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An optimal allocation hauls sampling in order to reduce bias within fishing trip in trawlers operating in the Grand Sole and Porcupine areas (NE Atlantic)

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Abstract

Spanish demersal trawlers which operate in the Grand Sole and Porcupine Areas usually make between 50 and 80 hauls in each fishing trip, lasting around 15 days where fishing is almost continuous. Since the observer is not able to sample every haul, it is crucial to define a robust number of hauls to be sampled by the observer. A bootstrap analysis was carried out to determine the minimum number of hauls to be sampled to reduce significantly intra-variance within a fishing trip. Additionally, number of vessels and trips per vessel to be sampled was also analysed. Taking account the multistage sampling design and partitioning the over-all variability over the various stages, optimum sample sizes was estimated. On the other hand, fishermen may vary its retained catch and discard patterns whilst fishing trip occurs. Particular targets, discarded fish length or proportion of discarded/retained may change according to weather, occasional presence/absence of main target, storage space, quota exceeded, etc… To look into these plausible differences, every fishing trip was divided in three periods, beginning of the trip, half period and ending period, containing each one the same number of hauls. Several statistical tests were applied to these three periods to look for differences as well as to fit a consistent division of hauls to every period. Finally, an optimal allocation sampling scheme is suggested, both in terms of minimum number of hauls to be sampled and temporal division of those hauls along the fishing trip.

Keywords: sampling design, optimal allocation, hauls bootstraps, fishing trip.

Introduction

Current fisheries policy, both at international management bodies and national level, emphasises the need to find the causes and consequences of by-catches and discarding practices. The FAO Code of Conduct for Responsible Fisheries (Anon, 1995) establishes a framework for the management based on the conservation and sustainable use of fishery resources within ecosystems. In an European context, EU has recently adopted and funded a global community program for the collection of the fisheries data needed to conduct the common fisheries policy (EU Regulation 1639/2001). This sampling program establishes discards as one of the subjects of estimation in all European waters, even extending discards sampling to European fleets in other waters.

The main reason for the scarce information about discards is the large research effort needed to sample these data. Obtaining adequate discard information requires a continuous and intensive sampling programme, which is difficult and expensive.

One of the main problems when dealing with observer data is the high variation they usually show both spatially and temporal. If the sampling design does not account for that, this high variation could hide some bias in the estimation. Then this bias may be transferred to the raising estimates to the whole fleet or strata. Last ICES Workshop on Discard Sampling Methodology and Raising Procedures (Anon, 2003) describe methods to minimise bias intra-stratum with a final precision of the estimate as well as a detailed state-of-the-art.

Spanish demersal trawlers which operate in the Grand Sole and Porcupine Areas (ICES areas VIIc,k,j) usually make between 50 and 80 hauls in each fishing trip, lasting around 15 days where fishing is almost continuous. To improve the quality of the estimate and because of the observer is not able to sample every haul, it is crucial to define a robust number of hauls to be sampled along the fishing trip. A bootstrap analysis was carried out to determine the minimum number of hauls to be sampled to reduce significantly intra-variance within a fishing trip. A right number of vessels and trips per vessel to be sampled are also important. Taking account of the multistage sampling design and partitioning the over-all variability over the various stages, optimum sample sizes was estimated.

On the other hand, fishermen may vary its retained catch and discard patterns whilst fishing trip occurs. Particular targets, length and/or proportion of fish discarded/retained may change according to weather, occasional presence/absence of main target, storage space, etc… To look into these plausible differences within the same fishing trip, every fishing trip was divided in three periods, beginning, half and ending period, containing each one the same number of hauls. An ANOVA and Tukey test for Unequal Sample Sizes were applied to these three periods to look for differences as well as to fit a consistent division of hauls to every period.

Finally, an optimal allocation sampling design is suggested, both in terms of minimum number of hauls, trips and vessels to be sampled and temporal division of those hauls along the fishing trip.

Material and methods

Data set

The sampling covers fishing activities of bottom otter-trawlers in ICES Division VII. The sampling of this fleet was achieved in the second semester of 1999. Six vessels, six trips, and 230 hauls were sampled, totalling 998 fishing hours sampled. These trawlers have as main fishing target megrim and hake and they make trips which last from 13 to 17 days, comprising between 50 and 80 hauls in each fishing trip. The observer programme is carried out based on stratified random sampling per Fishery Unit, which comprises area, gear and target species. Figure 1 shows a flow diagram with the sampling scheme in every step.

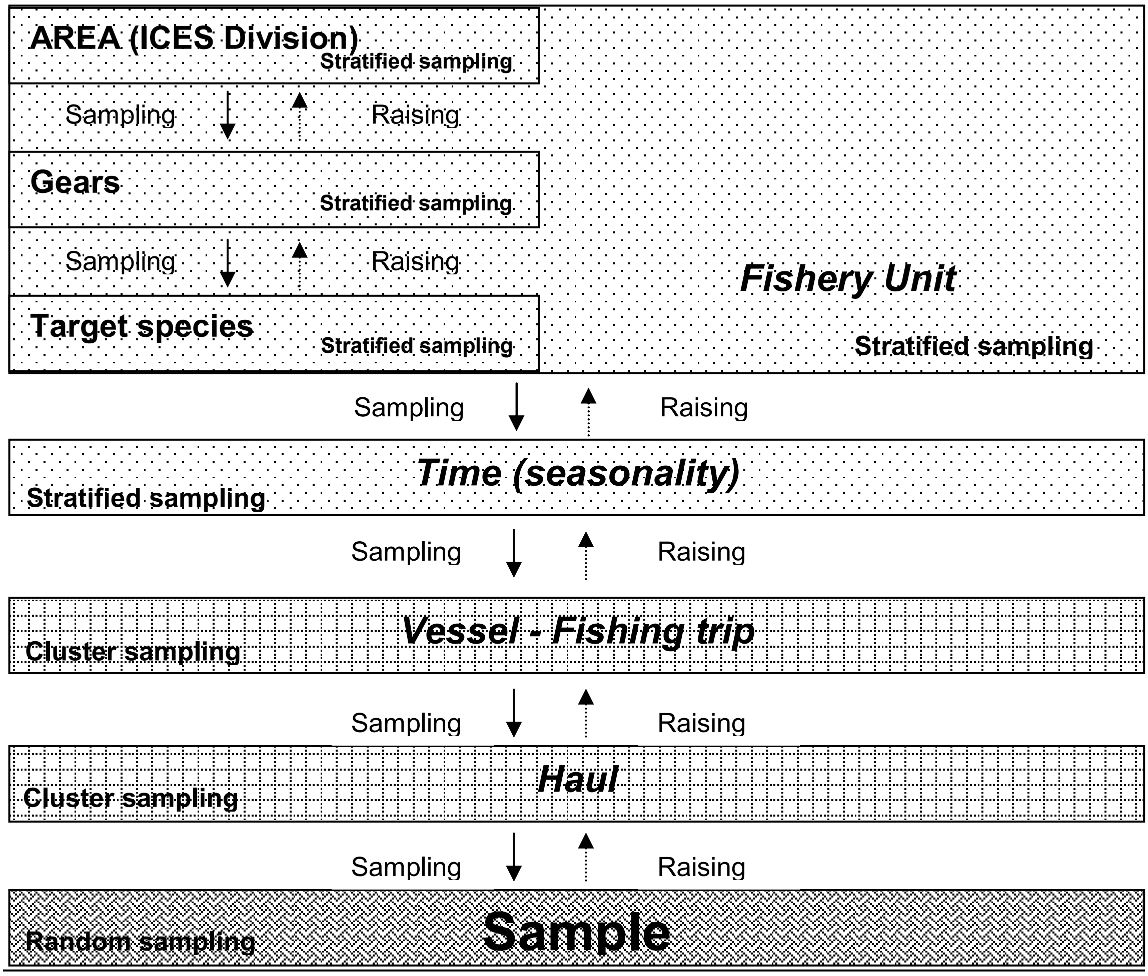

Figure 1. Flow diagram and sampling scheme in every step

The observers recorded the amount, both in weight and number, discarded and retained by species and haul as well as location, duration of hauls, environmental variables and vessel characteristics (horse power, ship speed, etc.). Samples of the catches and discards were recorded by species in order to estimate the length composition of the most abundant species. Incidental catches of marine mammals and sea birds were taken when happened. When landings were sorted in size categories, sampling of landings was also stratified.

Hauls bootstraps

A re-sampling method of bootstrap analysis was applied to data to determine the minimum number of hauls to be sampled to reduce significantly intra-variance within a fishing trip. Several groups comprising 10, 20, 30,… up to 100 hauls were selected in each fishing trip and a mean and Coefficient of Variance (CV) were estimated. This procedure was bootstrapped 500 times for every haul group and trip. The final estimated CVs were merged, achieving 3000 estimations by haul group (500 simulations by 6 fishing trips). The inter-quartile range and percentiles of CV were used to identify the percentage of decrease of variance when numbers of hauls are increased within the fishing trip. Finally CV with confidence intervals (95% and 5%) and median (50%) were plotted.

Fishing trips and vessels optimal sample size

Surveys to estimate the amount of fish discarded from commercial fishing vessels typically use a multistage sampling comprising up to six levels (i.e. vessels, trips, hauls, boxes, fish length and fish age), each of which contribute to the variability (Allen et al., 2002). We consider here only three: *V* is the number of vessels in the fleet, T is the average number of trips per vessel, and H the average number of hauls per trip. For simplicity we have assumed that T and H are constant. The lower case equivalents (v, t, and h) are the corresponding numbers in the samples.

Taking account the multistage sampling design and partitioning the over-all variability over the various stages, optimum sample sizes can be estimated (Allen et al., 2002). This then provides guidance to the on-board samples in relation with the minimum number of trips, which need to be sampled to achieve a target precision (Allen et al., 2002). Vessels, trips and hauls are assumed to be selected with equal probability for this study.

Data for estimation of the variance components are the weight and the number of hake and megrim discarded at haul level. As data are unbalanced with respect to different number of hauls per trip, and trips per vessel, analysis of variance (ANOVA), cannot be applied, (Allen et al., 2002). Hence, the residual maximum likelihood method was used to analyse the data with the condition that the residual variation is greater than zero and the remaining variance parameters are greater than or equal to zero (Allen et al., 2002).

No log transformation was needed to apply because the data are normally distributed (K-S test). The estimate variance components were used to calculate the optimal average number of trips per vessel that require sampling to achieve target precision, formula below (Allen et al., 2002).

The mean discard, both in weight and number, is given by:

$$\overline{\overline{y}} = \sum_{i=1}^{v} \sum_{j=1}^{t} \sum_{k=1}^{h} y_{ijk} / vth$$

and the variance is:

$$Var\left(\overline{\overline{y}}\right) = \left(1 - \frac{v}{V}\right)\frac{S_V^2}{v} + \left(1 - \frac{t}{T}\right)\frac{S_{VT}^2}{vt} + \left(1 - \frac{h}{H}\right)\frac{S_{VTH}^2}{vth}$$

The optimum values for the number of vessels to sample, v_{opt} are, for a target variance:

$$v_{opt} = \frac{S_V^2 + \left(1 - \frac{t}{T}\right)\frac{S_{VT}^2}{t} + \left(1 - \frac{h}{H}\right)\frac{S_{VTH}^2}{th}}{Var_{target} + (S_V^2 / V)}$$

Average number of haul per trip was kept constant at the average value and the number of sampled trip per vessel, ranging from 1 to 6, was evaluated for CVs of 12.5, 20, 30 and 40% for both weight and number of discard fish (megrim and hake).

Retaining and discard behaviour along the fishing trip

The total number of sampled hauls by trip was divided in three different chronological groups, each including the ten first, the ten intermediate and the last ten hauls. An exploratory data analysis was used (one-way ANOVA, F test) and in order to answer whether discards in weight and number, by some target species group, showed significant differences for each of the study groups, a Tukey HSD for Unequal Sample Sizes was applied.

Retaining and discarding behaviour by length were also compared for the main commercial species, based on the adjusted curve of retained/total catch by length observed.

Results and Discussion

Hauls bootstraps

Table 1 shows the bootstraps results. The percentage of decrease shows a large reduction from the 30 haul group, remaining more or less asymptotic for the group 50 and higher. This could be seen also in Figure 1, although maybe it is not so clear like in the table numbers.

This lead us to suggest that the sampling onboard should take at least 30 hauls in a fishing trip, with an optimal number of around 40 hauls.

Fishing trips and vessels optimal sample size

According the EU Regulation 1639/2001 *"data related to annual estimates of discards must lead to a precision level that make possible to estimate a parameter with precision of plus or minus 25% for a 95% confidence level."* This implies that the estimated CV of the parameter is (at most) 12.5% (ICES, 2004).

For discard weight sampling on an average of 38.3 hauls per trip achieving a CV of 12.5% need one trip per vessel for 70 vessels or two trips per vessel for 52 vessels. For CV of 20% need one trip per vessel for 37 vessels or two trips per vessel for 28 vessels. Increasing the CV to 30% need one trip per vessel for 19 vessels or two trips per vessel for 14 vessels. For discard number sampling on a same average hauls per trip achieving a CV to 30% need similar values on one trip per vessel for 18 vessels or two trips per vessel for 13 vessels (Figure 2).

The current sampling level is monthly, i.e. 12 vessels and one trip per vessel. This implies a CV of around 40%. It seems that to achieve a precision level of CV of 12.5% could imply a quite expensive sampling program (one trip in 70 vessels or two trips in 52 vessels).

Retaining and discard behaviour along the fishing trip

Table 2 shows no significant differences in total discard weight (weight of all discarded species) among the three groups of hauls proposed analysed. Target species, particularly four spot megrim, hake or witch, show significant differences in the discarded weight almost among some of the groups. Regarding discard numbers, differences are also significant among some of the studied groups, except for greater fork beard.

Characteristics of fishing hauls such as haul duration, depth and location may affect discards. However discard behaviour may be altered by storage space and market price along the fishing trip. Number of discarded fish usually decreases throughout the fishing trip duration, with higher discard rate at its beginning period for most of the species (Table 3). This is due to the retention of more (usually smaller) fish at the end of the trips. This is also shown in the large difference in the adjusted curve of retained/total catch number by length (Figure 3), what finally reflect differences on on-board discards processing by the crew.

This indicates the fishermen preferences to larger sizes. However at the end of the trip, if the market price is profitable and they have enough storage space they could retain fish sizes that would be discarded in other circumstances. Hence, our sampling effort has to take into account this fact and it has to be allocated proportionally along the whole trip.

Conclusions

According the results we suggest a sampling design of around 40 hauls to be sampled, with a proportion of 12 to 18 hauls in every chronological group, i.e. beginning, intermediate and ending trip periods. To achieve a precision level of CV of 12.5% could imply a quite expensive sampling program.

Finally, it should be highlighted that sampling on discards will be continuous and not subjected to particular research projects on discards from 2003 onwards. Data collection will be structured throughout the new National Sampling Program for fisheries, with a period from 2003 to 2006. This will allow a more efficient use of this data in any further option of assessment.

Acknowledgements

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References cited

Allen, M. D. Kilpatrick, M. Armstrong, R. Briggs, G. Course and N. Pérez, 2002. Multistage cluster sampling design and optimal sample sizes for estimation of fish discards from commercial trawlers. Fisheries research 55 (2002) 11-24.

Anon, 1995. The FAO Code of Conduct for Responsible Fisheries. Adopted by the Twenty-eighth Session of the FAO Conference on 31 October 1995 (see http://www.fao.org/fi/agreem/codecond/codecon.asp)

Anon, 2003. Report of ICES Workshop on Discard Sampling Methodology and Raising Procedures. Charlottenlund, Denmark, 2-4 September 2003.

ICES, 2004. Report of ICES Workshop on Sampling and Calculation Methodology for Fisheries data. ICES CM 2004/ ACFM: 12.

Table 1. Values of the 500 bootstraps simulation for every trip and haul group for Megrim and Hake, both in weight and number.

CV Bootstraps Megrim (Catch in weight)

Haul Group	Percentiles 0.05	0.5	0.95	DIF (95% - 5%)	% decrease
10	40.01	72.87	120.04	80.03	0.00
20	48.51	75.57	115.31	66.80	-16.52
30	52.43	77.45	111.35	58.92	-26.38
40	**54.50**	**77.41**	**109.77**	**55.27**	**-30.93**
50	**56.10**	**77.53**	**110.16**	**54.05**	**-32.45**
60	56.59	77.02	107.76	51.16	-36.06
70	57.84	77.25	108.21	50.37	-37.05
80	57.62	77.37	107.03	49.40	-38.26
90	58.29	77.27	107.14	48.86	-38.95
100	58.91	76.78	107.41	48.50	-39.40

CV Bootstraps Hake (Catch in weight)

Haul Group	Percentiles 0.05	0.5	0.95	DIF (95% - 5%)	% decrease
10	90.60	171.14	316.23	225.63	0.00
20	116.87	182.35	310.09	193.22	-14.36
30	121.42	185.03	272.11	150.69	-33.21
40	**128.47**	**184.69**	**262.59**	**134.11**	**-40.56**
50	**128.34**	**184.38**	**260.90**	**132.56**	**-41.25**
60	128.01	186.39	251.56	123.55	-45.24
70	129.37	184.25	250.57	121.21	-46.28
80	130.55	186.40	242.15	111.59	-50.54
90	131.52	187.49	241.46	109.94	-51.27
100	132.34	188.41	238.77	106.43	-52.83

CV Bootstraps Megrim (Catch in number)

Haul Group	Percentiles 0.05	0.5	0.95	DIF (95% - 5%)	% decrease
10	41.77	73.88	116.35	74.58	0.00
20	50.02	76.33	111.79	61.77	-17.18
30	53.37	77.78	109.22	55.84	-25.12
40	**55.98**	**78.69**	**106.52**	**50.54**	**-32.24**
50	**55.63**	**78.90**	**104.26**	**48.64**	**-34.78**
60	56.09	79.43	104.82	48.72	-34.67
70	57.49	79.53	104.15	46.66	-37.43
80	58.22	79.48	103.96	45.75	-38.66
90	58.47	79.70	102.89	44.42	-40.44
100	58.90	79.56	102.87	43.97	-41.04

CV Bootstraps Hake (Catch in number)

Haul Group	Percentiles 0.05	0.5	0.95	DIF (95% - 5%)	% decrease
10	83.08	163.02	316.23	233.15	0.00
20	101.25	167.21	297.55	196.30	-15.81
30	105.15	165.94	257.75	152.60	-34.55
40	**106.56**	**167.05**	**248.27**	**141.72**	**-39.22**
50	**108.95**	**167.99**	**239.37**	**130.42**	**-44.06**
60	108.32	170.52	234.88	126.56	-45.72
70	109.72	170.92	233.10	123.38	-47.08
80	110.04	170.91	229.33	119.30	-48.83
90	112.38	171.86	223.27	110.89	-52.44
100	111.12	173.19	223.60	112.48	-51.75

Table 2. Analysis of discard in weight variable per hauls groups, Tukey HSD for Unequal Sample Sizes, for species. Differences are significant at p < .05000 (in bold).

Total discarded species	Hauls	First Group	Interm. Group	Last Group
First Group	70		0.996	0.680
Intermediate Group	49	0.996		0.635
Last Group	50	0.680	0.635	
Four spot megrim	Hauls	First Group	Interm. Group	Last Group
First Group	49		0.7252	**0.0003**
Intermediate Group	36	0.7252		**0.0237**
Last Group	48	**0.0003**	**0.0237**	
Megrim	Hauls	First Group	Interm. Group	Last Group
First Group	49		**0.0342**	0.4600
Intermediate Group	44	**0.0342**		0.4058
Last Group	45	0.4600	0.4058	
Hake	Hauls	First Group	Interm. Group	Last Group
First Group	43		**0.0075**	0.9598
Intermediate Group	34	**0.0075**		**0.0034**
Last Group	60	0.9598	**0.0034**	
Witch	Hauls	First Group	Interm. Group	Last Group
First Group	33		**0.0655**	**0.0314**
Intermediate Group	30	**0.0655**		0.7232
Last Group	19	**0.0314**	0.7232	
Greater fork beard	Hauls	First Group	Interm. Group	Last Group
First Group	42		0.7256	0.1288
Intermediate Group	21	0.7256		**0.0636**
Last Group	35	0.1288	**0.0636**	
Nephrops	Hauls	First Group	Interm. Group	Last Group
First Group	20		**0.0194**	0.9029
Intermediate Group	13	**0.0194**		**0.0567**
Last Group	18	0.9029	**0.0567**	

Table 3. Analysis of discard in number variable per hauls groups, Tukey HSD for Unequal Sample Sizes, for species. Differences are significant at p < .05000 (in bold).

Four spot megrim	Hauls	First Group	Interm. Group	Last Group
First Group	49		0.8925	**0.0036**
Intermediate Group	36	0.8925		**0.0314**
Last Group	48	**0.0036**	**0.0314**	
Megrim	Hauls	First Group	Interm. Group	Last Group
First Group	49		**0.0064**	**0.0396**
Intermediate Group	44	**0.0064**		0.8090
Last Group	45	**0.0396**	0.8090	
Hake	Hauls	First Group	Interm. Group	Last Group
First Group	43		**0.0015**	0.9840
Intermediate Group	34	**0.0015**		**0.0026**
Last Group	60	0.9840	**0.0026**	
Witch	Hauls	First Group	Interm. Group	Last Group
First Group	32		**0.0134**	**0.0147**
Intermediate Group	30	**0.0134**		0.8094
Last Group	18	**0.0147**	0.8094	
Greater fork beard	Hauls	First Group	Interm. Group	Last Group
First Group	41		0.4626	0.4605
Intermediate Group	21	0.4626		0.0901
Last Group	34	0.4605	0.0901	
Nephrops	Hauls	First Group	Interm. Group	Last Group
First Group	18		**0.0464**	0.9805
Intermediate Group	13	**0.0464**		0.0667
Last Group	18	0.9805	0.0667	

Figure 1. Bootstraps Simulation and its CV estimation for Megrim and Hake, both in terms of weight and number. X-axis shows number of hauls in the fishing trip and dashed lines confidence intervals 5 % and 95 %, black line is the median 50%.

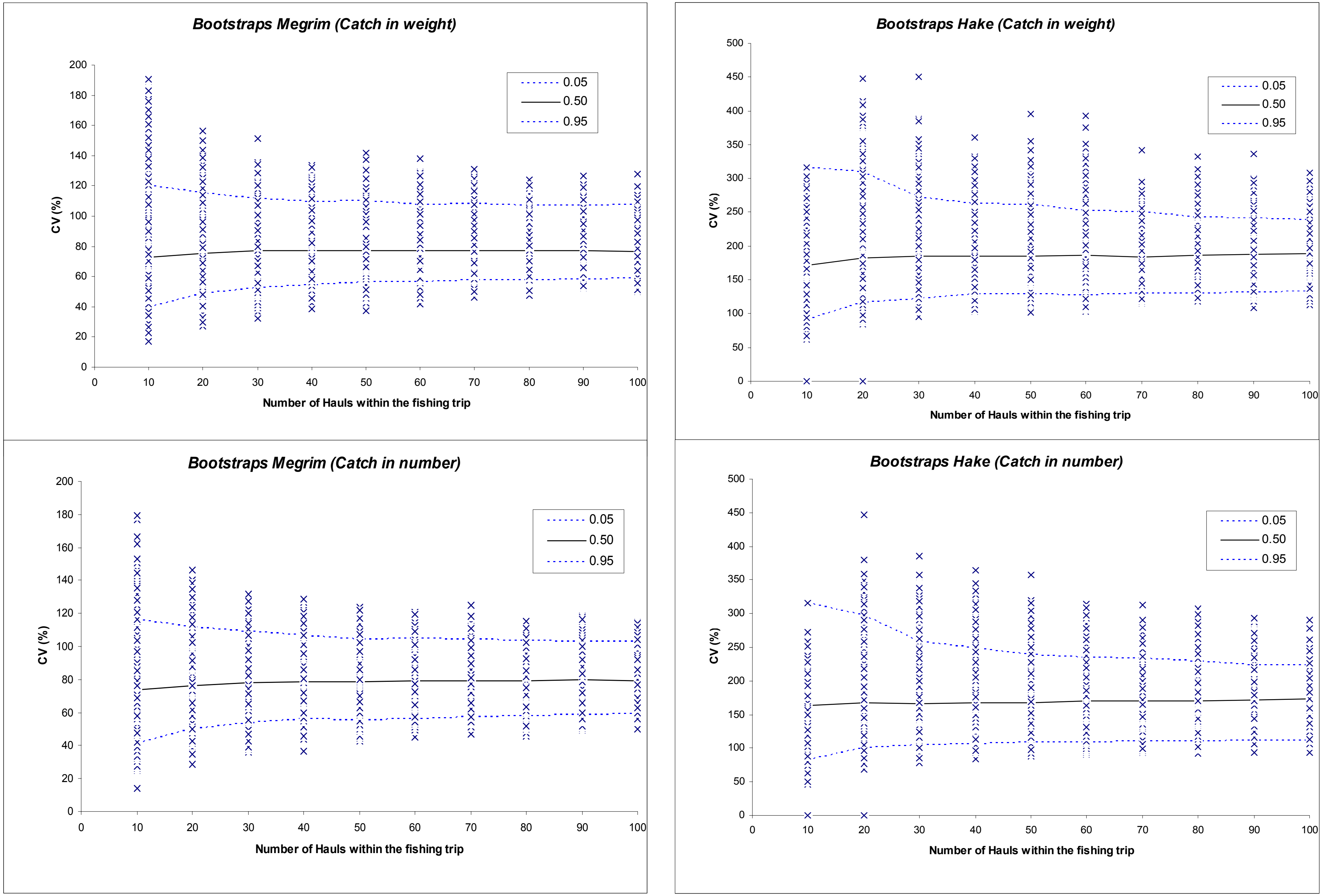

Figure 2. Optimal number of vessels obtained for average (38.3) hauls, varying the average number of trips per vessel and the CV for the Spanish baka trawlers in Sub-area VII for 1999.

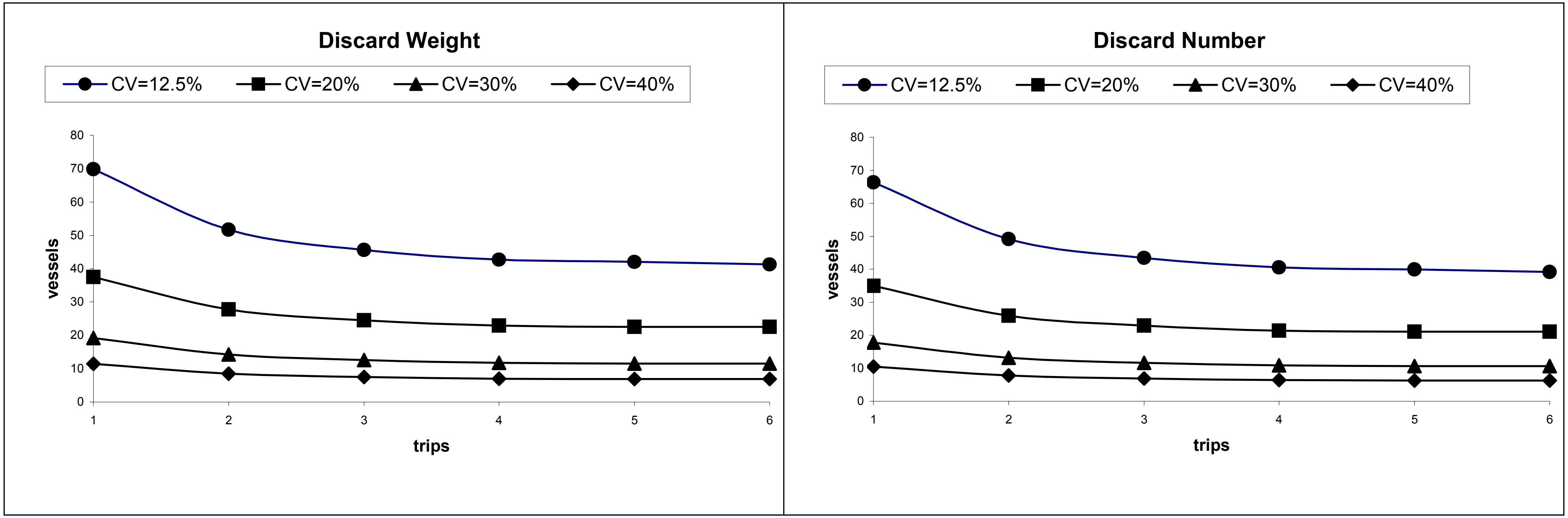

Figure 3. Adjusted logistic retention curves (% retained by length) for Four spot megrim, Megrim, Hake and Witch.