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Occurrence of *Pandalus montagui* in Trawl Survey Samples from NAFO Subareas 0+1 2000-2015.

by

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Abstract

Stratified random bottom trawl surveys have been carried out since 1988 in NAFO Subarea 1 and a small part of NAFO Division 0A (East of 59°30'W) as a component of the assessment of the stock of *Pandalus borealis* off West Greenland. *Pandalus montagui* has occurred to some degree as by-catch in the surveyed area. This paper updates the earlier reported time series with data from surveys up to 2015.

Biomass estimates for *P. montagui* were calculated. However, as the survey design was applied for investigating the stock of *P. borealis* it was not optimal for *P. montagui*. Hence the resulting biomasses are considered to be somewhat underestimated.

P. montagui is caught as by-catch in the commercial fishery for *P. borealis*. The proportion of *P. montagui* compared to the catches of *P. borealis* has been below 1.6 % since 1994.

Introduction

Since 1988, Greenland Institute of Natural Resources has conducted annual stratified random bottom trawl surveys in the distribution area of *Pandalus borealis* in Davis Strait. Occurrence of other species in the catches has been recorded, and this paper presents an update of data on biomass estimates of *Pandalus montagui*.

Materials and Methods

The basic survey design has been constructed with reference to the distribution of the stock of *Pandalus borealis*, as has the allocation of stations to the various strata (Burmeister 2015). For the sampling period 1988 to 1999 trawl stations were allocated to strata proportionally to the area of the strata, but since 2000 station allocation have been weighted towards strata with observed high *P. borealis* variance (Kingsley et al. 1999).

The total area for the stratified-random survey is about 136 000 km², covering depths between 150 and 600 m, extending from Cape Farewell to 72°30'N. Since 1991, some 30 stations per year in depths below 150 meters were also taken to obtain information on occurrence and possible changes in fish populations. In total, 200-300 stations have been occupied annually.

Through all the years the surveys have been conducted with a 722 GRT trawler, initially using a 3000/20-mesh *Skjervøy* bottom trawl with a twin cod-end. Mesh size in the cod-end was changed from 44 mm to 20 mm (stretched) in 1993 and the small meshed codend was used thereafter. In 2005 the *Skjervøy* 3000 trawl equipped with a heavy bobbin footrope was replaced with a 'rock hopper' *Cosmos* 2000 trawl with a bobbin / rubber disk ground gear. Trawl geometry was measured with *Scanmar* acoustic sensors mounted on the trawl doors, and a *Furuno* trawleye on the headrope (Kingsley et al. 2011).

In order to minimise the influence of daily vertical migrations of shrimp, trawling was carried out between 0800 and 2000 UTC only. Length of the trawl track was measured by the distance between the (GPS) positions at the beginning and the end of the tow. Swept area was calculated for each haul as the length of the trawl track multiplied by the mean width (i.e. wingspread) of the trawl as calculated from the measured door distance (Kingsley et al. 2011).

In 2003 P. Kannevorff reported biomass estimates for *P. montagui* from 1988–2003. In 2011 biomass estimates for *P. montagui* from 1988–2011 was reported (Siegstad and Arboe, 2012). In this paper we reanalyzed and updates biomass indices for *P. montagui* from 2001–2015 and provides new information on population structure (biomass and abundance of males and females). The data has been analyzed according to methods described in Kingsley et al. 2011.

Results and Discussion

Overall Biomass and Area Distribution.

From 2001–2015 biomass estimates have been calculated for strata divided into region: C (Canadian Zone), D (Disko Bay and Vaigat), N (North of 69°30'N), W (South of 69°30'N), S (South of 61°N) and shallow areas (50–150m) (Fig. 1). Biomass calculations from survey data are based on catch per swept area unit, averaged over each stratum, assumed to represent mean densities. For each region a. total biomass estimates (T) are given in Table 1, b.ECV (error coefficients of variation (%)) in Table 2 and c. estimated mean densities (t/km²) are presented in Table 3 and Figure 2. Shallow water regions (areas with depths < 150 meter) are included in the analysis even though the coverage (number of stations per area unit) in these areas is less than in the other regions.

Reported biomass estimates for *P. montagui* from 1988–2003 (Kannevorff, 2003) did not include shallow water regions (areas with depths < 150 meter), however for comparison data up till 2003 and recent analyses from 2001–2015 is presented in table 4 and Figure 3.

The basic survey design has been constructed with reference to the distribution of the stock of *P. borealis*. Considering this the estimated biomass for *P. montagui* is probably underestimated, but overall, *P. montagui* appears to occur at a density of the order of 1% of that of *P. borealis* (Table 4). *P. montagui* distribution is different from *P. borealis*: it is relatively rare north of the northern margin of Store Hellefiskebanke, and south of that limit it occurs in shallower water than *P. borealis*, possibly associated with a greater tolerance for colder water. Due to low historical variances of *P. borealis* in depths shallower than 200 meters these areas were covered with a lower number of stations per area unit than in larger depths since 1988. The present sampling scheme is thus less suitable for a good description of the distribution of *P. montagui*.

Depth distribution of the shrimp biomass.

P. montagui is recorded from all depths within the survey area, but occurs more often in shallower water than *P. borealis*. While 83% on average (from 2001–2015) of the biomass of *P. montagui* is recorded in depths less than 200 m (Table 6 and Figure 5), on average 10% or less of the *P. borealis* biomass are found in these depths (Fig. 6). In some years, a considerable proportion of the observed *P. montagui* biomass has been recorded in the 200–300 m layer, probably occurring mainly in the upper part of this depth stratum. The biggest proportion of the biomass of *P. borealis* is found in the depth between 200–300 m. Prior to 2000 the bulk of the biomass of *P. borealis* was found between 300 and 400 m depth (Fig.7).

The total estimated biomass for *P. montagui* (for depths between 150 and 600 m) has been quite variable through the time series with large estimates in 1995, 1998, 2002, 2006 and 2013. Compared to the estimated size of the *P. borealis* stock, the *P. montagui* biomass is possibly less than one percent of the large stock of northern shrimp (Fig. 3 and Table 4).

Numbers, spawning stock biomass and abundance

Length frequencies of *Pandalus montagui* in the shallow water (LT 150 m) and offshore (GT 150M) and the Disko Bay/Vaigat area from 2012–2015 are showed in figure 6. *P. montagui* shrimp are smaller (max length 24 CLP) than *P. borealis*. Females of *P. montagui* are both in biomass and in numbers unusually high: the proportion of female biomass is 73% (Table 8), and in numbers female is 57% of total numbers (Table 7).

Conclusion

P. montagui appears to occur at a density of the order of 1% of that of *P. borealis*. The main distribution area of *P. montagui* in the West Greenland area is observed to be in depths less than 200 m around the shallow banks. Its distribution is different: it is relatively rare north of the northern margin of Store Hellefiskebanke, and south of that limit it occurs in shallower water than *P. borealis*, possibly associated with a greater tolerance for colder water. Large variations both in the depth distribution and in the estimated biomasses from year to year are observed.

The survey has never had the investigation of *P. montagui* among its design objectives, and effort is allocated principally according to the distribution of *P. borealis*. Given the localised and shallow-water distribution of *montagui*, catches of *montagui* in the survey are therefore sporadic and survey results an inaccurate measure of trends in biomass. The biomass indices from the trawl survey as at present conducted will most likely not constitute a satisfactory means of determining whether the stock of *P. montagui* is within safe biological limits. Analyse of results of previous surveys to find out whether, or how, it might be possible to alter the basis on which the survey is designed to improve its usefulness for monitoring the state of the stock of *P. montagui*.

References

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Table 1. Biomass estimates (t) for survey subdivisions and standard errors for the survey, 2001 - 2015

Year	Shallow LT 150	N1-9/ U1-3	C1-3/C0 ¹	W1-2	W3-4	W5-7	S/W8-9	D1-9/I1-2	Total	SE
2001	437	0	0	6	3	707	1623	132	2908	1.9
2002	2364	0	0	19	18	3641	2881	3	8926	4.2
2003	4687	0	0	0	58	962	67	67	5840	2.0
2004	5944	0	0	0	196	109	18	60	6327	4.1
2005	3047	0	0	176	15	49	36	56	3379	2.4
2006	7773	0	0	0	44	5691	119	40	13667	8.4
2007	2389	0	0	5	0	202	15	0	2611	2.3
2008	82	0	0	0	3	335	62	3	485	0.3
2009	1197	0	0	0	4	575	132	6	1914	0.7
2010	377	3	0	14	2	59	1	694	1150	0.7
2011	23	0	-	51	0	104	2	13	195	0.1
2012	2671	18	-	0	1	1409	18	0	4117	2.0
2013	14041	0	0	3	3	1276	2	7	15332	12.9
2014	662	1	-	79	18	88	2	225	1075	0.3
2015	1917	0	-	59	802	538	4	234	3555	2.0

¹:: Canada(C) in 2011-12, 2014-15 was not sampled due to icecondition

Table 2. Error coefficients of variation (%) for the biomass estimates in main survey regions and the entire survey area 2001-2015

Year	Shallow LT 150	N1-9/ U1-3	C1-3/C0	W1-2	W3-4	W5-7	S/W8-9	D1-9/I1-2	Total survey	Number of hauls
2001	66.7	0.0	100.0	74.1	96.0	45.6	98.5	98.7	58.0	240
2002	95.8	0.0	0.0	92.0	97.3	41.1	94.2	67.3	42.6	237
2003	39.7	0.0	0.0	0.0	64.9	56.1	64.7	63.0	32.6	205
2004	68.8	75.0	0.0	85.8	85.8	53.1	92.7	100.0	64.1	214
2005	79.0	0.0	0.0	78.4	76.5	53.1	90.1	62.6	71.5	218
2006	96.7	0.0	0.0	65.9	197.3	64.1	67.7	47.3	61.1	251
2007	95.8	0.0	0.0	100.0	-	2.7	68.2	-	87.9	262
2008	41.6	0.0	0.0	69.7	69.7	80.5	85.7	100.0	57.2	258
2009	41.3	0.0	0.0	70.8	70.8	93.4	96.8	100.0	38.7	279
2010	55.3	100.0	0.0	64.9	81.8	98.0	63.5	100.0	63.2	299
2011	53.3	62.9	-(¹)	70.7	100.0	89.6	11.9	100.0	52.4	216
2012	65.4	100.0	-(¹)	85.1	85.1	74.5	36.7	-	49.5	220
2013	91.7	-	0	68.0	92.6	97.3	59.8	100.0	84.4	211
2014	38.8	100.0	-(¹)	83.6	97.1	66.8	33.9	88.0	31.6	226
2015	88.8	0.0	-(¹)	92.0	98.6	96.3	71.4	67.2	55.0	221

Mean 2001-2015

56.66

¹:: Canada(C) in 2011-12, 2014-15 was not sampled due to icecondition

Table 3. Estimated mean densities (t/km²) for survey subdivisions in 2001–2015

Year	Shallow LT 150	N1-9/ U1- 3	C1-3/C0	W1-2	W3-4	W5-7	S/W8-9	D1-9/I1-2
2001	0.01	0.00	0.00	0.23	0.14	37.72	248.92	0.01
2002	0.05	0.00	0.00	0.71	2.75	194.31	441.92	0.00
2003	0.09	0.00	0.00	0.00	0.00	51.34	11.03	6.91
2004	0.12	0.00	0.00	0.00	9.56	5.04	3.17	6.16
2005	0.07	0.00	0.00	7.20	0.73	2.28	6.23	5.73
2006	0.17	0.00	0.00	0.02	2.17	263.87	20.77	4.09
2007	0.05	0.00	0.00	0.20	0.00	9.37	2.61	0.00
2008	0.00	0.00	0.00	0.00	0.13	15.54	10.88	0.29
2009	0.03	0.00	0.00	0.00	0.20	26.67	23.09	0.60
2010	0.01	0.07	0.00	0.58	0.10	2.72	0.13	69.64
2011	0.00	0.01	0.00	2.10	0.02	4.84	0.34	1.35
2012	0.06	0.37	0.00	0.00	0.06	65.32	3.18	0.00
2013	0.31	0.00	0.00	0.12	0.16	59.17	0.30	0.71
2014	0.01	0.02	0.00	3.26	0.85	4.08	0.40	22.57
2015	0.04	0.00	0.00	2.41	38.85	24.95	0.78	23.51

Table 4. Survey Estimates of total *P. montagui* and *P. borealis* biomass (tons) in regions C, D, N and W. From 2001-2015 shallow water (50-150) are included for *P. montagui* and from 2003 -2015 shallow water (50-150) are included for *P. borealis*

Year	<i>P. montagui</i>	<i>P. borealis</i>	<i>P. montagui</i>
	Biomass incl. shallow 2003-2015		% of total
1988	42	229,677	0.0%
1989	101	225,673	0.0%
1990	7	215,308	0.0%
1991	125	149,939	0.1%
1992	1,838	204,402	0.9%
1993	1,365	230,785	0.6%
1994	2,315	235,418	1.0%
1995	16,396	191,383	7.9%
1996	2,536	215,850	1.2%
1997	2,915	177,665	1.6%
1998	12,877	261,230	4.7%
1999	4,381	260,577	1.7%
2000	2,338	316,876	0.7%
2001	2,776	326,670	0.8%
2002	12,062	420,176	2.8%
2003	5,234	644,089	0.8%
2004	5,559	600,133	0.9%
2005	3,379	554,526	0.6%
2006	13,667	487,410	2.7%
2007	2,611	353,979	0.7%
2008	485	284,589	0.2%
2009	1,914	279,011	0.7%
2010	1,149	353,837	0.3%
2011	195	568,742	0.0%
2012	4,117	194,962	2.1%
2013	15,332	234,026	6.1%
2014	1,075	180,679	0.6%
2015	3,555	290,311	1.2%

Table 5. Survey estimates of *Pandalus montagui* biomass (tons) in Regions C, D, N and W from 1988 - 2015. From 2001 shallow stations are included

Year	Region				Biomass (excl shallow water)	Shallow LT 150 m	Biomass (incl shallow water)	Error of coefficients of variation(%)
	C	D	N	W				
1988	0	-	0	42	42			64.9
1989	0	-	0	101	101			33.6
1990	0	-	0	7	7			68.3
1991	0	10	0	115	125			56.0
1992	0	53	0	1,785	1,838			44.4
1993	0	5	0	1,359	1,365			45.5
1994	0	19	0	2,296	2,315			28.1
1995	0	0	0	16,396	16,396			41.0
1996	1	3	1	2,531	2,536			25.0
1997	0	3	0	2,911	2,915			47.9
1998	0	1	0	12,877	12,877			63.3
1999	0	27	0	4,354	4,381			60.7
2000	0	75	0	2,263	2,338			37.6
2001	0	144	35	2,217	2,396	381	2,776	58.0
2002	0	3	0	10,000	10,004	2,058	12,062	42.6
2003	0	67	0	1,086	1,153	4,081	5,234	32.6
2004	0	60	0	323	383	5,176	5,559	64.1
2005	0	56	0	276	332	3,047	3,379	71.5
2006	0	40	0	5,854	5,894	7,773	13,667	61.1
2007	0	0	0	222	222	2,389	2,611	87.9
2008	0	3	0	400	403	82	485	57.2
2009	0	6	0	711	717	1,197	1,914	38.7
2010	0	694	3	75	772	377	1,149	63.2
2011	-	13	0	158	172	23	195	52.4
2012	-	0	18	1,428	1,446	2,671	4,117	49.5
2013	0	7	0	1,284	1,291	14,041	15,332	84.4
2014	-	225	1	187	413	662	1,075	31.6
2015	-	234	0	1,403	1,637	1,917	3,555	55.0

Region C: Canadian Zone: NAFO Division 0A (East of 59°30'W),
Region N: North of 69°30'N,

Region D: Disko Bay and Vaigat,
Region W: South of 69°30'N

Table 6. Distribution (in percent) of *P. montagui* biomass in depth strata in regions C, D, N and W from 1988-2000. From 2001-2015 shallow water (50-150) are included

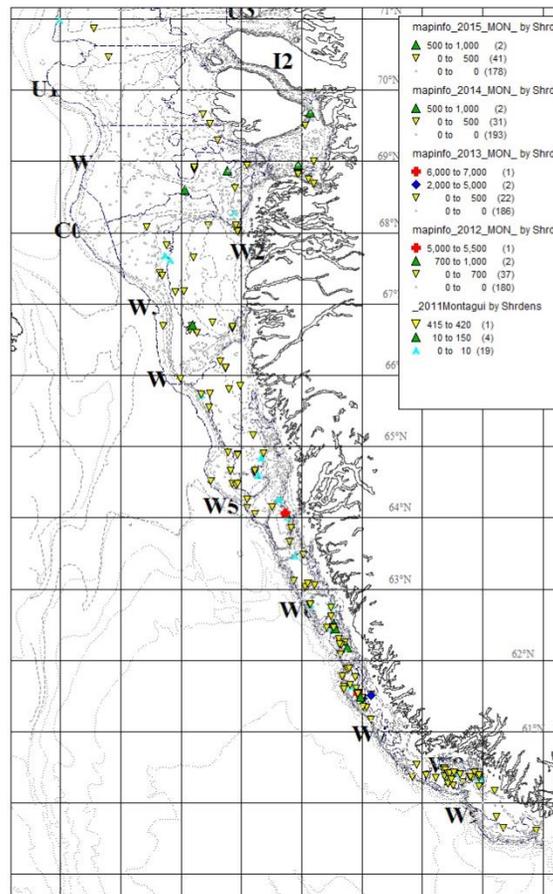
Year	Depth strata				
	50-150	150-200	200-300	300-400	400-600
1988		86.7	7.7	5.0	0.5
1989		44.6	55.2	0.1	0.1
1990		23.6	76.4	0.0	0.0
1991		12.4	82.7	4.9	0.0
1992		5.4	94.2	0.4	0.0
1993		0.4	78.4	1.6	19.6
1994		81.6	11.2	0.0	7.2
1995		85.8	4.7	9.5	0.0
1996		42.0	57.7	0.3	0.0
1997		68.7	31.1	0.0	0.1
1998		84.9	13.6	1.4	0.0
1999		83.4	16.0	0.5	0.0
2000		62.2	34.6	3.0	0.2
2001	34.7	14.4	44.9	1.8	4.1
2002	35.9	48.0	15.7	0.4	0.0
2003	80.0	5.1	14.6	0.0	0.3
2004	94.4	1.0	1.5	0.0	3.0
2005	92.7	1.2	6.1	0.0	0.0
2006	57.5	39.6	2.9	0.0	0.0
2007	92.0	6.7	1.2	0.0	0.0
2008	19.5	68.4	11.7	0.1	0.3
2009	67.4	1.2	31.2	0.2	0.0
2010	83.5	2.5	14.0	0.0	0.0
2011	12.8	22.6	52.6	11.9	0.0
2012	65.4	11.0	23.5	0.0	0.0
2013	91.6	8.1	0.2	0.0	0.0
2014	78.2	10.0	11.8	0.0	0.0
2015	57.8	41.0	1.1	0.0	0.0
Average (2001-2015)	64.2	18.7	15.5	1.0	0.5

Table 7. Estimated numbers (*1000) by *P. montagui* sex from length analyses 2003–2015

Year	Males	Females	Total	Males %	Females %
2003	761	858	1619	47.0	53.0
2004	466	1195	1661	28.1	71.9
2005	459	537	997	46.1	53.9
2006	411	2359	2770	14.8	85.2
2007	204	429	633	32.2	67.8
2008	45	83	128	35.3	64.7
2009	214	303	517	41.5	58.5
2010	413	67	479	86.1	13.9
2011	9	33	41	21.1	78.9
2012	807	764	1571	51.4	48.6
2013	5175	2251	7426	69.7	30.3
2014	68	191	259	26.3	73.7
2015	788	443	1231	64.0	36.0
Average	755	732	1487	43	57

Table 8. Survey biomass estimates ('000 kg) by sex based on length-weight distributions 2003–2015

Year	Males	Females	Total	Males %	Females %
2003	1821	4190	6011	30.3	69.7
2004	915	5469	6384	14.3	85.7
2005	928	2451	3379	27.5	72.5
2006	1023	12644	13667	7.5	92.5
2007	514	2097	2611	19.7	80.3
2008	82	403	485	16.9	83.1
2009	471	1443	1914	24.6	75.4
2010	854	295	1149	74.3	25.7
2011	19	175	195	9.9	90.1
2012	929	3188	4117	22.6	77.4
2013	7324	8008	15332	47.8	52.2
2014	158	917	1075	14.7	85.3
2015	1448	2067	3515	41.2	58.8
Average	1268	3334	4603	27	73

Fig 1. *P. montagui* density and distribution in survey area 2003-2015

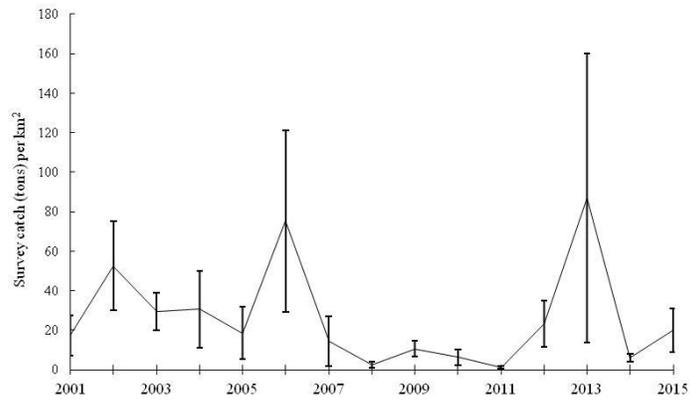


Fig. 2. Estimated average survey biomass density of *P. montagui* with standard errors 2001–2015

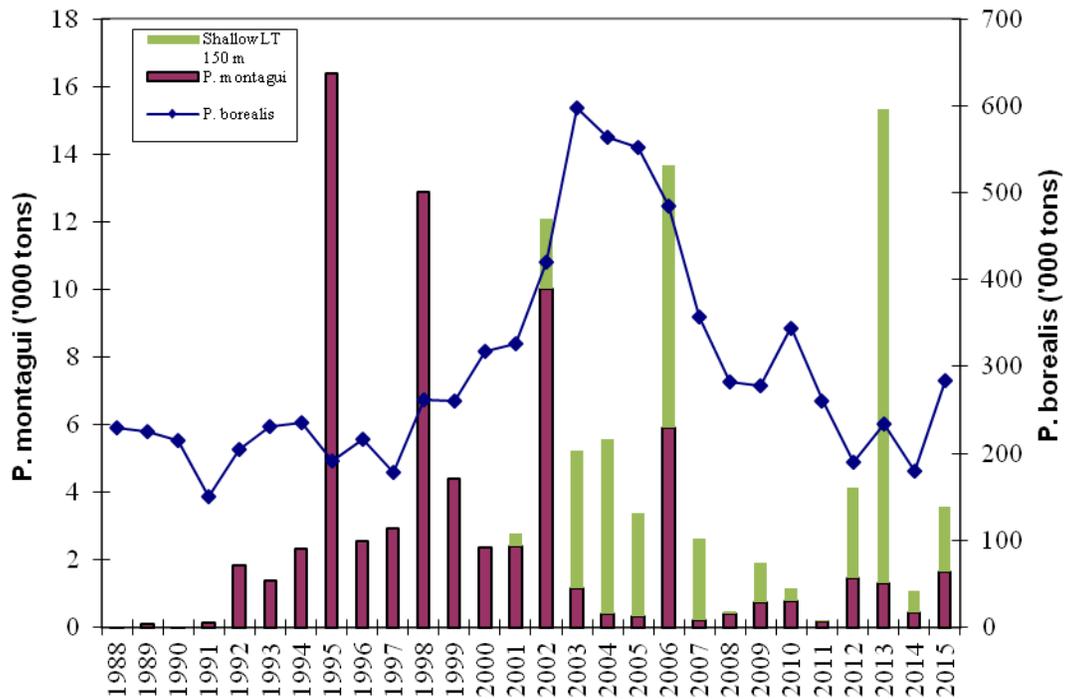


Fig. 3. Estimated biomass of *Pandalus montagui* and *P. borealis* 1988–2011 in areas with depths between 150 and 600 m and between 50–600 m from 2001 – 2015

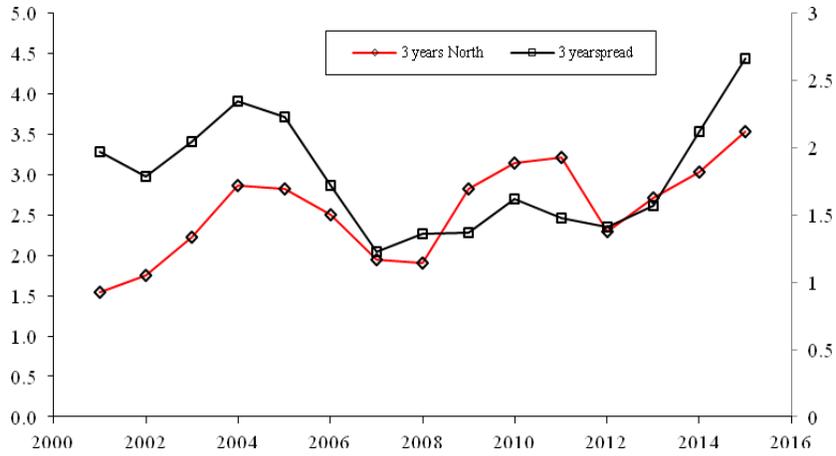


Fig. 4. *P. montagui* in West Greenland: indices of distribution and location of shrimp biomass in the West Greenland trawl survey in regions C, D, N and W 2001–2015 (3-point moving averages)

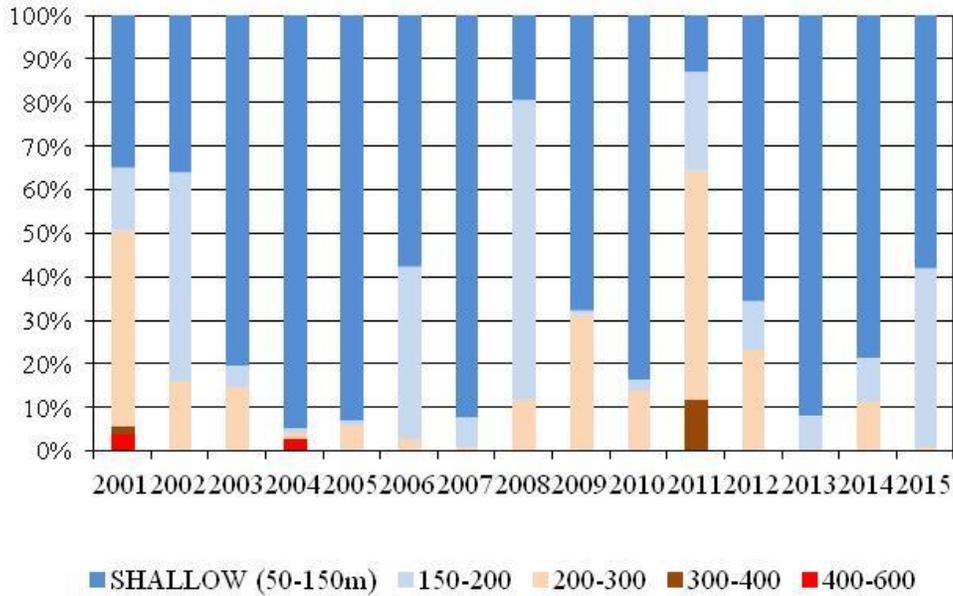


Fig. 5. Distribution (in percent) of *P. montagui* biomass in depth strata, 2001-2015

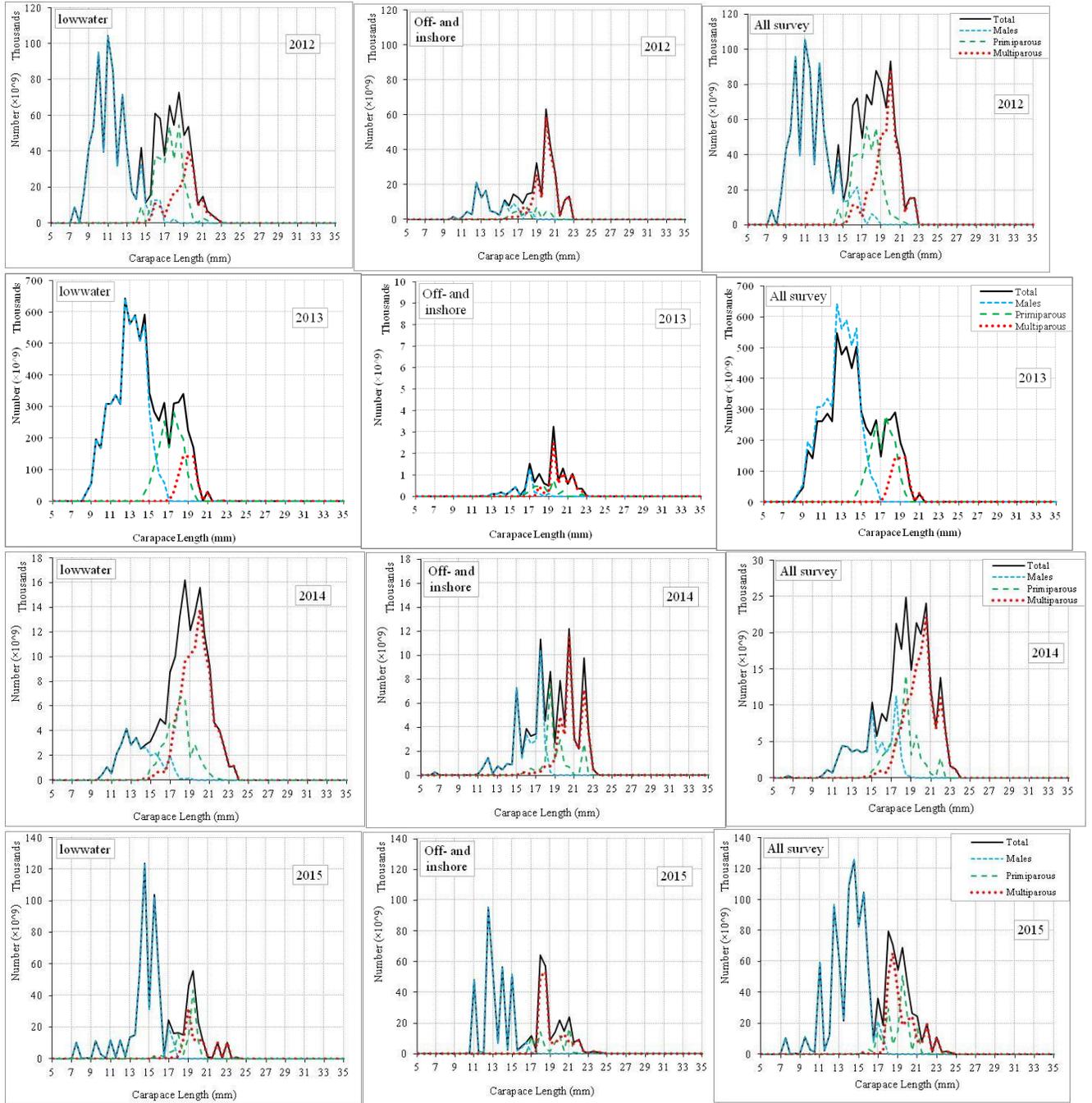


Fig. 6. Length frequencies of *Pandalus montagui* in the total offshore and the Disko Bay/Vaigat area, 2012–2015