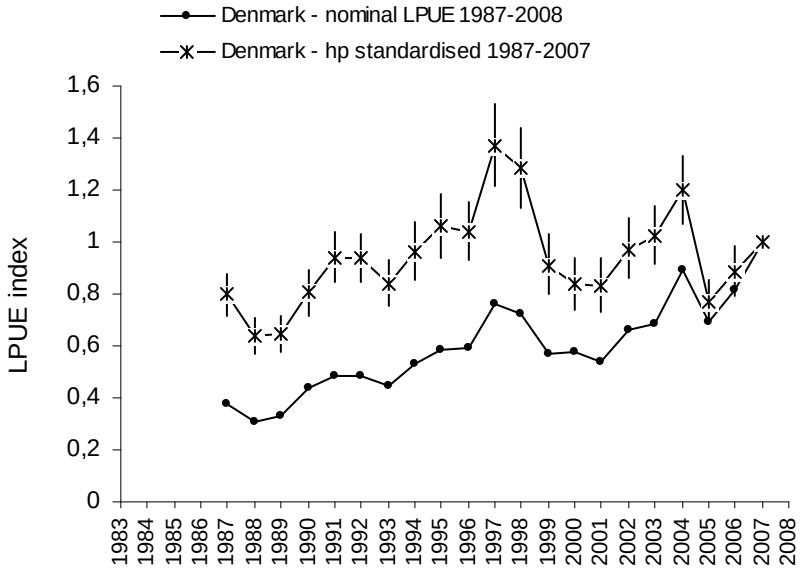


Fig. 7. Comparison of GLM-standardised and nominal LPUE time series. Std. errors are given for the standardised LPUE series.