*CCAMLR Science*, Vol. 3 (1996): 111-123

# BY-CATCH OF FISHES CAPTURED BY THE KRILL FISHING VESSEL *CHIYO MARU NO. 2* IN STATISTICAL AREA 58 (JANUARY TO MARCH 1995)

G. Watters
NOAA Fisheries
Southwest Fisheries Science Center
US AMLR Program
PO Box 271, San Diego
CA 92038, USA

Abstract

Armstrong (1995) presented a final report of scientific observations conducted aboard the Japanese krill fishing vessel *Chiyo Maru No. 2*. Unfortunately, Armstrong's fish by-catch data were not presented in a standardised manner. This paper presents a brief re-analysis of the by-catch data collected on board the *Chiyo Maru No. 2*; means and variances are calculated from the delta distribution. In numbers, an average of about 14 fish were caught per tonne of krill, and an average of about 25 fish were caught per hour of towing. In weight, an average of about 1.2 kg of fish were caught per tonne of krill, and an average of about 2.2 kg of fish were caught per hour of towing. Confidence intervals for mean by-catch estimates are wide suggesting that, in the future, more hauls should be sampled for by-catch. The proportion of hauls containing fish was much higher for the *Chiyo Maru No. 2* than it was for other Japanese and Ukrainian krill trawlers fishing in the Atlantic sector of the Southern Ocean. This difference may be related to differences in the amount of krill that was subsampled for making observations on fish by-catch. The by-catch data from the *Chiyo Maru No. 2* did not provide a clear picture of the relationship between haul-specific fish by-catch and the catch rate of krill, and this observation is different from those made in most other studies. It would be worthwhile to estimate an appropriate sample size (in numbers of hauls) and subsample size (as a fraction of haul-specific krill catches) for observers collecting data on fish by-catch.

Résumé

Armstrong (1995) a présenté le rapport final des observations scientifiques menées à bord du navire japonais pêchant le krill, le *Chiyo Maru N° 2*. Malheureusement, les données de capture accessoire de poisson n'étaient pas présentées selon les normes établies. Cette communication présente une brève nouvelle analyse des données de capture accessoire collectées sur le *Chiyo Maru N° 2*; les moyennes et variances sont calculées à partir de la distribution delta. En moyenne, la capture s'élevait à environ 14 poissons par tonne de krill et 25 poissons par heure de chalutage, soit quelque 1,2 kg de poisson par tonne de krill et 2,2 kg par heure de chalutage. Les intervalles de confiance des estimations de capture accessoire moyenne étaient étendus, ce qui laisse entendre qu'à l'avenir, il conviendrait d'échantillonner davantage de chalutages en vue d'y examiner la capture accessoire. La proportion de chalutages contenant des poissons était nettement plus élevée pour le *Chiyo Maru N° 2* que pour les autres chalutiers à krill japonais et ukrainiens menant des opérations de pêche dans le secteur Atlantique de l'océan Austral. Cette différence peut s'expliquer par les différentes quantités de krill sous-échantillonnées pour l'observation de la capture accessoire de poissons. Les données de capture accessoire du *Chiyo Maru N° 2* n'illustrent pas clairement le rapport entre la capture accessoire de poisson par chalutage et le taux de capture de krill, or cette observation diverge de celles de la plupart des autres études. Il serait utile d'estimer la taille convenable des échantillons (en nombre de chalutages) et celle des sous-échantillons (en pourcentage des captures de krill par chalutage) à l'intention des observateurs recueillant des données de capture accessoire de poissons.

Резюме

В работе Армстронга (1995) дается окончательный отчет о научных наблюдениях, проведенных на борту японского крилевого траулера *Chiyo Maru No. 2*. К сожалению в этой работе данные по прилову рыб не представлены в стандартизованной форме. В настоящей работе дается краткий повторный анализ собранных на борту *Chiyo Maru No. 2* данных по прилову, при этом средние и дисперсионные величины рассчитаны по дельта-распределению. В среднем около 14 рыб вылавливалось на тонну криля, и 25 рыб на час траления. В плане веса средний прилов рыбы на тонну криля составил 1,2 кг, и около 2,2 кг рыбы вылавливалось на час траления. Доверительные интервалы оценок среднего прилова являются широкими, что говорит о необходимости увеличения количества тралений, которые нужно проверять на предмет прилова. Доля содержащих рыбу тралений была гораздо больше на судне *Chiyo Maru No. 2*, чем на других японских и украинских траулерах, осуществлявших промысел криля в атлантическом секторе Южного океана. Это различие может быть связано с различиями в количестве криля, включенного в подвыборку с целью изучения прилова рыб. Данные по прилову с судна *Chiyo Maru No. 2* не дали четкой картины взаимосвязи между приловом рыб в конкретных уловах и интенсивностью вылова криля; это наблюдение отличается от наблюдений, сделанных при большинстве других исследований. Имеет смысл определить для собирающих данные по прилову рыбы наблюдателей подходящий размер выборки (количество тралений) и размер подвыборки (доля уловов криля, относящихся к конкретным тралениям).

Resumen

Armstrong (1995) presentó un informe final de las observaciones científicas realizadas a bordo del pesquero japonés de kril *Chiyo Maru No. 2*. Lamentablemente los datos de la captura incidental de peces no fueron presentados en formato estándar. Este trabajo presenta un nuevo y breve análisis de los datos de captura incidental recopilados a bordo del *Chiyo Maru No. 2*; los promedios y variancias fueron determinados de la distribución delta. En número, se capturó un promedio de unos 14 peces por tonelada de kril, y un promedio de 25 peces por hora de arrastre. En peso, se capturó un promedio de 1,2 kg de peces por tonelada de kril y un promedio de 2,2 kg de peces por hora de arrastre. Los intervalos de confianza de las estimaciones del promedio de la captura incidental son amplios lo que sugiere que, en el futuro, se debieran muestrear más arrastres para determinar la captura incidental. La proporción de los arrastres que contenían peces fue mucho mayor para el *Chiyo Maru No. 2* que para otros arrastreros japoneses o ucranianos que faenaron el kril en el sector atlántico del océano Austral. Esto puede deberse a diferencias en la cantidad de kril que fue submuestreada para las observaciones de peces en la captura incidental. Los datos de captura secundaria del *Chiyo Maru No. 2* no aclararon la relación entre la captura incidental de peces para un arrastre en particular y la tasa de captura de kril; esto difiere a lo observado en la mayoría de otros estudios. Sería conveniente estimar un tamaño adecuado de muestra (en números de arrastre) y de submuestra (como fracción de la captura de kril en un arrastre determinado) para los observadores que recopilan datos de los peces presentes en la captura incidental.

Keywords: by-catch, CCAMLR, delta distribution, juvenile fish, krill fishery

## INTRODUCTION

By-catch of non-target species is a problem in many trawl fisheries. Antarctic trawl fisheries are no exception, and CCAMLR is currently attempting to determine whether the Antarctic krill (*Euphausia superba*) fishery poses a threat to the recruitment of juvenile finfish. Antarctic krill are captured with midwater trawl gear, and juvenile fish occur in the by-catch of this fishery.

CCAMLR has received four reports summarising observations on the fish by-catch of Japanese krill trawlers fishing in Antarctic waters (Iwami, 1993, 1994, 1995; Armstrong, 1995). Most of the by-catch data in these reports were collected on vessels fishing in the Atlantic sector of the Southern Ocean (Statistical Area 48), but Armstrong (1995) reported on a vessel fishing in the south Indian Ocean (Statistical Area 58). In general, these observers showed that fish were present in the krill catches, but the levels of by-catch per tonne of krill appeared to be low.

CCAMLR has published a *Scientific Observers Manual* (CCAMLR, 1993) recommending that fish by-catch data collected from commercial krill trawlers be standardised by krill catch and fishing effort. Unfortunately, the by-catch data presented in Armstrong (1995) were not properly standardised. This paper presents Armstrong's by-catch data in a standardised format and provides estimates of the means and variances of the data. The results of this reworking of Armstrong's data are compared to results from previously published works, and special attention is given to the topic of subsampling the krill catch.

## METHODS

The haul-by-haul fish by-catch data from Armstrong (1995) are given in Table 1; these data were collected on board the *Chiyo Maru No. 2* while the vessel was fishing in Statistical Area 58 (see Figure 1 for fishing location). Table 1 includes standardised, haul-specific by-catches in terms of numbers and weight of fish per tonne of krill and numbers and weight of fish per hour of trawling. The data are presented for all fish species combined, *Dissostichus mawsoni*, *Notolepis coatsi* and 'unknown myctophids'. *D. mawsoni*, *N. coatsi* and unknown myctophids were the three most frequently identified species/families in the *Chiyo Maru No. 2*'s by-catch (Armstrong, 1995).

The data in Table 1 contain a large number of zero observations, so means and variances of the standardised by-catches were calculated from the statistics of mixture distributions having discrete probability masses at zero and conditional probability densities for non-zero data. This approach has previously been used for analysing fish by-catch data from a Ukrainian trawler (Pakhomov and Pankratov, 1994). The conditional density functions for Armstrong's data were identified by visual inspections of q-q plots. Normal q-q plots for the natural logarithms of the non-zero, standardised by-catches in Table 1 are presented in Figures 2 to 5. From a visual inspection, it appears that the distribution of the non-zero by-catch observations is lognormal for all fish species combined. In contrast, it also appears that species/family-specific distributions of non-zero by-catches are not lognormal.

Aitchison (1955) and Pennington (1983) provided efficient estimators for means and variances of data that come from a mixture distribution with a discrete probability mass at zero and a conditional distribution for non-zero observations that is lognormal. The density function of such a distribution is given by

$$f(x) = (1-p)\mathrm{I}_0[x] + p\frac{1}{x\kappa\sqrt{2\pi}}\exp\left(-\frac{(\ln x - \lambda)^2}{2\kappa^2}\right)\mathrm{I}_{(0,\infty)}[x] \qquad (1)$$

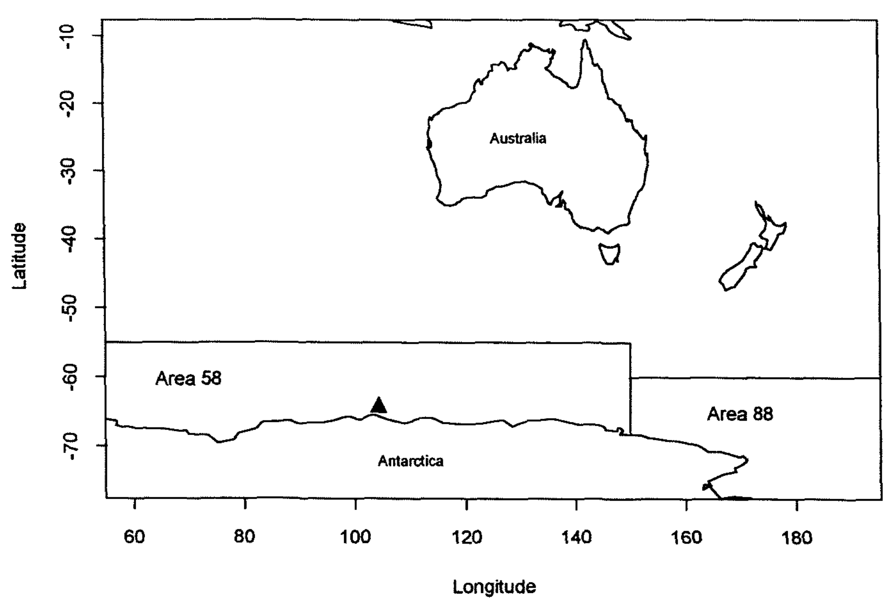


Figure 1: Location where the *Chiyo Maru No. 2* fished for krill during the period January to March 1995. The general location of fishing is marked by the solid triangle; specific haul positions are reported in Table 1.

Table 1: Haul characteristics and observed by-catches from the krill fishing vessel *Chiyo Maru No. 2* (Statistical Area 58, January-March 1995). The original data came from Armstrong (1995). Haul positions are recorded for the starting point of each haul.

| Haul Characteristics | | | | | | | | By-catch of All Fish Species Combined | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Haul | Tonnes Caught | Tonnes Sampled | Sampling Fraction | Tow Hours | Start Time | Degrees S Latitude | Degrees E Longitude | No. | Kg | No./ tonne | No./ hour | Kg/tonne | Kg/hour |
| 6 | 1.5 | 0.38 | 0.25 | 0.25 | 0315 | 63.642 | 104.633 | 1 | 0.01 | 2.67 | 4.00 | 0.029 | 0.044 |
| 17 | 5.0 | 0.02 | 0.004 | 1.08 | 2315 | 63.828 | 104.277 | 2 | 0.04 | 113.64 | 1.85 | 2.100 | 0.034 |
| 31 | 6.0 | 3.00 | 0.50 | 2.17 | 1705 | 63.947 | 104.532 | 55 | 2.56 | 18.33 | 25.35 | 0.853 | 1.180 |
| 43 | 6.5 | 6.50 | 1.00 | 1.17 | 0020 | 64.075 | 104.293 | 8 | 0.34 | 1.23 | 6.84 | 0.053 | 0.291 |
| 59 | 5.0 | 1.70 | 0.34 | 1.67 | 1720 | 64.222 | 104.650 | 34 | 0.74 | 20.00 | 20.36 | 0.434 | 0.441 |
| 62 | 10.0 | 7.00 | 0.70 | 1.58 | 0125 | 64.250 | 104.632 | 3 | 0.03 | 0.43 | 1.90 | 0.005 | 0.021 |
| 70 | 0.4 | 0.40 | 1.00 | 0.50 | 2005 | 63.802 | 105.002 | 3 | 0.97 | 7.50 | 6.00 | 2.430 | 1.940 |
| 75 | 10.0 | 2.50 | 0.25 | 1.83 | 0945 | 63.647 | 104.073 | 42 | 1.59 | 16.80 | 22.95 | 0.636 | 0.869 |
| 83 | 7.0 | 4.00 | 0.57 | 1.17 | 0730 | 63.782 | 104.293 | 1 | 0.14 | 0.25 | 0.85 | 0.035 | 0.120 |
| 86 | 12.0 | 3.00 | 0.25 | 2.08 | 1505 | 63.805 | 104.460 | 3 | 0.14 | 1.00 | 1.44 | 0.047 | 0.068 |
| 91 | 8.0 | 4.00 | 0.50 | 1.92 | 1050 | 63.657 | 103.555 | 24 | 0.23 | 6.00 | 12.50 | 0.058 | 0.120 |
| 98 | 5.0 | 2.00 | 0.40 | 1.58 | 0545 | 63.725 | 103.795 | 1 | 0.02 | 0.50 | 0.63 | 0.008 | 0.009 |
| 101 | 11.0 | 5.00 | 0.45 | 0.83 | 1345 | 63.723 | 103.747 | 41 | 2.75 | 8.20 | 49.40 | 0.549 | 3.310 |
| 107 | 5.5 | 4.00 | 0.73 | 1.50 | 0730 | 63.863 | 103.975 | 4 | 0.21 | 1.00 | 2.67 | 0.052 | 0.138 |
| 118 | 11.0 | 3.00 | 0.27 | 2.25 | 1300 | 64.045 | 103.917 | 151 | 10.73 | 50.33 | 67.11 | 3.580 | 4.770 |
| 132 | 12.0 | 7.00 | 0.58 | 1.25 | 0135 | 64.220 | 103.995 | 0 | 0.00 | 0.00 | 0.00 | 0.000 | 0.000 |
| 137 | 8.0 | 3.00 | 0.38 | 1.17 | 1415 | 64.200 | 104.140 | 230 | 19.36 | 76.67 | 196.58 | 6.450 | 16.500 |
| 146 | 8.0 | 8.00 | 1.00 | 1.67 | 1250 | 64.173 | 104.295 | 8 | 0.50 | 1.00 | 4.79 | 0.063 | 0.299 |
| 148 | 7.0 | 3.50 | 0.50 | 1.75 | 1825 | 64.183 | 104.267 | 118 | 6.50 | 33.71 | 67.43 | 1.860 | 3.710 |
| 152 | 5.0 | 2.50 | 0.50 | 1.67 | 0440 | 64.192 | 104.110 | 2 | 0.02 | 0.80 | 1.20 | 0.010 | 0.014 |
| 156 | 5.0 | 2.50 | 0.50 | 1.67 | 2310 | 64.223 | 104.163 | 6 | 1.42 | 2.40 | 3.59 | 0.567 | 0.849 |

| | By-catch of *D. mawsoni* | | | | | | By-catch of *N. coatsi* | | | | | | By-catch of Unidentified Myctophids | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Haul | No. | Kg | No./ tonne | No./ hour | Kg/ tonne | Kg/ hour | No. | Kg | No./ tonne | No./ hour | Kg/ tonne | Kg/ hour | No. | Kg | No./ tonne | No./ hour | Kg/ tonne | Kg/ hour |
| 6 | 1 | 0.01 | 2.67 | 4.00 | 0.029 | 0.044 | 0 | 0.00 | 0.00 | 0.00 | 0.000 | 0.000 | 0 | 0.00 | 0.00 | 0.00 | 0.000 | 0.000 |
| 17 | 1 | 0.01 | 56.82 | 0.93 | 0.682 | 0.011 | 0 | 0.00 | 0.00 | 0.00 | 0.000 | 0.000 | 0 | 0.00 | 0.00 | 0.00 | 0.000 | 0.000 |
| 31 | 0 | 0.00 | 0.00 | 0.00 | 0.000 | 0.000 | 48 | 2.28 | 16.00 | 22.12 | 0.760 | 1.050 | 6 | 0.03 | 2.00 | 2.76 | 0.009 | 0.013 |
| 43 | 4 | 0.04 | 0.62 | 3.42 | 0.007 | 0.038 | 3 | 0.09 | 0.46 | 2.56 | 0.013 | 0.073 | 0 | 0.00 | 0.00 | 0.00 | 0.000 | 0.000 |
| 59 | 1 | 0.01 | 0.59 | 0.60 | 0.007 | 0.007 | 33 | 0.73 | 19.41 | 19.76 | 0.426 | 0.434 | 0 | 0.00 | 0.00 | 0.00 | 0.000 | 0.000 |
| 62 | 3 | 0.03 | 0.43 | 1.90 | 0.005 | 0.021 | 0 | 0.00 | 0.00 | 0.00 | 0.000 | 0.000 | 0 | 0.00 | 0.00 | 0.00 | 0.000 | 0.000 |
| 70 | 0 | 0.00 | 0.00 | 0.00 | 0.000 | 0.000 | 0 | 0.00 | 0.00 | 0.00 | 0.000 | 0.000 | 0 | 0.00 | 0.00 | 0.00 | 0.000 | 0.000 |
| 75 | 0 | 0.00 | 0.00 | 0.00 | 0.000 | 0.000 | 33 | 1.34 | 13.20 | 18.03 | 0.536 | 0.732 | 9 | 0.03 | 3.60 | 4.92 | 0.010 | 0.014 |
| 83 | 0 | 0.00 | 0.00 | 0.00 | 0.000 | 0.000 | 0 | 0.00 | 0.00 | 0.00 | 0.000 | 0.000 | 0 | 0.00 | 0.00 | 0.00 | 0.000 | 0.000 |
| 86 | 0 | 0.00 | 0.00 | 0.00 | 0.000 | 0.000 | 3 | 0.14 | 1.00 | 1.44 | 0.047 | 0.068 | 0 | 0.00 | 0.00 | 0.00 | 0.000 | 0.000 |
| 91 | 0 | 0.00 | 0.00 | 0.00 | 0.000 | 0.000 | 0 | 0.00 | 0.00 | 0.00 | 0.000 | 0.000 | 23 | 0.01 | 5.75 | 11.98 | 0.003 | 0.006 |
| 98 | 0 | 0.00 | 0.00 | 0.00 | 0.000 | 0.000 | 1 | 0.02 | 0.50 | 0.63 | 0.008 | 0.009 | 0 | 0.00 | 0.00 | 0.00 | 0.000 | 0.000 |
| 101 | 0 | 0.00 | 0.00 | 0.00 | 0.000 | 0.000 | 39 | 2.50 | 7.80 | 46.99 | 0.500 | 3.010 | 0 | 0.00 | 0.00 | 0.00 | 0.000 | 0.000 |
| 107 | 0 | 0.00 | 0.00 | 0.00 | 0.000 | 0.000 | 3 | 0.05 | 0.75 | 2.00 | 0.014 | 0.036 | 0 | 0.00 | 0.00 | 0.00 | 0.000 | 0.000 |
| 118 | 1 | 0.01 | 0.33 | 0.44 | 0.004 | 0.005 | 149 | 10.50 | 49.67 | 66.22 | 3.500 | 4.670 | 0 | 0.00 | 0.00 | 0.00 | 0.000 | 0.000 |
| 132 | 0 | 0.00 | 0.00 | 0.00 | 0.000 | 0.000 | 0 | 0.00 | 0.00 | 0.00 | 0.000 | 0.000 | 0 | 0.00 | 0.00 | 0.00 | 0.000 | 0.000 |
| 137 | 1 | 0.01 | 0.33 | 0.85 | 0.004 | 0.009 | 214 | 19.30 | 71.33 | 182.91 | 6.430 | 16.500 | 15 | 0.05 | 5.00 | 12.82 | 0.017 | 0.043 |
| 146 | 1 | 0.01 | 0.13 | 0.60 | 0.001 | 0.007 | 7 | 0.49 | 0.88 | 4.19 | 0.061 | 0.293 | 0 | 0.00 | 0.00 | 0.00 | 0.000 | 0.000 |
| 148 | 0 | 0.00 | 0.00 | 0.00 | 0.000 | 0.000 | 118 | 6.50 | 33.71 | 67.43 | 1.860 | 3.710 | 0 | 0.00 | 0.00 | 0.00 | 0.000 | 0.000 |
| 152 | 2 | 0.02 | 0.80 | 1.20 | 0.010 | 0.014 | 0 | 0.00 | 0.00 | 0.00 | 0.000 | 0.000 | 0 | 0.00 | 0.00 | 0.00 | 0.000 | 0.000 |
| 156 | 0 | 0.00 | 0.00 | 0.00 | 0.000 | 0.000 | 4 | 0.12 | 1.60 | 2.40 | 0.048 | 0.072 | 0 | 0.00 | 0.00 | 0.00 | 0.000 | 0.000 |

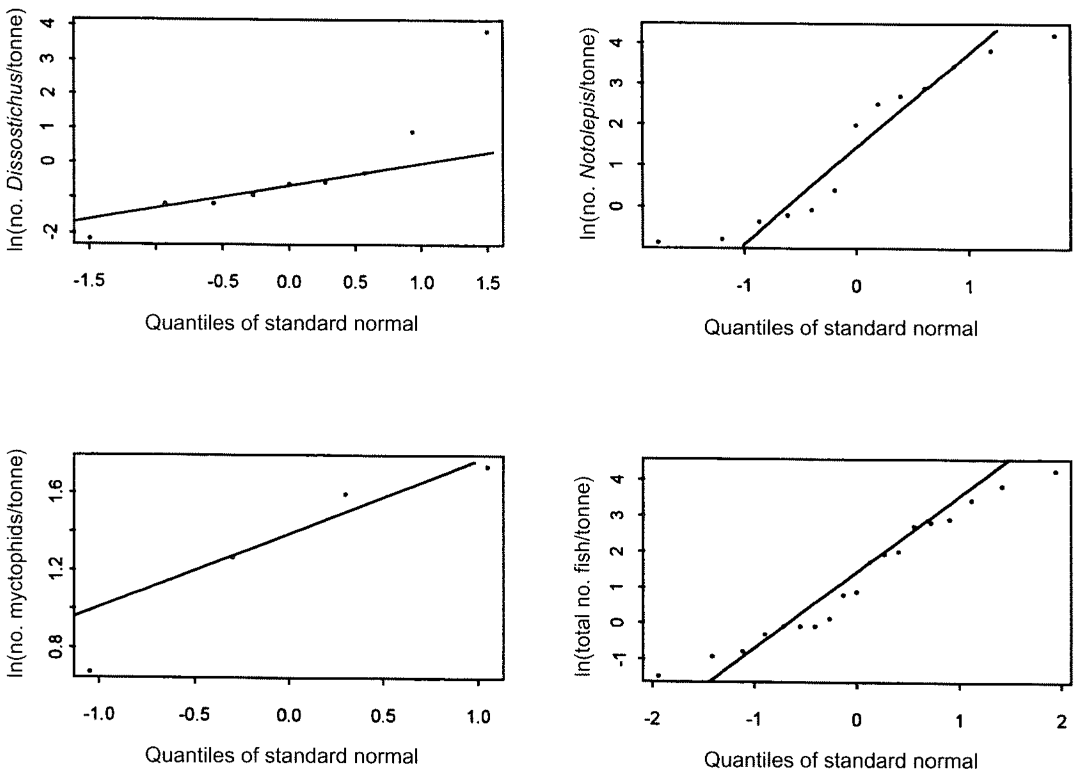


Figure 2: Normal q-q plots of ln(by-catch) in numbers of fish per tonne of krill sampled.

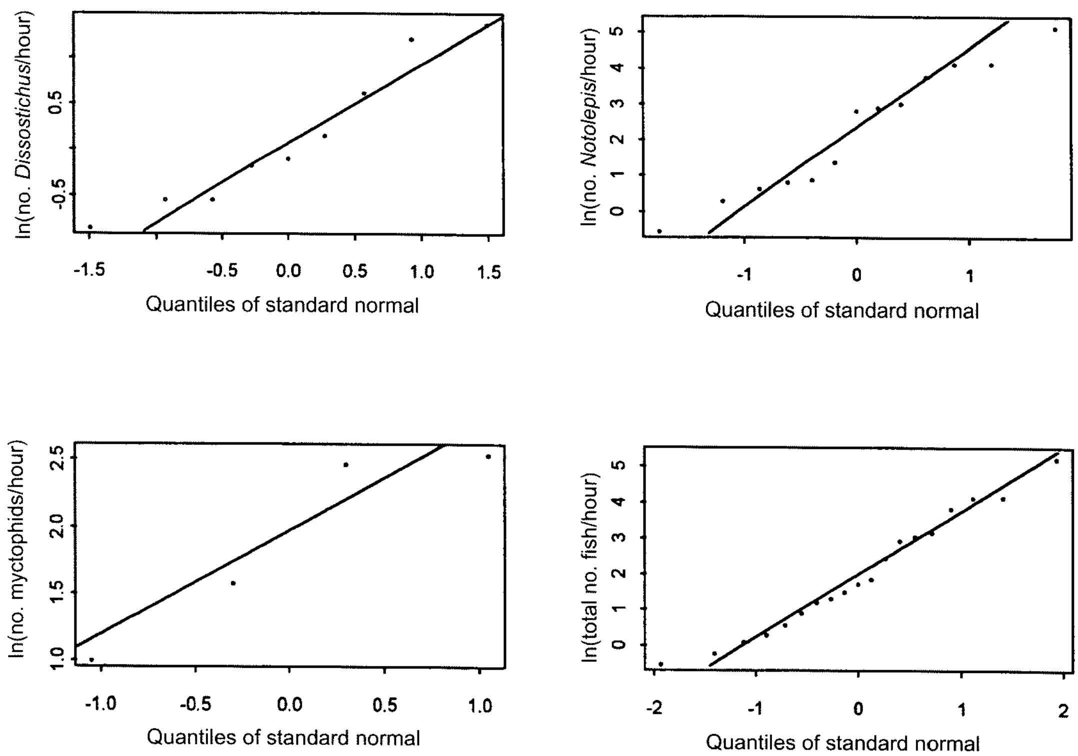


Figure 3: Normal q-q plots of ln(by-catch) in numbers of fish per hour of trawling for krill.

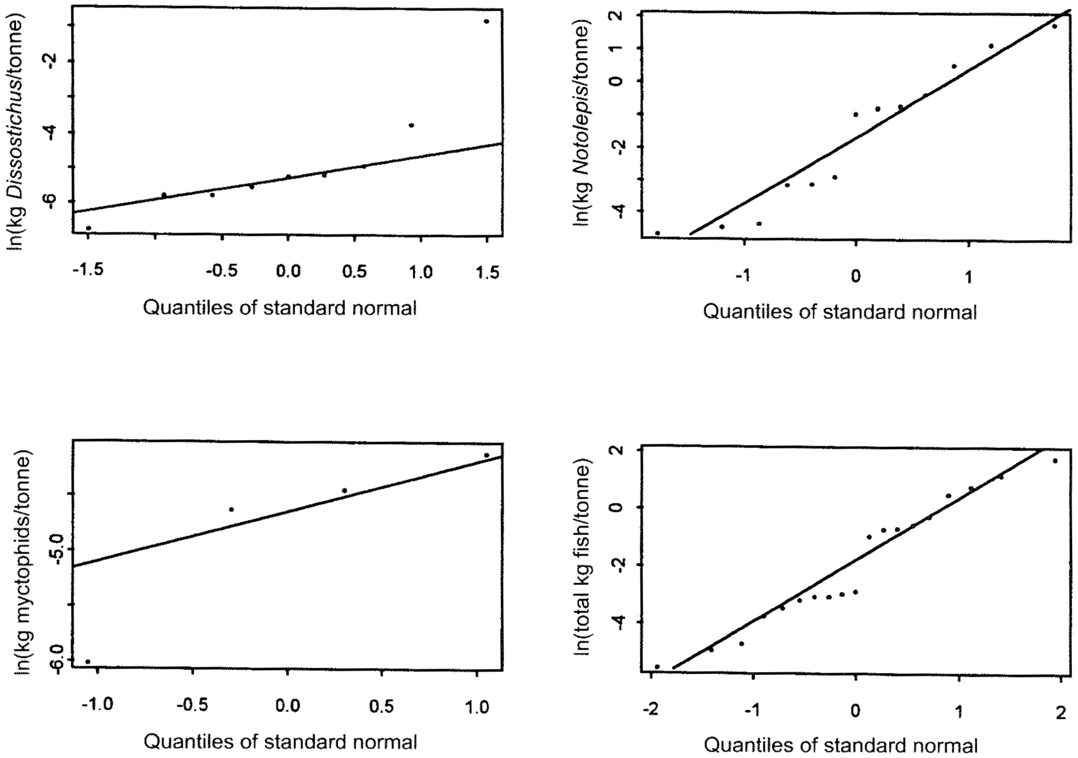


Figure 4: Normal q-q plots of ln(by-catch) in kilograms of fish per tonne of krill sampled.

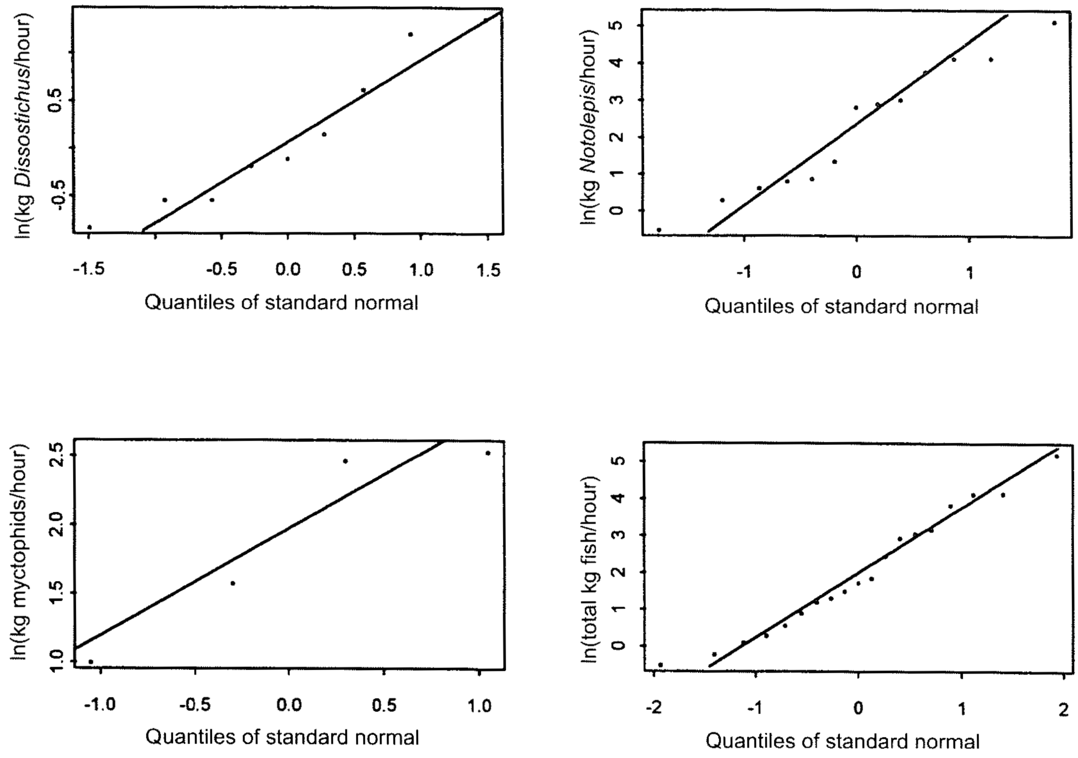


Figure 5: Normal q-q plots of ln(by-catch) in kilograms of fish per hour of trawling for krill.

where $p$ is the proportion of observations for which $x > 0$, and $\lambda$ and $\kappa^2$ are, respectively, the mean and variance of the lognormally distributed observations for which $x > 0$. $I_0[x]$ is an indicator function that takes the value 1 when $x = 0$ and the value 0 when $x > 0$; $I_{(0,\infty)}[x]$ is a second indicator function that takes the value 0 when $x = 0$ and the value 1 when $x > 0$. The mixture distribution in equation (1) is known as the delta distribution and the statistics of this distribution were used to analyse the standardised by-catches of all fish species combined (see Table 1).

When there is more than one non-zero observation, the mean of delta-distributed data is estimated as

$$c = \frac{m}{n}\exp(\bar{y})G_m\left(\tfrac{1}{2}s^2\right) \tag{2}$$

where $n$ is the total number of observations; $m$ is the number of non-zero observations; $\bar{y}$ is the sample mean of the natural logarithm of the non-zero observations; $s^2$ is the sample variance of the natural logarithm of the non-zero observations; and

$$G_n(t) = 1 + \frac{n-1}{n}t + \sum_{j=2}^{\infty}\frac{t^j(n-1)^{2j-1}}{j!\,n^j(n+1)(n+3)\ldots(n+2j-3)} \tag{3}$$

The variance of delta-distributed data with more than one non-zero observation is estimated as

$$d = \frac{m}{n}\exp(2\bar{y})\left\{G_m\left(2s^2\right) - \left(\frac{m-1}{n-1}\right)G_m\left(\frac{m-2}{m-1}s^2\right)\right\} \tag{4}$$

The variance of the mean of delta-distributed data with more than one non-zero observation is estimated as

$$\mathrm{var}_{\mathrm{est}}(c) = \frac{m}{n}\exp(2\bar{y})\left\{\frac{m}{n}G_m^2\left(\tfrac{1}{2}s^2\right) - \left(\frac{m-1}{n-1}\right)G_m\left(\frac{m-2}{m-1}s^2\right)\right\} \tag{5}$$

$c$, $d$ and $\mathrm{var}_{\mathrm{est}}(c)$ are minimum variance unbiased estimators. Asymptotic confidence intervals for the mean of delta-distributed data can be obtained by finding the roots of the following function:

$$q(c) = \left[\ln L\left(\mathbf{x};p,\lambda,\kappa^2\right)\middle| \begin{array}{l} p = \dfrac{m}{n} \\ \lambda = \dfrac{1}{m}\sum_{x_i>0}\ln x_i \\ \kappa^2 = \dfrac{1}{m}\sum_{x_i>0}\left(\ln x_i - \lambda\right)^2 \end{array}\right] - \sup\left[\ln L\left(\mathbf{x};p,\lambda,\kappa^2\right)\middle| \begin{array}{l} 0 < p \le 1 \\ \lambda = \ln\left(\dfrac{c}{pG_m\left(\frac{1}{2}\kappa^2\right)}\right) \\ 0 < \kappa^2 \le \infty \end{array}\right] - \tfrac{1}{2}\chi^2_{1,\alpha} \tag{6}$$

(de la Mare, 1994a, 1994b). W.K. de la Mare has provided CCAMLR with a piece of software that finds the roots of equation (6) (de la Mare, 1994a). The program is named 'TRAWLCI' and it was used to estimate confidence limits for the estimated mean by-catches of all fish species combined.

The data from one haul (Table 1, haul no. 17) were excluded from all analyses. These data were excluded because only about 20 kg of krill was subsampled for by-catch; this was an order of magnitude less than the next smallest subsample of krill (380 kg of krill were subsampled from haul no. 6). According to Armstrong's field notebook (unpublished work), haul no. 17's small sample size was a result of mechanical malfunctions in the *Chiyo Maru No. 2*'s conveyor system. Data collection from haul no. 17 was probably not comparable to data collection from the other hauls.

## RESULTS

*N. coatsi* was the most abundant fish (in numbers and weight) in the *Chiyo Maru No. 2*'s by-catch; this species occurred in 65% of the hauls sampled for by-catch (Table 1). *D. mawsoni* occurred in 45% of the hauls sampled for by-catch and 'unknown myctophids' occurred in 20% of the hauls sampled for by-catch (Table 1). Other fish species contained in the by-catch but not reported (because of rare occurrence) in Table 1 included *Anotopterus pharao, Magnisudis prionosa, Neopagetopsis ionah* and *Pseudocyttus maculatus* (Armstrong, 1995). Armstrong (1995) also reported the presence of *Psychroteuthis glacialis* and other, unidentified, squids in the *Chiyo Maru No. 2*'s by-catch.

Table 2: By-catch statistics for all fish species combined (data collected on board the *Chiyo Maru No. 2*). See text for a description of each statistic; the estimated mean by-catches are outlined by a dashed box. By-catch data from haul no. 17 were not included in the calculations.

| | No. fish/tonne krill | No. fish/hour | Kg fish/tonne krill | Kg fish/hour |
|---|---|---|---|---|
| $n$ | 20 | 20 | 20 | 20 |
| $m$ | 19 | 19 | 19 | 19 |
| $\bar{y}$ | 1.33 | 2.05 | -1.80 | -1.09 |
| $s^2$ | 3.05 | 2.72 | 4.74 | 4.46 |
| $G_m(^1/_2 s^2)$ | 3.90 | 3.39 | 7.83 | 6.98 |
| $G_m(2s^2)$ | 119.09 | 76.09 | 1031.03 | 729.69 |
| $G_m(s^2(m-2)/(m-1))$ | 11.68 | 9.15 | 38.68 | 31.85 |
| $c$ | 14.01 | 25.02 | 1.23 | 2.23 |
| $d$ | 1467.14 | 3864.83 | 25.81 | 75.12 |
| $\mathrm{var}_{est}(c)$ | 36.15 | 97.63 | 0.49 | 1.48 |
| 95% CI for $c$ | (5.59, 65.15) | (10.66, 102.75) | (0.36, 10.69) | (0.68, 16.70) |

Summary statistics for the by-catch of all fish species combined are given in Table 2. In numbers, an average of about 14 fish were caught per tonne of krill, and about 25 fish were caught per hour of trawling. In weight, an average of about 1 kg of fish was caught per tonne of krill, and about 2 kg of fish were caught per hour of trawling. Confidence intervals for these means are wide, so there is a large amount of uncertainty about these estimates.

The *Chiyo Maru No. 2* caught an estimated 1 264 tonnes of krill (Armstrong, 1995). Extrapolating the mean by-catch (in numbers of fish per tonne of krill caught) for all fish species to the *Chiyo Maru No. 2*'s total krill catch gives an estimate of 17 709 total fish ($T$) in the by-catch. There is a large amount of uncertainty in the estimate of $T$; $\Pr(7\ 066 \leq T \leq 82\ 350) \approx 0.95$. Extrapolating the mean weight of fish by-catch (all species) to the *Chiyo Maru No. 2*'s krill catch gives an estimate of about 1 555 total kilograms ($Tkg$) of fish in the total by-catch, and $\Pr(455 \leq Tkg \leq 13\ 512) \approx 0.95$.

## DISCUSSION

Table 3 provides a comparison of the results from this study to some of the results available from previous studies on fish by-catch in krill trawls. The table shows that by-catch studies have been conducted over a wide range of vessel nationalities and types, times of year, areas and depths. The differences within these parameters have contributed to significant variation in the species compositions of reported by-catches. The number of fish species in the *Chiyo Maru No. 2*'s by-catch was in the middle of the range of previously-reported species numbers, but the *Chiyo Maru No. 2* was the first vessel to have *N. coatsi* as the most abundant species in the fish by-catch (Table 3).

On the *Chiyo Maru No. 2*, 95% of the hauls that were sampled for by-catch contained fish (Tables 1 and 3) (Armstrong, 1995). This proportion is much higher than has been found on Japanese and Ukrainian krill trawlers fishing in Statistical Area 48 (Table 3). The proportions of hauls containing fish reported by Iwami (1993, 1994 and 1995) and Pakhomov and Pankratov (1994) may be lower than that on the *Chiyo Maru No. 2* because of the previously-noted differences in by-catch species composition but, alternatively, these proportions may be lower because of differences in sampling methodology. Compared to Armstrong, Iwami and Pakhomov and Pankratov subsampled much smaller fractions of each haul's krill catch while looking for fish. Iwami reported a range of sampling fractions (subsample weights divided by total catch weights) from 0.2 to 0.8%, while Pakhomov and Pankratov reported sampling fractions in the range 0.1 to 5% (Table 3). In contrast, Armstrong's sampling fractions on the *Chiyo Maru No. 2* ranged from 25 to 100% (Tables 1 and 3). Note that the results of Pankratov and Pakhomov (1992) and Everson et al. (1991) are based on large sampling fractions, and these authors have also shown that most sampled hauls actually contain fish (Table 3).

With small subsamples of krill, it is likely that by-catch will not be observed from hauls which actually contain fish. Results presented by Slosarczyk (1983a, 1983b and 1986) and Slosarczyk and Rembiszewski (1982) support this conclusion. These four Polish studies provide data on a number of hauls where fish were

Table 3: Results from various studies of juvenile fish by-catch in krill trawls. Question marks identify missing pieces of information and the word 'unclear' identifies results that are available but difficult to interpret.

| | This Study and Armstrong 1995 | Iwami 1995 | Iwami 1994 | Pakhomov and Pankratov 1994 | Iwami 1993 | Pankratov and Pakhomov 1992[1] | Everson et al. 1991[2] | Everson et al. 1991[3] | Everson et al. 1991[2] |
|---|---|---|---|---|---|---|---|---|---|
| Vessel nationality | Japan | Japan | Japan | Ukraine | Japan | Ukraine | Russia | Russia | Russia |
| Vessel type | FV | FV | FV | FV | FV | FV | RV | RV | RV |
| Time of year | Jan-Mar 1995 | Jan-Feb 1995 | Jan-Feb 1994 | May-Jul 1992 | Jul-Aug 1992 | Jan-Feb 1988 | Apr-May 1981 | Jan-Feb 1987 | Mar 1981 |
| CCAMLR subarea/division fished | 58.4.1 | 48.1 | 48.1 | 48.3 | 48.3 | 58.4.2 | 48.3 | 48.2 | 48.6 |
| Bottom depth (m) | > 2500 | > 500 | ? | < 300 | 80 - 350 | 300 - 4200 | 110 - 5120 | 100 - 4000 | 220 - 5200 |
| Minimum number of species | 7 | 5 | 13 | 4 | 3 | 7 | 5 | 7 | 8 |
| Most abundant species | *N. coatsi* | *E. antarctica* | *L. larseni* | *C. gunnari, L. larseni* | *L. larseni* | *P. antarcticum* | *C. gunnari* | ? | ? |
| % sampled hauls containing fish | 95 | 26 | 25 | 18 | 27 | 100 | 73 | 63 | 71 |
| Range of sampling fractions | 25 - 100 | 0.2 - 0.8 | ? | 0.1 - 5.0 | 0.2 - 0.4 | ? | 0.2 - 100.0 | 100.0 | 100.0 |
| Trend in by-catch with increasing krill CPUE | unclear | decreasing | decreasing | unclear | ? | decreasing | decreasing | decreasing | decreasing |

| | Slosarczyk 1986 | Slosarczyk 1983a | Slosarczyk 1983b | Slosarczyk and Rembiszewski 1982 |
|---|---|---|---|---|
| Vessel nationality | Poland | Poland | Poland | Poland |
| Vessel type | RV | RV | RV | RV |
| Time of year | Dec 1983 - Jan 1984 | April 1981 | Jan-Feb 1978 | Feb-Mar 1981 |
| CCAMLR subarea/division fished | 48.1 | 48.3 | 88.1 | 48.1 |
| Bottom depth (m) | 91 - 3100 | < 1000 | 1100 - 2750 | 60 - 3700 |
| Minimum number of species | 14 | 6 | 2 | 23 |
| Most abundant species | *C. aceratus* | *C. gunnari, L. larseni* | *T. bernacchii* | *C. dewitti* |
| % sampled hauls containing fish | 89 (19)[4] | 88 (12)[4] | 100 (7)[4] | 97 (39)[4] |
| Range of sampling fractions | ? - 100 | ? | ? | ? - 100 |
| Trend in by-catch with increasing krill CPUE | decreasing | unclear | decreasing | ? |

1 Data from commercial trawl catches only    2 *Akademik Knipovich* data only    3 *Evrika* data only
4 Numbers in parentheses indicate the percentage of hauls where none of the observed by-catch fishes were represented in the original subsample of krill.

present in the by-catches but not represented in the subsamples; this occurred in 7 to 39% of the sampled hauls (Table 3). It is not possible to calculate sampling fractions from the information given in the four Polish papers, but subsample sizes ranged from 1 to 160 kg of krill. When by-catch is not observed from hauls actually containing fish, estimates of the mean and total by-catch will be biased because the parameter $p$ from equation (1) will be underestimated.

The by-catch data from the *Chiyo Maru No. 2* did not provide a clear picture of the relationship between haul-specific fish by-catch and the catch rate of krill (Figure 6, top two panels). This observation is different from observations made in previous studies where, in general, fish by-catch decreased with increasing krill catch rates (Table 3). The top two panels of Figure 6 are, however, similar to results presented by Pakhomov and Pankratov (1994). The results of this study and of Pakhomov and Pankratov (1994) suggest that there may not be a simple, negative correlation between fish by-catch and krill catch rate.

A comparison of the results from this paper and the results from previous studies indicates that inferences drawn from by-catch data are sensitive to the amount of krill that is subsampled. Therefore, it would be worthwhile for CCAMLR to re-evaluate its recommendation that observers look for by-catch in 40 to 50 kg subsamples of krill (CCAMLR, 1993). Future recommendations regarding subsample size should probably be expressed in terms of examining a minimum fraction of each haul's krill catch.

It is obvious that there is a great deal of uncertainty in the estimates of mean and total by-catch (Table 2). In the future this uncertainty can probably be reduced by sampling a larger number of hauls for by-catch (recall that Table 1 includes 20 'useable' hauls). Unfortunately, sampling additional hauls may be difficult since CCAMLR's *Scientific Observers Manual* (CCAMLR, 1993) lists by-catch sampling as the second lowest priority for observers on commercial krill trawlers. Increased by-catch sampling can only occur at the expense of placing less emphasis on other sampling activities, and CCAMLR may wish to re-evaluate the current list of priority tasks for krill fishery observers. To assist such a re-evaluation, it may be useful to attempt to estimate the sample size (in hauls or kilograms of krill) required to obtain a reasonably precise estimate of the total or mean by-catch.

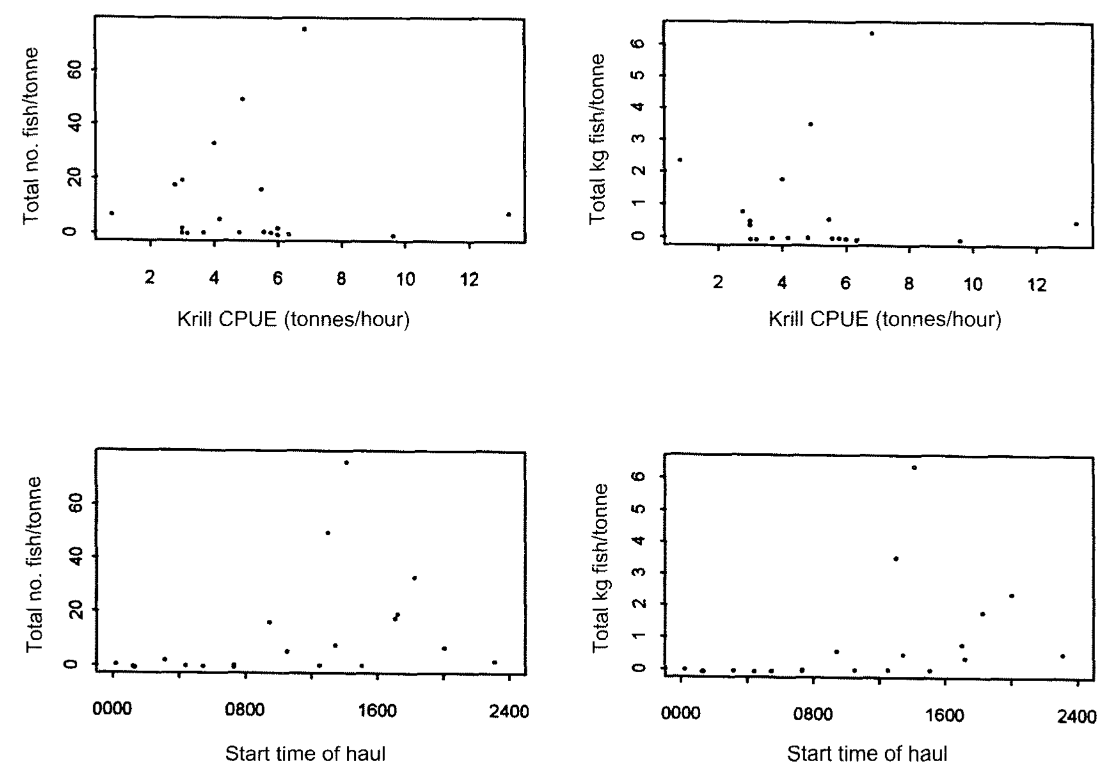


Figure 6: Observed relationships between total fish by-catch (in numbers and tonnes) and krill CPUE and between by-catch and time of haul.

Besides recommending standardisation of fish by-catch data, CCAMLR's *Scientific Observers Manual* (CCAMLR, 1993) outlines the importance of reporting by-catches in reference to the geographic position and time of day for each haul. It is not feasible to make contour plots of the *Chiyo Maru No. 2*'s by-catch; the spatial separation of the data does not lend itself to contouring. Haul-specific fish by-catches from the *Chiyo Maru No. 2* were highest between about 1200 and 1800 hours local time (Figure 6, bottom two panels); *N. coatsi* was the most abundant fish in the by-catch during this time interval (Table 1).

ACKNOWLEDGEMENTS

I would like to thank Mr W. Armstrong for providing data on the *Chiyo Maru No. 2*'s by-catch and Drs Z. Cielniaszek, T. Iwami and E. Pakhomov for useful criticisms of a draft version of this paper. Thanks are also due to Dr W. de la Mare for providing the program used to compute confidence intervals for the means of delta-distributed data.

REFERENCES

Aitchison, J. 1955. On the distribution of a positive random variable having a discrete probability mass at the origin. *Journal of the American Statistical Association*, 50: 901-908.

Armstrong, W. 1995. Final report of scientific observations of commercial krill harvest aboard the Japanese fishing vessel *Chiyo Maru No. 2*, 19 January - 2 March 1995. Document *SC-CAMLR-XIV/BG/10 Rev. 1*. CCAMLR, Hobart, Australia: 17 pp.

CCAMLR. 1993. *Scientific Observers Manual*. Pilot Edition. CCAMLR, Hobart, Australia: 68 pp.

de la Mare, W.K. 1994a. Estimating confidence intervals for fish stock abundance estimates from trawl surveys. *CCAMLR Science*, 1: 203-207.

de la Mare, W.K. 1994b. Estimating krill recruitment and its variability. *CCAMLR Science*, 1: 55-69.

Everson, I., A. Neyelov and Y.E. Permitin. 1991. By-catch of fish in the krill fishery. In: *Selected Scientific Papers, 1991 (SC-CAMLR-SSP/8)*. CCAMLR, Hobart, Australia: 381-401.

Iwami, T. 1993. Fishes caught along with the Antarctic krill in the vicinity of the South Georgia Island during the austral winter months of 1992. Document *WG-Krill-93/51*. CCAMLR, Hobart Australia: 3 pp.

Iwami, T. 1994. Fishes caught along with the Antarctic krill in the vicinity of the South Shetland Islands during the austral summer months of 1994. Document *WG-Krill-94/25*. CCAMLR, Hobart, Australia: 5 pp.

Iwami, T. 1995. Fishes incidentally caught by Japanese Antarctic krill commercial fishery to the north of the South Shetland Islands during the 1994/95 austral summer. Document *WG-EMM-95/56*. CCAMLR, Hobart, Australia: 6 pp.

Pakhomov, E.A. and S.A. Pankratov. 1994. By-catch, growth and feeding of Antarctic juvenile fish taken in krill (*Euphausia superba* Dana) fisheries in the South Georgia area, in 1992. *CCAMLR Science*, 1: 129-142.

Pankratov, C.A. and E.A. Pakhomov. 1992. On the problem of by-catch of juvenile fish in krill fishery. Document *WG-FSA-92/10*. CCAMLR, Hobart, Australia: 34 pp.

Pennington, M. 1983. Efficient estimators of abundance, for fish and plankton surveys. *Biometrics*, 39: 281-286.

Slosarczyk, W. 1983a. Preliminary estimation of abundance of juvenile Nototheniidae and Channichthyidae within krill swarms east of South Georgia. *Acta Ichthyologica et Piscatoria*, 13: 3-11.

Slosarczyk, W. 1983b. Juvenile *Trematomus bernacchii* and *Pagothenia brachysoma* (Pisces, Nototheniidae) within krill concentrations off Balleny Islands (Antarctic). *Polish Polar Research*, 4: 57-69.

Slosarczyk, W. 1986. Attempts at a quantitative estimate by trawl sampling of distribution of postlarval and juvenile notothenioids (Pisces, Perciformes) in relation to environmental conditions in the Antarctic Peninsula region during SIBEX 1983-84. *Memoirs of the Institute for Polar Research*, 40: 299-315.

Slosarczyk, W. and J.M. Rembiszewski. 1982. The occurrence of juvenile Notothenioidei (Pisces) within krill concentrations in the region of the Bransfield Strait and the southern Drake Passage. *Polish Polar Research*, 3: 299-312.

## Liste des tableaux



## Liste des figures



## Список таблиц



## Список рисунков

Lista de las tablas



Lista de las figuras