SHORT NOTE

CPUE INDICES USED IN SOVIET KRILL FISHERY STATISTICS FROM 1977 TO 1992 AND THEIR POSSIBLE UTILITY FOR EVALUATION OF RELATIVE CHANGES IN KRILL BIOMASS

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Abstract

Key catch-per-unit-effort (CPUE) indices used in Soviet krill fishery statistics, as well as the main sources of data and primary data for their calculations, were examined. The main CPUE indices were catch per vessel-days fished (CVDF), catch per extended vessel-days fished (CEVDF) and catch per hour of trawling (CHT). A relatively high correlation between mean monthly values of CVDF and CEVDF, and CVDF and CHT was observed. However, the correlation between daily mean values was quite low as a result of significant fluctuations in haul duration due to the different fishing strategies used when targeting krill intended for different end products, i.e. human consumption, krill meal and frozen krill. Daily mean CVDF and CHT calculated for specific strategies were well correlated. Depending on the fishing strategy used, the number of hauls per day ranged from 1 to 15. The duration of hauls ranged from 0.1 to 16 hours. When a final product of higher quality was required, haul durations were shorter and, accordingly, the number of hauls per day was higher. The correlation between catch and tow time was considered to be an indicator of homogeneity in krill distribution. The utility of CPUE for direct evaluation of relative changes in quantitative parameters of krill distribution inside fishing grounds is assessed.

Résumé

Les indices clés de capture par unité d'effort (CPUE) utilisés dans les statistiques de la pêcherie soviétique de krill sont examinés, de même que les principales sources de données et les données primaires ayant servi à les calculer. Les principaux indices de CPUE sont la capture par jours de pêche/navire (CVDF), la capture par jours passés dans la zone de pêche/navire (CEVDF) et la capture par heure de chalutage (CHT). Une corrélation relativement forte est observée entre les valeurs mensuelles moyennes de la CVDF et de la CEVDF, et entre celles de la CVDF et de la CHT. Cependant, la corrélation entre les valeurs journalières moyennes était assez faible du fait de la forte fluctuation de la durée des chalutages qui dépendait des stratégies de pêche suivies selon le produit final attendu, c-à-d., consommation par l'homme, farine de krill et krill congelé. La CVDF et la CHT journalières moyennes calculées pour des stratégies spécifiques présentent une bonne corrélation. Selon la stratégie de pêche suivie, le nombre de chalutages par jour variait de 1 à 15. La durée des chalutages variait de 0,1 heure à 16 heures. Lorsque la qualité du produit final devait être supérieure, la durée des chalutages était plus courte et, en conséquence, le nombre de chalutages par jour était plus élevé. La corrélation entre la capture et la durée du chalutage est considérée comme un indicateur de l'homogénéité de la répartition du krill. L'utilité de la CPUE pour l'évaluation directe des changements relatifs des paramètres quantitatifs de répartition du krill sur les lieux de pêche est évaluée.

Резюме

Рассмотрены основные показатели вылова на промысловое усилие (CPUE), использовавшиеся в советской статистике по промыслу криля, а также их основные источники и первичные данные для их расчетов. Основными показателями CPUE были вылов на судо-сутки лова (ВСЛ), вылов на судо-сутки промысла (ВСП) и улов на час траления (УЧ). Существовала довольно высокая корреляция между среднемесячными величинами ВСЛ и ВСП, а также ВСЛ и УЧ. Однако, корреляция между среднесуточными величинами была довольно низкой, вследствие значительных флюктуаций в продолжительности тралений, вызванных различиями в стратегии рыболовства, которое могло быть нацелено на получение криля для производства пищевых продуктов, крилевой муки или мороженого криля. Среднесуточные величины ВСЛ и УЧ, рассчитанные для конкретной стратегии, хорошо коррелировали друг с другом. В зависимости от выбранной стратегии промысла, число тралений в сутки колебалось от 1 до 15. Продолжительность тралений колебалась от 0.1 до 16 часов. Когда требовался конечный продукт более высокого качества, траления были короче и, соответственно, число тралений в сутки было выше. Корреляция между уловом и его продолжительностью рассматривалась в качестве показателя однородности в распределении криля. Оценивается применимость CPUE для прямой оценки относительных изменений в количественных параметрах распределения криля внутри промысловых участков.

Resumen

Se analizaron los índices principales de captura por unidad de esfuerzo (CPUE) utilizados en las estadísticas de la pesca de kril de la Unión Soviética, así como las fuentes principales de datos y los datos primarios utilizados en sus cálculos. Los principales índices de CPUE fueron: captura por días de pesca por barco (CVDF), captura por días de pesca extendidos por barco (CEVDF) y captura por hora de arrastre (CHT). Se observó una correlación relativamente alta entre el promedio mensual de CVDF y CEVDF, y entre CVDF y CHT. No obstante, la correlación entre los valores promedios diarios fue muy baja debido a las grandes variaciones en la duración de los lances por las distintas estrategias de pesca utilizadas de acuerdo al producto deseado, es decir, para consumo humano, como harina de kril, o kril congelado. El promedio diario de CVDF y de CHT calculados para estrategias de pesca específicas guardaron una buena correlación. Dependiendo de la estrategia de pesca utilizada, el número de lances por día varió entre 1 y 15. La duración de los lances varió entre 0,1 y 16 horas. Cuando se requirió un producto de mejor calidad, los lances fueron más cortos y, por consiguiente, el número de lances diarios fue mayor. Se consideró que la correlación entre la captura y el tiempo de arrastre revela homogeneidad en la distribución de kril. Se examina la utilidad del CPUE en la evaluación directa del cambio relativo en los parámetros cuantitativos de la distribución de kril en los caladeros de pesca.

Keywords: Antarctic krill, catch per unit effort (CPUE), Soviet krill fishery, vessel-days fished, extended vessel-days fished, krill fishery strategy, changes in krill abundance, CCAMLR

Introduction

Commercial fishery data, and catch-per-unit-effort (CPUE) indices in particular, represent comprehensive and long-term datasets which could be very useful for analyses of relative changes in krill abundance. However the high variability of CPUE indices, which are influenced by many factors, means that they may not always be appropriate for that purpose (Siegel et al., 1998). In addition to the evaluation of fluctuations in krill abundance, CPUE indices are very useful for forecasting trends in the fishery and tuning of krill stock assessment models (Hilborn and Walters, 1992). Various CPUEs used in the krill fishery have been considered in a number of papers (Endo and Ichii, 1989; Miller, 1989; Sushin and Myskov, 1992; Fedoulov et al., 1996; Siegel et al., 1998; Sushin, 1998; Kawaguchi et al., 1997; Litvinov et al., 2002), but their utility still remains open to question (SC-CAMLR, 2002). Furthermore, quantitative parameters of indices such as haul duration and number of hauls per day in relation to different fishing strategies have never been described in detail. The main objective of this paper is to describe various CPUE indices used in the Soviet krill fishery from 1977 to 1991 and to determine the correlation between these indices, as recommended by CCAMLR (SC-CAMLR, 2002), as well as their utility for the evaluation of relative changes in krill abundance.

Materials and methods

Two sources were used: the *Atlas of Fisheries in the Southwestern Atlantic* (Anon., 1978–1992) and the AtlantNIRO computerised database containing haul-by-haul data from 1986 to 1991, so-called 'RIF' statistics.

Atlas of Fisheries in the Southwestern Atlantic

The *Atlas of Fisheries in the Southwestern Atlantic* (Anon., 1978–1992) contains data from 1977 to 1991 by a fishery operator (Regional Fishery Association – RFA), by vessel type and subarea, mean monthly catch per vessel-days fished (CVDFs) and per extended vessel-days fished (CEVDFs) (for explanation of these parameters see 'Results'), quantity of frozen krill, mean monthly catch per hour (only for Sevryba RFA), depth of trawling and species composition of catches. The *Atlas* is considered to be the most reliable and the longest time series of data on the Soviet krill fishery (Fedoulov et al., 1996; Litvinov et al., 2003).

RIF Statistics

The RIF statistics contain haul-by-haul data from 1986 to 1991. These data are not as complete as in the *Atlas*; however, they are much more detailed and include vessel call sign, vessel name, vessel type, gear, time, date, catch per haul, haul duration, coordinates and catch composition. Compared to the *Atlas*, the RIF statistics contain from 2 to 78% of data for various years and 34.2% of data for the entire period from 1986 to 1991. In total, the RIF statistics contain data on 28 324 trawls.

Both sources contain data necessary for the calculation of CPUE, i.e. catch per haul and haul duration, that would allow many different types of CPUE to be derived, such as CVDF and catch per hour and per minute, mean weekly and monthly catch etc., as well as krill density parameters (e.g. g/m^2 and g/m^3 etc.). In practice, the most commonly used indices in the Soviet krill fishery were CVDF and catch per hour of trawling (CHT), which are discussed below.

In order to calculate correlation coefficients (CCs) between between catch per haul (tonnes) and tow time (hours) the primary data were grouped by subarea, period, standard vessel type, selected year, selected month, areas of krill fleet concentration and fishing strategy; a description of these groups is given in the footnotes to Table 2.

The term 'biomass' is widely used in the literature. It should be noted that in this paper the term refers to the quantity of krill on fishing grounds, as described in Sushin (1998), or within fishing areas, as described in Kasatkina and Ivanova (2003).

Results

The *Atlas* Dataset

The main unit of fishing effort used in Soviet fishery statistics was vessel-days fished (Litvinov et al., 2003). Accordingly, CVDF was very widely used, and most CPUE data were presented in this form. An index of catch per vessel-days fished plus days with no actual catch due to stormy weather or absence of suitable krill aggregations (CEVDF) was also used. This index was introduced for the purpose of forecasting trends in the fishery in order to evaluate the situation on fishing grounds, namely the presence of krill aggregations and suitable weather conditions. In reality, extended vessel-days fished would include days spent waiting for fuel or for catch transhipment and time lost due to other operational reasons, so it was quite difficult to use it for fishery forecasting. The number of extended vessel-days fished and CEVDF can be equal to or higher than vessel-days fished and CVDF; the CC between CEVDF and CVDF is 0.896086.

Mean monthly CEVDF ranged from 10 to 150 tonnes, but typically from 40 to 100 tonnes (81.8% of the total mean monthly CEVDF); CVDF ranged from 10 to 170 tonnes, but typically from 50 to 110 tonnes (82.7% of the total mean monthly CVDF) (Figure 1). Mean monthly CHT ranged from 2 to 13 tonnes, but in most cases from 5 to 10 tonnes (80% of the total mean monthly CHT) (Figure 2). The CC between the mean monthly values of CVDF and CHT was relatively high, at 0.768586.

Total mean monthly fishing effort and mean monthly CPUE can be used effectively for analyses of krill fishery distribution and CPUE variability in relation to environmental factors on a global scale (Fedoulov et al., 1996; Litvinov et al., 2003), but since the values were averaged by month, the *Atlas* is of limited use.

The RIF statistics dataset

Description of CPUE data

According to the RIF statistics, catches per haul from 1986 to 1991 ranged from 0.2 to 104 tonnes, but in most cases from 10 to 40 tonnes (Figure 3). Haul duration ranged from 0.1 to 16 hours, but in most cases from 3 to 8 hours (Figure 4). The duration of hauls depended on the number of hauls per

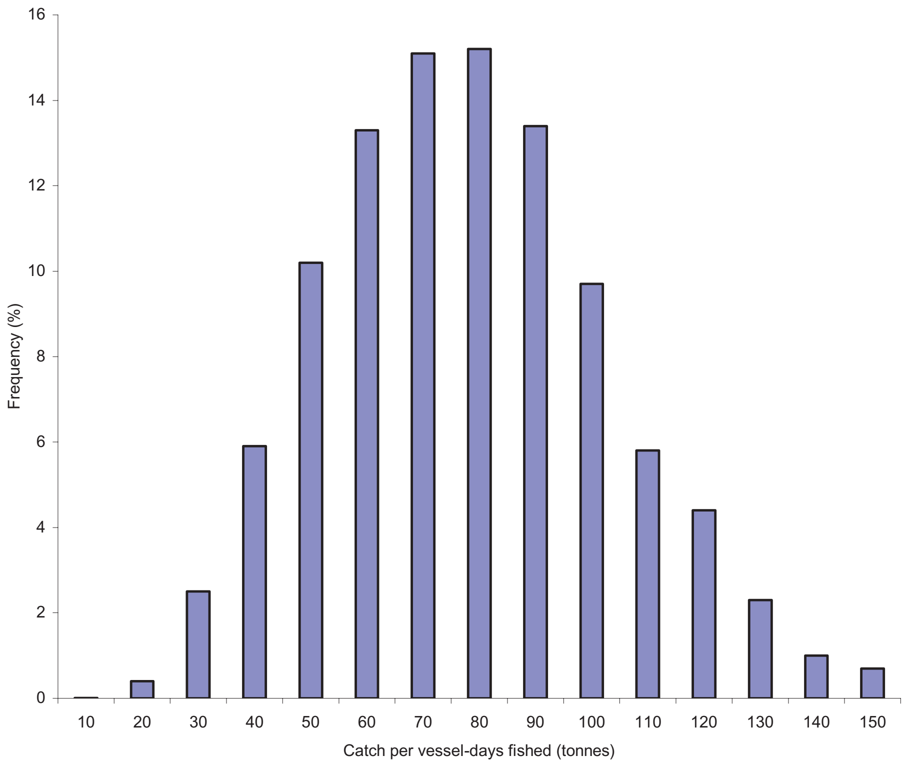

Figure 1: Catches per vessel-days fished (CVDF) in the Soviet krill fishery from 1977 to 1991 (Anon., 1978–1992, mean monthly values).

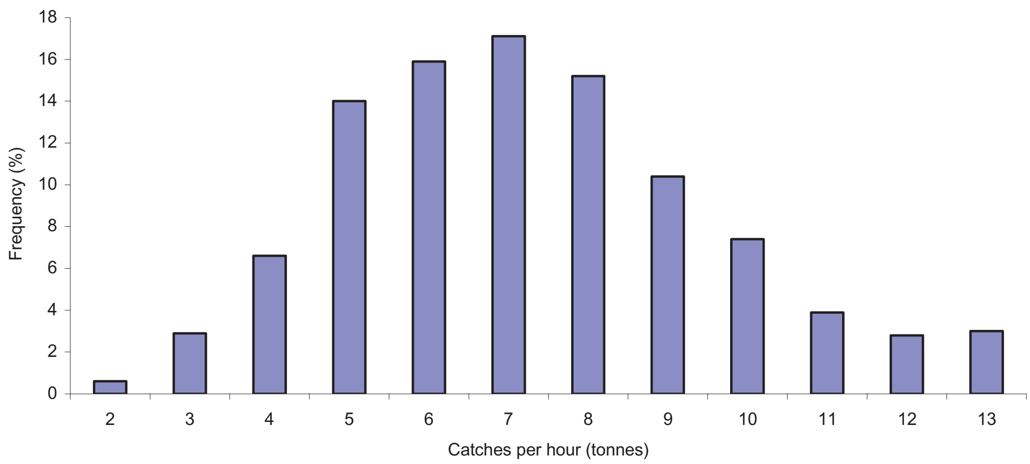

Figure 2: Catches per hour in the Soviet krill fishery from 1977 to 1992 (Anon., 1978–1992, mean monthly values).

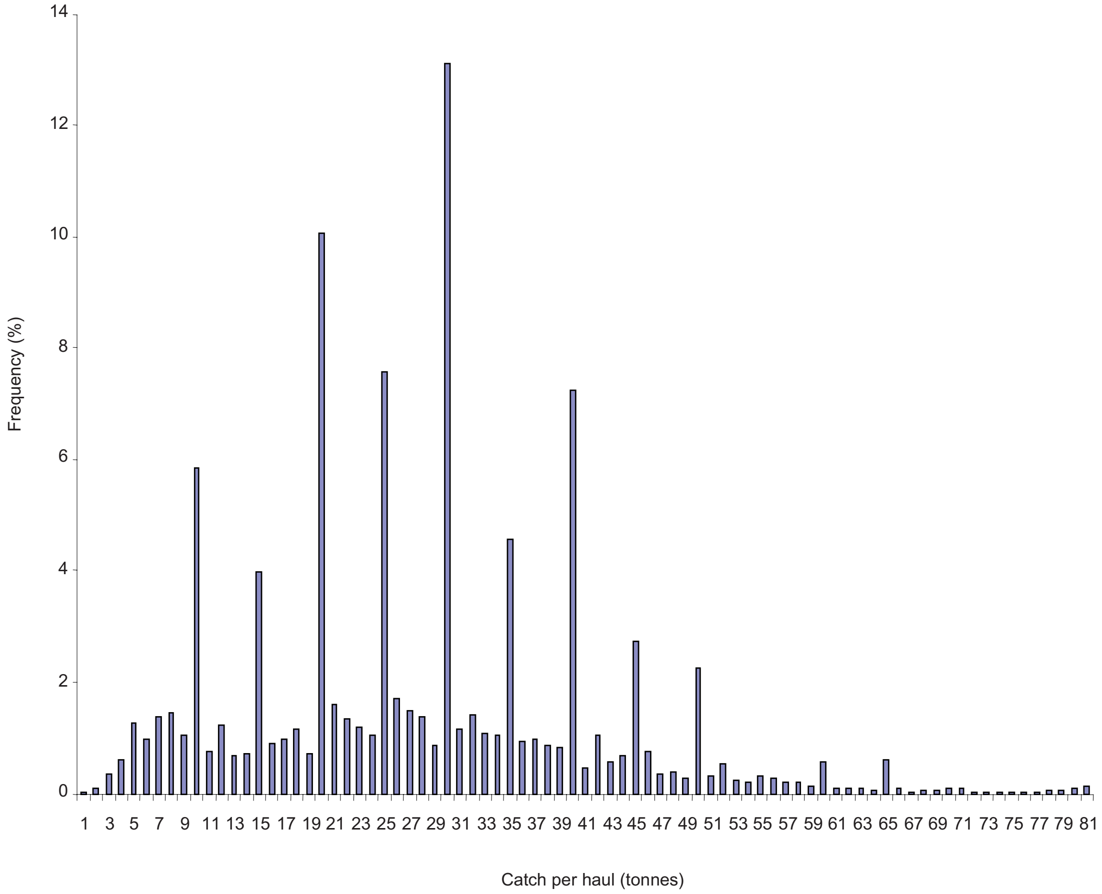

Figure 3: Catches per haul in the Soviet krill fishery from 1986 to 1991 (RIF statistics, haul-by-haul data).

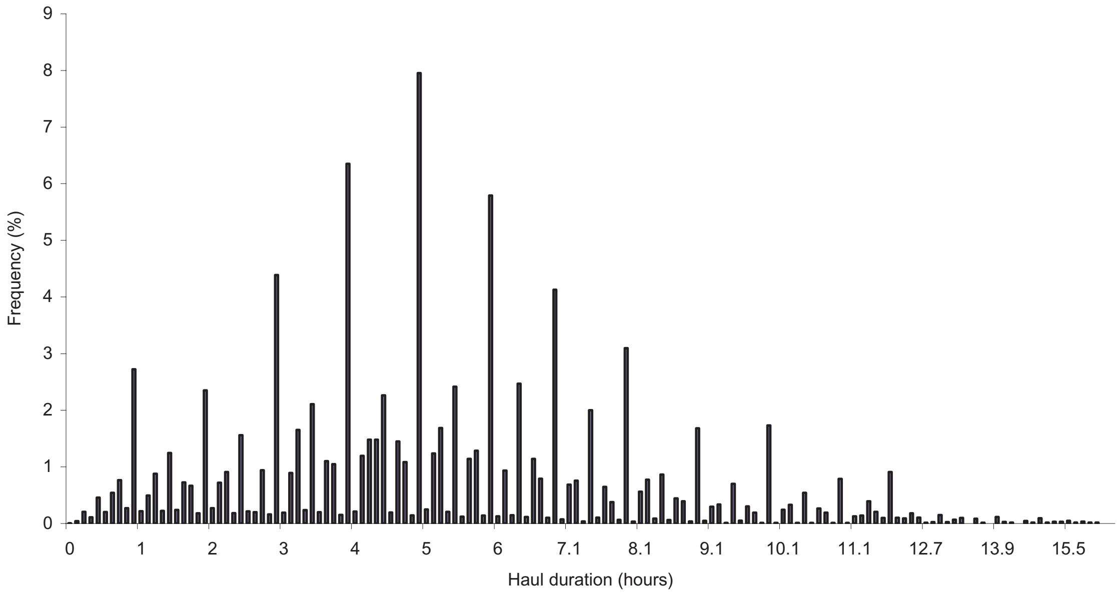

Figure 4: Duration of hauls in the Soviet krill fishery from 1986 to 1991 (96 937.1 hours in total, RIF statistics).

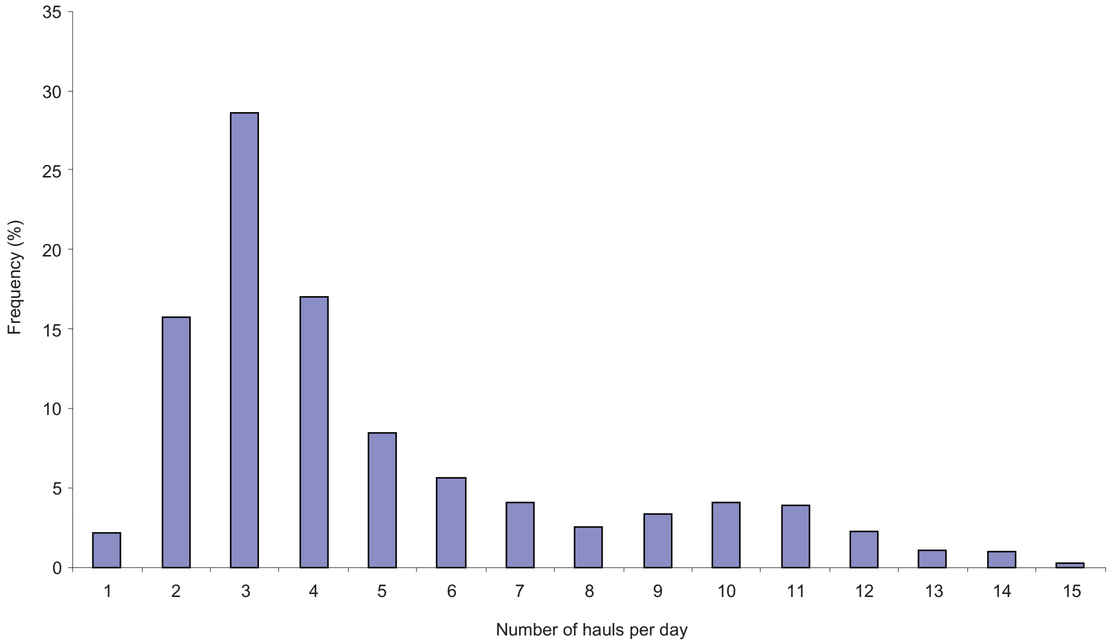

Figure 5: Number of hauls per day in the Soviet krill fishery from 1986 to 1991 (RIF statistics).

day which ranged from 1 to 15, in most cases from 2 to 4 (Figure 5), due to the fact that the Soviet krill fishery was generally aiming to maximise the quantity rather than the quality of krill caught. When the duration of a haul was long and the catch exceeded 10 tonnes, more than 80% of the krill were damaged and losses of the raw krill material could be 20% or more (Anon., 2001). Another, much smaller, peak in Figure 5 is associated with 8–12 hauls per day. This peak is associated with a relatively small number of vessels designed to process krill for human consumption; for these vessels, catches per haul were less than 10 tonnes and the hauls were relatively short. Since this type of product is a small proportion of the overall production, it is difficult to trace the peaks associated with short hauls and low catches in Figures 3 and 4. At the same time, it is to be borne in mind when grouping primary data for further processing, that these two strategies utilised different tow time.

During the period from 1986 to 1991, 50 to 60 large-capacity trawlers of different types fished for krill. A list and description of the vessel types is given in Table 2 of Litvinov et al. (2003), and vessel characteristics by CPUE are described in Litvinov et al. (2002). Based on their krill processing methods, the vessels can be divided into three groups:

(i) Vessels producing mainly canned krill, krill meat and krill oil for human consumption, as well as some krill meal. These were mostly specialised BATKRR (RKTS), and several modified BATM and BMRT vessels. These vessels varied significantly in their fishing capacity. There were significant differences in krill processing capacity and tow time between the vessels designed to process krill for human consumption and other vessels. The tow time could not be longer than 1–1.5 hours when final products were destined for human consumption without damaging raw krill; vessels processing krill for other types of product aimed only at maximising catches.

(ii) Vessels producing mainly krill meal and a small quantity of frozen krill (modified BMRT type – BMMT).

(iii) Vessels producing mainly frozen unprocessed krill and some krill meal (PPR, BMRTA, BATSP, BATM, RTMS, RTMA and BMRT of various types).

Based on their krill processing capacity, the vessels can also be divided into the following groups:

(i) up to 100–150 tonnes of raw krill per day: BATKRR, PPR, BMRTA, BATM;

(ii) up to 70–100 tonnes of raw krill per day: BMRTIB, RTMS, BMMT;

(iii) up to 40–70 tonnes of raw krill per day: BMRT, RTMA.

Table 1: Correlation between catch per vessel-days fished (CVDF) and catch per hour of trawling (CHT), based on the RIF statistics. CC – correlation coefficient.

Correlation – CVDF/CHT	CC Total Daily	*N*	CC Mean Monthly	*N*
All vessels, all subareas, entire period	0.288514	8109	0.427214	253
All vessels, all subareas, entire period, separately for 2–4 hauls per day	0.426797	6134	-	-
All vessels, all subareas, entire period, separately for 9–12 hauls per day	0.700456	734	-	-
PPR[1], all subareas, entire period	0.264715	2674	0.871687	42
Subarea 48.1, all vessels, entire period	0.287009	1103	0.449296	46
Subarea 48.1, PPR, entire period	0.260134	443	0.871284	10
Subarea 48.2, all vessels, entire period	0.28757	2737	0.531212	81
Subarea 48.2, PPR, entire period	0.265175	1108	0.895931	16
Subarea 48.3, all vessels, entire period	0.289145	4269	0.436638	126
Subarea 48.3, PPR, entire period	0.264715	1123	0.883425	16

[1] See Table 2 in Litvinov et al., 2003

The main indices used in the fishery forecasting based on historical data are CVDF and CHT. Therefore, evaluation of the correlation between them is very important. Table 1 shows that daily index totals are poorly correlated for all vessels and subareas: CCs ranged from 0.26 to 0.29. When the calculations are performed separately for the vessels that used different fishing strategies, CCs are much higher for hauls targeting krill for human consumption (0.700456) and are somewhat higher for other hauls (0.426797), demonstrating a fairly high correlation between CVDF and CHT. It can be assumed that the correlation between CVDF and CHT is also relatively high in the case of Japanese krill vessels, which normally use the former strategy (Butterworth, 1988b).

CPUE values as indicators of homogeneity in krill distribution

With regard to using CPUE for the evaluation of fluctuations in krill biomass, CPUEs of vessels processing krill for human consumption correlate with targeted hauls (i.e. acoustics-guided hauls as used in the CCAMLR-2000 Krill Synoptic Survey (Trathan et al., 2001). The CPUEs of the vessels processing krill for other purposes correlate with random hauls (i.e. in terms of location and time). In the latter case, the longer the haul duration, the more closely the CPUE reflects the krill biomass in a fishable aggregation. In fact, such hauls could not be considered as absolutely random, as the vessel would have conducted a preliminary search along the planned haul trajectory using an echo sounder.

The main sources of uncertainty in modelling krill distribution and using fishery statistics for the evaluation of krill biomass are inconsistencies between haul duration, size and density of krill swarms and CPUE values (Butterworth, 1988a; Dolzhenkov et al., 1988; Mangel, 1988). Therefore, a detailed analysis of the correlation between CPUEs and tow time was carried out. Generally speaking, when krill is distributed in the water column absolutely homogeneously, there will be a linear relationship between the CPUE values and tow time. In the simplest case, it will be the relationship between catch per haul and haul duration, where the CC between these values will be 1.0. In other words, the closer the CC value is to 1.0, the more homogeneous the krill distribution and the more reason there is to use the CPUE values for the evaluation of krill abundance and biomass.

The CCs calculated for the data grouped on a haul-by-haul, daily, 10-day and monthly basis are presented in Table 2.

Conclusions

Analysis of the CCs given in Table 2 shows that:

(i) for all the values calculated, the correlation for haul-by-haul and total daily, 10-day and monthly values was higher than for the mean values; this corresponds to Butterworth's (1988a) conclusion that: '… total/total ratio indices are preferred because they are more precise than the corresponding "average individual ratios" indices…';

(ii) the correlation for haul-by-haul data was generally low, but increased steadily when a single subarea was considered in a single

Table 2: Correlation coefficients (CCs) between catch per haul (tonnes) and tow time (hours) calculated for haul-by-haul, total daily, mean daily, total 10-day, mean 10-day, total monthly and mean monthly data.

	Correlation catch/tow time	CC, haul by haul[6]	*N*[7]	CC, mean daily[8]	CC, total daily[9]	*N*	CC, total 10-day[10]	CC, mean 10-day[11]	*N*	CC, total monthly[12]	CC, mean monthly[13]	*N*
1.	All vessels[1], all subareas, entire period	0.454057	28 310	0.335806	0.191362	8 109	0.756315	0.423967	1 454	0.835461	0.430646	750
2.	PPR[2], all subareas, entire period	0.039964	7 780	0.068209	0.038593	2 674	0.775863	0.112442	483	0.854429	0.112753	248
3.	Subarea 48.1, all vessels, entire period	0.484053	3 330	0.378727	0.395523	1 103	0.901593	0.467621	242	0.942038	0.593271	114
4.	Subarea 48.1, PPR, entire period	0.125319	1 296	0.302604	0.08935	443	0.911598	0.1841	104	0.957012	0.213585	43
5.	Subarea 48.2, all vessels, entire period	0.448241	9 764	0.110387	0.331205	2 737	0.715697	0.394673	456	0.801379	0.384414	239
6.	Subarea 48.2, PPR, entire period	0.070236	3 378	0.025759	0.073433	1 108	0.722752	0.141762	180	0.820892	0.027183	92
7.	Subarea 48.3, all vessels, entire period	0.476495	15 195	0.258279	0.036561	4 269	0.779936	0.47515	741	0.874812	0.459098	397
8.	Subarea 48.3, PPR, entire period	0.052595	3 106	0.153241	0.070317	1 123	0.834462	0.191123	196	0.921401	0.224543	113
9.	All subareas, all vessels, entire period, separately for 2–4 hauls per day[3]	0.108223	17 385	0.034232	0.023223	4 908	-	-	-	-	-	-
10.	PPR, all subareas, entire period, separately for 2–4 hauls per day	–0.005410	6 950	–0.05519	–0.01916	2 371	-	-	-	-	-	-
11.	All subareas, entire period, separately for 9–12 hauls per day[3]	0.096632	3 835	0.0.09603	0.103949	372	-	-	-	-	-	-
12.	Subarea 48.1, all vessels, entire period, separately for 2–4 hauls per day	0.174732	2 378	0.222354	0.179073	871	-	-	-	-	-	-
13.	Subarea 48.1, all vessels, entire period, separately for 9–12 hauls per day	0.213142	116	-	-	-	-	-	-	-	-	-
14.	Subarea 48.2, all vessels, entire period, separately for 2–4 hauls per day	0.087186	5 970	–0.01708	–0.082981	2 080	-	-	-	-	-	-
15.	Subarea 48.2, all vessels, entire period, separately for 9–12 hauls per day	–0.03202	1 594	–0.03631	–0.04269	157	-	-	-	-	-	-
16.	Subarea 48.3, all vessels, entire period, separately for 2–4 hauls per day	0.148147	9 018	0.152792	0.173431	3152	-	-	-	-	-	-
17.	Subarea 48.3, all vessels, entire period, separately for 9–12 hauls per day	0.154811	2 117	0.254102	0.245755	203	-	-	-	-	-	-
18.	Subarea 48.3, all vessels, 1988[4]	0.587074	8 694	0.231748	0.496454	2 174	0.791724	0.619056	360	0.847173	0.623774	278
19.	Subarea 48.3, all vessels, June 1988[5]	0.659817	2 208	0.198025	0.601568	512	0.811576	0.738157	84	0.889179	0.731961	38

	Correlation catch/tow time	CC, haul by haul	*N*	CC, mean daily	CC, total daily	*N*	CC, total 10-day	CC, mean 10-day	*N*	CC, total monthly	CC, mean monthly	*N*
20.	Subarea 48.3, PPR, 1988	0.061007	2 014	0.163504	0.086213	711	0.828155	0.289348	114	0.89988	0.389602	57
21.	Subarea 48.3, PPR, June 1988	0.176714	405	0.30364	0.171311	141	0.864575	0.558036	21	0.934532	0.678786	9
22.	Subarea 48.3, all vessels, June 1988, western area[5]	0.430502	692	0.200978	0.425426	212	-	-	-	-	-	-
23.	Subarea 48.3, all vessels, June 1988, eastern area	0.715288	1 517	0.206614	0.664994	301	-	-	-	-	-	-
24.	Subarea 48.3, all vessels, June 1988, western area, separately for 2–4 hauls per day	0.167527	553	0.126722	0.276973	133	-	-	-	-	-	-
25.	Subarea 48.3, all vessels, June 1988, western area, separately for 9–12 hauls per day	0.108698	41	0.719388	0.621737	4	-	-	-	-	-	-
26.	Subarea 48.3, all vessels, June 1988, eastern area, separately for 2–4 hauls per day	0.262574	491	0.143855	0.28507	174	-	-	-	-	-	-
27.	Subarea 48.3, June 1988, all vessels, eastern area, separately for 9–12 hauls per day	0.325857	536	0.514296	0.576959	51	-	-	-	-	-	-
28.	Subarea 48.3, June 1988, western area, separately for 2–4 hauls per day, PPR	0.186357	261	0.081798	0.353418	85	-	-	-	-	-	-
29.	Subarea 48.3, June 1988, western area, separately for 9–12 hauls per day, PPR	-	-	-	-	-	-	-	-	-	-	-
30.	Subarea 48.3, June 1988, eastern area, separately for 2–4 hauls per day, PPR	0.106065	138	0.002857	0.07968	50	-	-	-	-	-	-
31.	Subarea 48.3, June 1988, eastern area, separately for 9–12 hauls per day, PPR	-	-	-	-	-	-	-	-	-	-	-

1 For a description of vessel types see Table 2 of Litvinov et al. (2003), all subareas: 48.1+48.2+48.3, entire period (as given above for the RIF statistics).
2 It was recommended that this vessel type be used in standardising fishing effort (Litvinov et al., 2002).
3 The data were used for CPUE calculation only when the number of hauls per vessel per day was within this range, according to the fishing strategy described.
4 This year was selected as the most representative of the whole dataset according to the RIF statistics.
5 This month was selected because the two areas (western and eastern) of krill fleet concentration ('basic fishing grounds' using the terminology of Sushin et al. (2002), examples of such distribution can be found in Sushin et al. (2002)) were most clearly visible.
6 CCs between catch per haul and the tow time were calculated.
7 Number of values compared.
8 CCs were calculated for total catches per day aggregated by vessel type divided by the number of hauls, and their total tow time divided by the number of hauls.
9 CCs between total catch per day aggregated by vessel type and total tow time were calculated.
10 CCs between total catch per 10-day period aggregated by vessel type and its total tow time were calculated.
11 CCs were calculated for total catch per 10-day period aggregated by vessel type divided by the number of hauls, and its total tow time divided by the number of hauls.
12 CCs between total catches per month aggregated by vessel type and their total tow time were calculated.
13 CCs were calculated for total catches per month aggregated by vessel type divided by the number of hauls, and their total tow time divided by the number of hauls.

year (0.587074), in a single month (0.695817) and in a single area of krill fleet concentration (0.715288);

(iii) the correlation for daily data was even lower than for haul-by-haul data, however the CC was relatively high for a single subarea in a single year and a single month (0.601568);

(iv) the correlation for total 10-day data was relatively high for all groups of data (0.715697–0.911598);

(v) the CCs for total monthly values, particularly for PPR vessels, were the highest (0.820892–0.957012);

(vi) for PPR vessels, the CCs calculated for haul-by-haul and daily data were even lower than for all vessel types, but the CCs for total 10-day and monthly data were the highest;

(vii) further splitting of data was not possible due to the low number of values considered (e.g. Subarea 48.3, all vessels, June 1988, western patch, separately for 9–12 hauls per day: $N = 4$).

It can therefore be concluded that the total monthly and total 10-day CCs, calculated as described above, show stable and high correlations between catches per haul and tow time. Monthly and 10-day CPUEs adequately reflect the state of krill biomass in fishing areas and can be used without further modification to monitor 10-day, monthly and longer-term fluctuations in krill biomass. It is, of course, necessary to use comparable data for a standard vessel type or to apply appropriate conversion factors.

It should be noted that for short hauls targeting single swarms of krill, CHT characterises the density of single krill swarms, but for long hauls it reflects the relative abundance of krill over the whole of the fishing ground. An analysis of mean monthly values of CVDF and CHT shows that the correlation between them is relatively low for all vessels (0.43–0.53) and is very high (0.87–0.88) for the PPR-type vessels.

Thus, it may be concluded that for the purpose of forecasting trends in the krill fishery, it is possible to use total daily CPUEs for the vessels targeting krill for human consumption and mean monthly values for the other vessels, but considered separately by vessel type.

As shown above, the degree of uncertainty in krill fishery statistics can be decreased significantly if the data are grouped according to various parameters. This would facilitate the use of such data for many purposes, including the evaluation of relative changes in krill biomass. Statistics containing more primary data (e.g. vessel type, haul duration, number of hauls per day, gear type, catch composition, end product, coordinates etc.) can be used to carry out more detailed analyses of recurrent patterns in CPUE indices and, therefore, to obtain more reliable estimates of krill abundance. This is also applicable to non-krill fisheries. The results and conclusions of the present paper are based on analyses of very detailed statistics on the Soviet krill fishery, the largest krill fishery in history, in which fishing effort reached 1 000 vessel-days fished per month, with more than 30 vessels fishing for krill at the same time (Litvinov et al., 2003). However it is clear that even this enormous dataset is not always sufficient for all the necessary calculations to be carried out.

It is widely recognised that there are grounds to believe that the krill fishery could expand greatly in the near future (Nicol and Foster, 2003). It is therefore very important to collect detailed statistical data on the krill fishery in order to be able to evaluate fluctuations in krill biomass caused by environmental factors or fishery pressure. The RIF statistics are a good example of such a database.

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