NAFO Sci. Coun. Studies, 20: 93–102

Problems with Bottom Photography as a Method for Estimating Biomass of Shrimp (*Pandalus borealis*) off West Greenland

by

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Abstract

Bottom photography equipment was used in NAFO Subarea 1 off West Greenland from 1977 to 1985 as a means of determining shrimp (*Pandalus borealis*) abundance. The method was expected to have many advantages over standard sampling by trawl gear. The biomass estimates obtained by means of photography were higher than the fishable biomass determined from trawl surveys. Mathematical models used were found to need further refinement for describing density variations. As a result of poor agreement between the sampling methods, the photographic method was discontinued until further analyses might show suitable correction factors.

Key words: Abundance, biomass, photography, sampling, shrimp

Introduction

The commercial fishery for shrimp (*Pandalus borealis*) off West Greenland started on a small scale in 1935, and expanded rapidly from around 1950. Until 1969, the fishery was carried out in inshore areas only. The offshore fishery started in 1970, and since then its importance has been steadily increasing.

The state of the stock has been assessed annually by ICNAF/NAFO since 1976 (NAFO, 1980; 1992), primarily based on catch and effort information from logbooks. A trawl survey in 1976 provided an estimate of the stock biomass in part of the offshore distribution of the shrimp.

In an effort to obtain estimates for the absolute density of shrimp, a photographic sampling system was developed in 1976 (Kanneworff, 1979). Bottom photographs covering a known area were analyzed with regard to the number of shrimp in different size categories. During the period 1977–85 regular sampling on shrimp abundance was carried out in parts of NAFO Subarea1 by means of the bottom photography equipment. In this paper, the history and the various problems involved in this sampling method are discussed. The biomass estimates obtained from part of the commercial fishery are evaluated in relation to catch per unit effort (CPUE) indices, and number and size distribution of shrimp in trawl samples obtained from the photographic sampling sites.

Materials and Methods

The photographic method

Throughout the period of assessment of the Greenland shrimp stocks, catch and effort data together with analyses of biological samples have been used to examine the distribution and state of the stocks. This assessment method is still the main basis for scientific advice on management of the Greenland stocks (NAFO, 1992). In 1975, a new sampling method based on bottom photography was introduced in West Greenland to obtain further data on the density of shrimp (Kanneworff, 1978; 1979). The expected advantages of this method over sampling methods based on trawl gear were:

1. A fairly quick method for obtaining density indices from the large areas of shrimp distribution.
2. A more direct observation method without mesh selection problems offering density estimates in absolute terms.
3. Sampling could also be carried out in areas with rough bottom unfit for trawling.
4. Detection of smaller shrimp than those retained by trawling gear, offering possibility of an early information on changes in recruitment.

Some disadvantages and limiting factors in the use of this technique were also anticipated or experienced later:

1. Although a detection of smaller individuals than retained by the trawl would be possible, this sampling had also a minimum detectable size depending of the optical system and the type of film used.

2. The sampling would be very sensitive to suspended bottom material. This has proven to be a problem at certain sampling sites. Reduced visibility close to the bottom increases the minimum detectable size of the shrimp to an unknown level and causes severe difficulties in estimating the numbers and mean weights in the affected size groups.

3. Using a short exposure distance from the bottom (in order to get optimal light conditions) sampling would be sensitive to the movements of the ship. Thus, working with a fairly small vessel (167 GRT), the sampling would be limited to good weather conditions with winds below 10 m/sec and only light swell.

4. It was not possible to determine optimal sample size (i.e. number of photographs per station) during the sample operation. Both shrimp density and distributional pattern, as well as eventual problems connected with items 2 and 3 above, were unknown until after development and reading of the films.

5. This technique would only detect shrimp actually situated on the bottom. To estimate the total stock in a certain area would require knowledge about diel and long term vertical migrations, so that suitable correction factors could be applied. Sampling in the free water masses by means of photography was not regarded as a useful method to gather information on the size of the stock, partly because of the immense volumes of water and partly because the sampled volume would not be sufficiently well defined.

6. For an optimal sampling procedure the patchiness of the shrimp on the bottom should be known beforehand, so that a suitable sampling unit (i.e. exposure distance) and a sufficient number of photographs per sampling site could be chosen.

7. The individual length of shrimp was measured on the photographs, but it proved difficult to determine the actual size of individuals for allocation into appropriate size category. This was due to: (a) different enlargements in different parts of the photographs, because technical reasons made it necessary to work with a wide-angle lens and with the camera tilted 10° from vertical, and (b) measurements on the reading screen could only be carried out very roughly, which made it difficult to compare photographic samples with biological samples.

8. Reading of the films involved some interpretation problems. Thus, a fairly long period of training proved to be necessary to avoid individual bias between readers.

9. Working with instruments from a smaller vessel in offshore areas very often led to functional problems. Even though the equipment was built very robust some malfunctions due to rough handling were encountered from time to time. It was not always possible to detect certain technical failures during the sampling procedure or even during the cruise. Therefore, when the films were developed and read after the cruise, many sites were found to have been very poorly sampled.

Historical view

In 1976, a stratified trawl survey was carried out in part of the Davis Strait (Horsted, 1978), and the minimum fishable biomass was estimated on the basis of 'swept area' method to be about 55 000 tons. During the first 2 years of offshore photographic sampling (1977–78) the measured densities of shrimp and the calculated biomasses per unit area were used directly as stratum indices in the same stratum system as used in the trawl survey, in order to compare the two methods (Kanneworff, MS 1978; MS 1979). Having obtained a better knowledge of the region during the first years of operation, most of the strata used in the trawl survey were found to be too large to be treated as unit areas with uniform conditions for the shrimp population. Therefore, a new stratification system was introduced in 1978 (Carlsson and Kanneworff, MS 1979; Doubleday, 1981), and this has been used as the basis for all the photographic sampling since then.

The sampling scheme covered the areas between 66°00'N and 69°30'N in water depths from 100 to 600 m (parts of Div. 0A, 1A, 1B and 1C), totalling 56 406 km^2. The planned station grid for the surveys was the same throughout the years, but the success of sampling varied much from year to year with an almost complete coverage in the last three years only (Fig. 1).

Results and Discussions

The biomass estimates obtained by means of photography (Kanneworff, MS 1979) were much higher than the estimate for the fishable biomass from the trawl survey in 1976, and furthermore showed an increasing trend in the years 1977–79

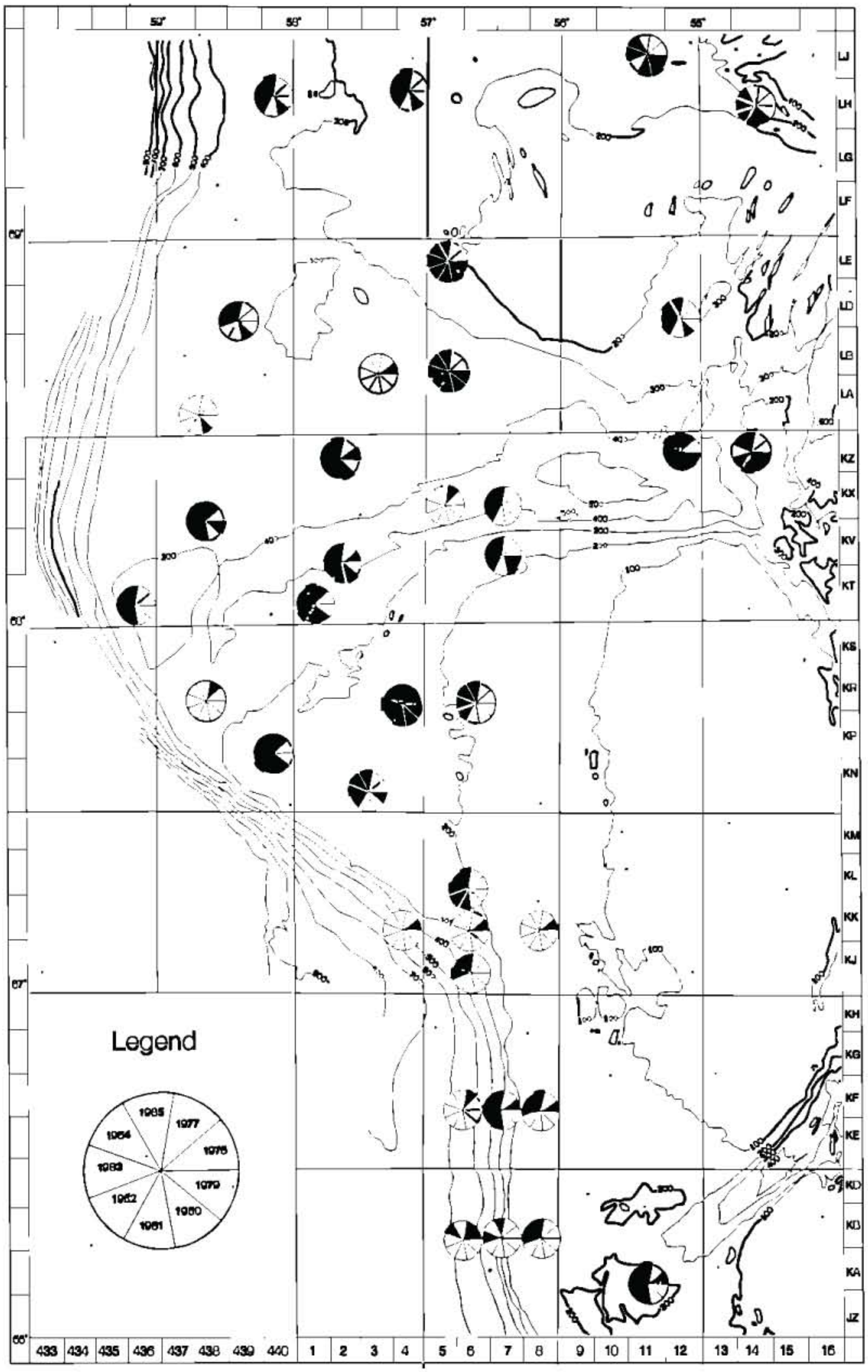

Fig. 1. Map of sampling stations in 1977–85. The shaded areas in the circles denote years in which sampling has been carried out, and the 'exploded' parts of the circles show years in which small shrimp (groups 1 and 2) have been dominating.

(Fig. 2) in contrast to a rather steep decrease in CPUE-indices for the same area and period (NAFO, 1980). Some doubt was therefore raised as to whether the photographic figures could be used directly as density indices.

Following an earlier attempt to use a simple mathematical model based on analysis of variance (Kanneworff, 1978), a multiplicative shrimp distribution model was introduced (Jørgensen and Kanneworff, MS 1980). By means of this model, biomass indices for the strata as measured by the photographic sampling were analyzed for their dependency on a series of variables. The model was updated following each year's survey (Kanneworff, MS 1981; MS 1983; MS 1984; MS 1985; MS 1986): an optimal combination of variables was determined, estimates of those variables were found, and a calculation of total biomass for all strata within the region surveyed (66°00'N–69°30'N in depths between 100 and 600 m) was carried out.

After a series of years with sampling, it was thought that an examination of the year-to-year variation in shrimp density could be carried out including a major part of the sampling sites (Kanneworff, MS 1986). This study showed that the size groups in which the shrimp were sorted had clearly different patterns of distribution, and that analyses of the variations in density necessarily had to be carried out for each group separately. However, analyses with separate groups did not increase the goodness of fit for the models tested, and it was thus concluded that other measures should be taken to refine this type of model for describing shrimp density variations.

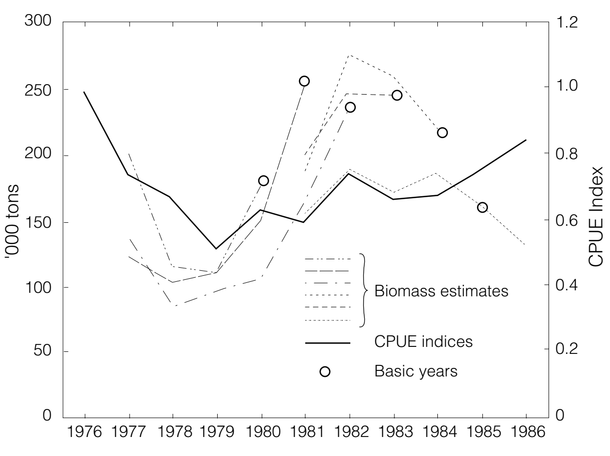

Fig. 2. Biomass estimates from photographic models used during 1977–85 compared with CPUE-indices 1976–86 from a part of the commercial shrimp fishery. The basic years for the different photographic models are shown.

A comparison of CPUE-indices from the commercial shrimp fishery (Carlsson & Kanneworff, MS 1987) with the photographic biomass estimates from all the different models used through the years is given in Fig. 2. Apart from the 1985 model, none of the models exhibited an acceptable correlation with the CPUE-figures, but all of them reflected the main trends in CPUE, however, with some distortion.

The apparent good correlation of the figures from the 1985 model was discussed by Kanneworff (MS 1986). This model was not regarded as reliable, exhibiting too low correlation coefficients, and further, the correlation with the CPUE-figures was made difficult due to the photographic sampling period and sites not covering precisely the same time and area as the commercial fishery.

In order to obtain information on the size distribution of shrimp during the photographic surveys, trawling was performed at all stations with suitable bottom conditions to collect biological samples. These data were used for comparison of length frequency distributions with photographic data. The CPUE-figures from the research vessel were not used, as they were considered unreliable due to the size of the research vessel and variations in crew through the years. The relative compositions and the estimated individual shrimp weights from the two sampling methods have been compared and discussed by Kanneworff (MS 1981; MS 1983). This comparison was based on sorting in three size groups. A larger amount of smaller shrimp in the photographic samples is to be expected, as well as a lower average individual weight due to the mesh selection of the trawl, but some discrepancies from the expected pattern were noted, and the material showed no real consistency.

In order to gain more information on the size distribution from the photographic material, all photographs were re-analyzed (Kanneworff, MS 1985), and five size groups were identified with mean weights of 2.8, 3.9, 5.7, 8.0 and 10.0 g, respectively. When comparing the distribution of the new size groups in the photographic and the trawl material for the period 1981–85 (Table 1), it was evident that in most stations there was a tendency to have relatively larger animals in trawl samples. New information on development of commercial trawls with higher opening (from 5–10 m in the beginning of the fishery to up to 20 m in the newest models) resulted in higher catch rates (Carlsson & Kanneworff, MS 1987) and this may explain the obvious low comparability between the two sets of data (Fig. 3). Size groups 1–3 occurred more numerously in the photographic material than in the trawl samples, while in group 5 the proportion was reversed. Only size

TABLE 1. Distribution of shrimp in samples from photographic and trawl samples, 1981–85. The relative numbers given are per-thousand of the largest size group.

Year	Station number	Gear	Relative numbers in gr 1	gr 2	gr 3	gr 4	gr 5	Average weight (g)
1981	6019	Photo	690	651	1 000	1 000	380	6.0
		Trawl	96	157	448	657	1 000	8.6
1981	6020	Photo	810	1 000	291	51	0	3.8
		Trawl	219	644	1 000	572	566	6.7
1981	6021	Photo	52	86	1 000	621	138	6.8
		Trawl	7	46	536	1 000	907	8.8
1981	6023	Photo	161	627	1 000	233	10	5.2
		Trawl	912	840	1 000	366	458	5.4
1981	6024	Photo	920	1 000	387	167	42	4.1
		Trawl	977	688	734	590	1 000	6.4
1981	6026	Photo	73	346	458	1 000	257	7.2
		Trawl	28	34	68	267	1 000	10.3
1981	6027	Photo	1 000	863	301	92	13	3.8
		Trawl	636	409	1 000	480	160	5.3
1981	6028	Photo	981	1 000	494	474	94	4.7
		Trawl	227	414	1 000	912	503	6.9
1981	6029	Photo	17	325	1 000	658	145	6.6
		Trawl	48	686	1 000	651	681	7.1
1981	6030	Photo	0	0	49	1 000	37	8.3
		Trawl	0	0	56	213	1 000	11.1
1981	6033	Photo	1 000	81	248	177	9	3.9
		Trawl	36	120	518	1 000	426	7.9
1981	6034	Photo	615	582	1 000	763	78	5.5
		Trawl	152	843	764	1 000	555	6.8
1981	6037	Photo	488	1 000	768	138	5	4.5
		Trawl	1 000	525	866	300	67	4.6
1982	6216	Photo	1 000	377	421	156	0	4.0
		Trawl	384	1 000	472	194	199	5.0
1982	6218	Photo	16	327	1 000	599	145	6.5
		Trawl	87	603	1 000	614	707	7.2
1982	6219	Photo	1 000	678	311	54	6	3.7
		Trawl	971	1 000	364	193	175	4.4
1982	6222	Photo	28	159	1 000	347	40	6.2
		Trawl	86	268	1 000	677	601	7.4
1982	6223	Photo	31	97	1 000	841	198	7.1
		Trawl	41	99	595	898	1 000	8.6
1982	6224	Photo	173	125	1 000	744	286	6.9
		Trawl	28	148	844	1 000	484	7.7
1982	6225	Photo	723	990	1 000	723	123	5.3
		Trawl	102	307	1 000	903	676	7.5

Table 1. (Continued).

Year	Station number	Gear	Relative numbers in gr 1	gr 2	gr 3	gr 4	gr 5	Average weight (g)
1982	6227	Photo	258	174	1 000	545	30	6.0
		Trawl	52	116	480	653	1 000	8.8
1982	6228	Photo	983	699	1 000	305	10	4.6
		Trawl	14	89	575	678	1 000	8.8
1982	6229	Photo	1 000	991	769	236	37	4.4
		Trawl	109	184	1 000	897	753	7.7
1982	6232	Photo	303	655	1 000	99	21	4.9
		Trawl	76	1 000	344	134	56	4.9
1982	6234	Photo	36	332	1 000	528	36	6.2
		Trawl	5	172	951	951	1 000	8.2
1982	6235	Photo	97	149	667	1 000	179	7.2
		Trawl	4	53	259	490	1 000	9.5
1982	6236	Photo	685	957	1 000	351	39	4.9
		Trawl	117	599	1 000	687	196	6.2
1982	6237	Photo	1 000	553	488	75	5	3.9
		Trawl	74	526	1 000	634	314	6.6
1983	6428	Photo	0	73	1 000	809	73	6.9
		Trawl	30	67	1 000	940	1 000	8.4
1983	6429	Photo	106	622	1 000	324	27	5.5
		Trawl	271	751	1 000	334	82	5.3
1983	6430	Photo	592	1 000	327	47	0	4.0
		Trawl	435	858	1 000	543	105	5.3
1983	6435	Photo	34	288	1 000	202	14	5.7
		Trawl	77	333	1 000	208	62	5.7
1983	6437	Photo	0	0	1 000	250	0	6.5
		Trawl	0	0	609	565	1 000	9.1
1983	6438	Photo	500	0	1 000	0	0	4.7
		Trawl	0	132	1 000	105	26	5.8
1983	6440	Photo	500	1 000	500	222	83	4.7
		Trawl	1 000	706	579	421	278	5.1
1983	6442	Photo	229	1 000	310	35	1	4.2
		Trawl	622	1 000	625	248	54	4.5
1983	6443	Photo	530	1 000	312	27	0	4.0
		Trawl	1 000	127	52	29	14	2.6
1983	6444	Photo	85	893	1 000	141	17	5.0
		Trawl	89	473	1 000	274	232	6.1
1983	6445	Photo	380	815	1 000	482	47	5.3
		Trawl	246	241	1 000	716	478	7.0
1983	6446	Photo	228	1 000	596	88	18	4.6
		Trawl	554	737	1 000	389	26	4.9

Table 1. (Continued).

Year	Station number	Gear	Relative numbers in gr 1	gr 2	gr 3	gr 4	gr 5	Average weight (g)
1983	6454	Photo	764	651	1 000	193	21	4.6
		Trawl	215	456	1 000	762	370	6.6
1983	6455	Photo	32	138	1 000	351	53	6.3
		Trawl	8	148	1 000	727	489	7.6
1983	6457	Photo	154	769	1 000	368	38	5.4
		Trawl	240	275	1 000	927	815	7.6
1983	6458	Photo	543	879	1 000	246	45	4.9
		Trawl	265	94	767	1 000	951	8.0
1983	6459	Photo	379	348	1 000	466	0	5.5
		Trawl	16	16	92	582	1 000	10.1
1983	6460	Photo	748	110	1 000	577	18	5.4
		Trawl	0	19	315	478	1 000	9.9
1983	6462	Photo	0	57	1 000	395	57	6.5
		Trawl	0	62	391	573	1 000	9.3
1984	6713	Photo	0	512	1 000	488	43	6.0
		Trawl	93	394	1 000	653	220	6.5
1984	6714	Photo	0	0	1 000	333	0	6.8
		Trawl	250	400	1 000	350	150	5.8
1984	6716	Photo	0	0	1 000	0	0	5.7
		Trawl	0	100	1 000	167	0	5.8
1984	6719	Photo	1 000	311	71	6	3	3.0
		Trawl	1 000	941	450	265	118	4.4
1984	6720	Photo	179	1 000	935	117	24	4.8
		Trawl	270	1 000	902	202	54	5.0
1984	6721	Photo	1 000	981	370	53	34	3.8
		Trawl	644	970	1 000	211	157	4.9
1984	6722	Photo	85	236	1 000	425	85	6.2
		Trawl	31	361	1 000	840	490	7.3
1984	6723	Photo	175	100	1 000	100	100	5.6
		Trawl	240	745	1 000	426	489	6.2
1984	6724	Photo	87	378	1 000	186	11	5.5
		Trawl	75	251	1000	381	63	6.1
1984	6725	Photo	6	209	1 000	173	6	5.8
		Trawl	193	530	1 000	598	152	6.1
1984	6726	Photo	0	279	1 000	58	0	5.5
		Trawl	221	972	1 000	406	110	5.4
1984	6728	Photo	227	448	1 000	364	20	5.5
		Trawl	327	571	1 000	816	293	6.2
1984	6729	Photo	718	1 000	684	260	12	4.5
		Trawl	87	283	1 000	673	276	6.8

Table 1. (Continued).

Year	Station number	Gear	Relative numbers in gr 1	gr 2	gr 3	gr 4	gr 5	Average weight (g)
1984	6733	Photo	495	287	1 000	396	69	5.4
		Trawl	13	179	576	748	1 000	8.8
1984	6734	Photo	17	131	1 000	623	114	6.8
		Trawl	5	37	384	1 000	674	8.7
1984	6737	Photo	1 000	108	203	159	9	3.8
		Trawl	16	65	350	508	1 000	9.5
1984	6738	Photo	1 000	327	328	62	0	3.7
		Trawl	117	458	1 000	400	135	6.0
1984	6740	Photo	631	1 000	863	35	0	4.3
		Trawl	970	940	1 000	251	40	4.4
1984	6749	Photo	495	1 000	131	0	0	3.8
		Trawl	1 000	594	436	54	3	3.7
1985	1	Photo	13	244	1 000	179	6	5.7
		Trawl	88	396	1 000	858	175	6.6
1985	5	Photo	0	73	1 000	683	110	6.9
		Trawl	3	55	1 000	618	249	7.1
1985	7	Photo	0	1 000	0	0	0	4.3
		Trawl	949	1 000	620	139	165	4.6
1985	8	Photo	1 000	236	218	31	0	3.4
		Trawl	63	470	1 000	727	352	6.8
1985	9	Photo	29	29	1 000	514	51	6.7
		Trawl	11	52	736	1 000	271	7.6
1985	10	Photo	0	213	1 000	449	125	6.5
		Trawl	0	9	568	1 000	967	9.3
1985	12	Photo	17	486	1 000	348	17	5.7
		Trawl	0	112	878	822	1 000	8.7
1985	13	Photo	399	1 000	925	424	32	5.1
		Trawl	111	284	839	1 000	379	7.2
1985	14	Photo	1 000	565	707	136	13	4.2
		Trawl	3	74	853	1 000	274	7.6
1985	19	Photo	32	561	1 000	145	10	5.3
		Trawl	8	155	1 000	530	364	7.3
1985	21	Photo	0	121	1 000	220	11	6.0
		Trawl	0	69	720	799	1 000	8.7
1985	23	Photo	619	1 000	489	51	3	4.1
		Trawl	23	412	1000	347	125	6.1

group 4 exhibited a fair correlation between the two data sets, however, with considerable variations. One of the possible reasons for the obvious underestimation of the number of large shrimp in the photographic material could be that this part of the population tends to swim more actively in the free water masses than do the smaller shrimp.

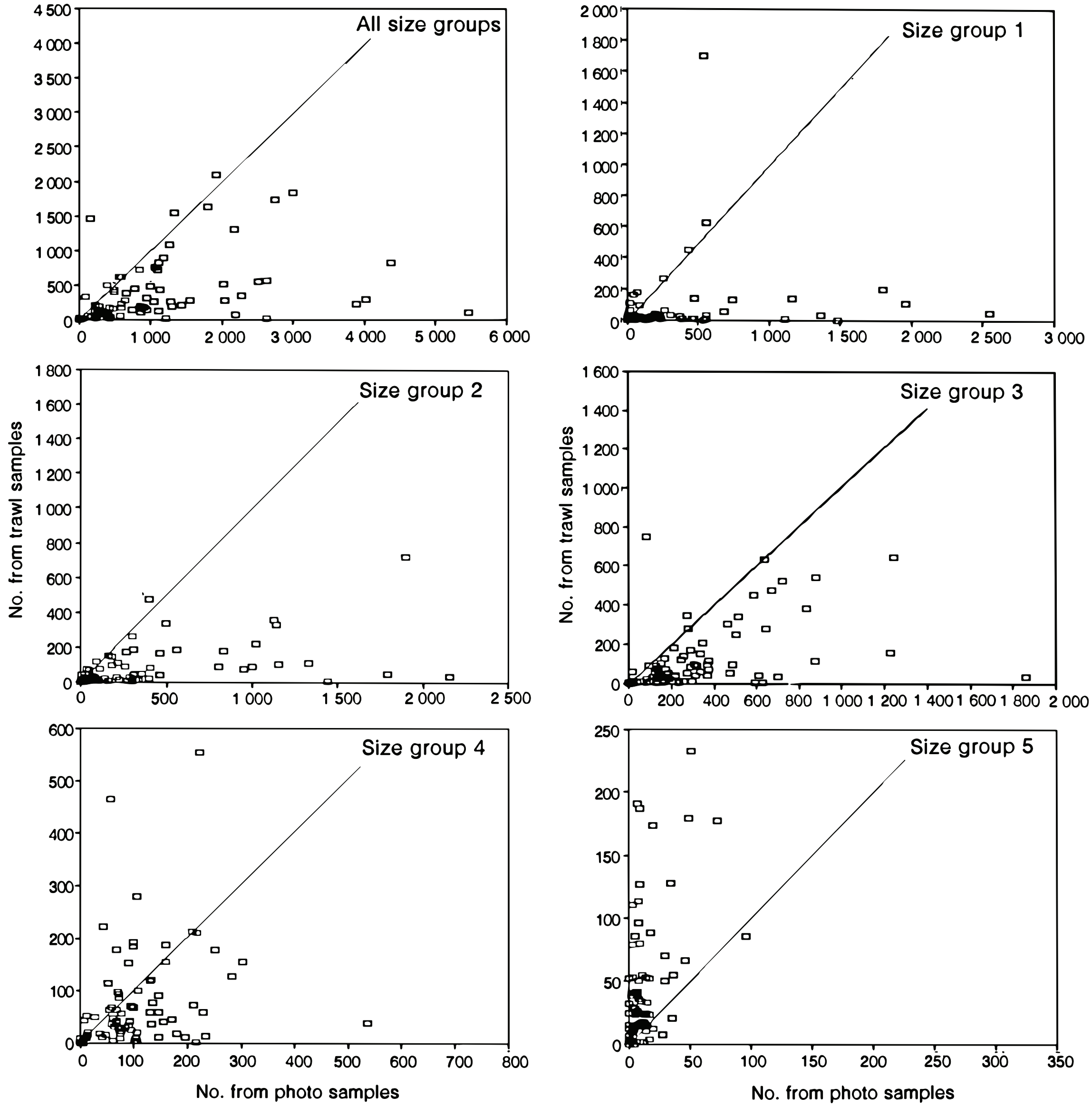

Fig. 3. Shrimp number per 1 000 m² in trawl samples *versus* photographic samples 1981–85. The solid line shows the 1:1 ratio between the two datasets.

Conclusions

Comparison of the biomass estimates and information on abundance of different size groups obtained by means of bottom photography with data on CPUE from the commercial fishery and the size distributions from biological samples have shown poor agreement between the photographic data and data from other sources. It was therefore decided that sampling by the photographic method should be discontinued until further analysis, including also a study of diel migration of the shrimp, shows that suitable correction factors could be applied to the photographic data.

References

DOUBLEDAY, W. G. (ed.). 1981. Manual of Groundfish Surveys in the Northwestern Atlantic. *NAFO Sci. Coun. Studies*, **2**: 7–55.

CARLSSON, D. M., and P. KANNEWORFF. MS 1979. Areas of basic strata in West Greenland, ICNAF/NAFO Subarea 1. *ICNAF Res. Doc.*, No. 11, Serial No. N022, 7 p.

MS 1987. The shrimp fishery in NAFO Subarea 1 in 1985 and 1986. *NAFO SCR Doc.*, No. 8, Serial No. N1267, 32 p.

HORSTED, Sv. Aa. 1978. A trawl survey of the offshore shrimp grounds in ICNAF Division 1B and an estimate of the shrimp biomass. *ICNAF Sel. Pap.*, **4**: 23–30.

JØRGENSEN, A. G., and P. KANNEWORFF. MS 1980. Biomass of shrimp (*Pandalus borealis*)in NAFO Subarea 1 in 1977–80 estimated by means of bottom photography. *NAFO SCR Doc.*, No. 169, Serial No. N256, 14 p.

KANNEWORFF, P. 1978. Estimated density of shrimp, Pandalus borealis, in Greenland waters and calculation of biomass on the offshore grounds based on bottom photography. *ICNAF Sel. Pap.*, **4**: 61–65.

MS 1978. Density of shrimp (*Pandalus borealis*) in 1978 in ICNAF Subarea 1 based on bottom photography. *ICNAF Res. Doc.*, No. 89, Serial No. 5305, 6 p.

1979. Density of shrimp (*Pandalus borealis*) in Greenland waters observed by means of bottom photography. *ICES Rapp. Proc. Verb.*, **175**: 134–138.

MS 1979. Stock biomass in 1979 of shrimp (*Pandalus borealis*) in NAFO Subarea 1 estimated by means of bottom photography. *NAFO SCR Doc.*, No. 9, Serial No. N020, 6 p.

MS 1981. Biomass of shrimp (*Pandalus borealis*) in NAFO Subarea 1 in 1977–81, estimated by means of bottom photography. *NAFO SCR Doc.*, No. 155, Serial No. N463, 19 p.

MS 1983. Biomass of shrimp (*Pandalus borealis*) in NAFO Subarea 1 in 1977–82 estimated by means of bottom photography. *NAFO SCR Doc.*, No. 1, Serial No. N639, 24 p.

MS 1984. Biomass of shrimp (*Pandalus borealis*) in NAFO SA 1 in 1978–83 estimated by means of bottom photography. *NAFO SCR Doc.*, No. 6, Serial No. N775, 24 p.

MS 1985. Biomass of shrimp (*Pandalus borealis*) in NAFO Subarea 1 in 1981–84, estimated by means of bottom photography. *NAFO SCR Doc.*, No. 8, Serial No. N942, 18 p.

MS 1986. Biomass of shrimp (*Pandalus borealis*) in NAFO SA 1 in 1981–85 estimated by means of bottom photography. *NAFO SCR Doc.*, No. 3, Serial No. N1101, 42 p.

NAFO. 1980. Reports of Scientific Council. *NAFO Sci. Coun. Rep.*, 189 p.

1992. Reports of Scientific Council. *NAFO Sci. Coun. Rep.*, 211 p.