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On Variability of Survey Results

by

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Abstract

Comparative trawling experiment between RV Cornide de Saavedra and RV Vizconde de Eza in Flemish Cap has been done in 2003 and 2004. Main results came from the comparison of the catches in parallel hauls. Those results are analysed in this paper taking into account the variability of catches of both vessels in the whole survey series 1988-2012. When results are interpreted globally, they indicate a somewhat higher catchability of RV Vizconde de Eza.

Introduction

The objective of this study was to compare results from a comparative trawling experiment done between RV Cornide de Saavedra and RV Vizconde de Eza in Flemish Cap in 2003 and 2004. The comparison was needed after the EU bottom trawl survey in Flemish Cap changed the vessel, even the trawl gear and rigging remain the same. Both vessels did 117 parallel hauls. The difference in catchability of both vessels was already considered for commercial species (González-Troncoso and Casas 2005) and for all species (Pérez-Rodriguez and Koen-Alonso 2010). It is not intended to revise previous results, but to present a global alternative view based on a general statement on catch variability.

Our approach takes into account that each of the vessels has done more than one thousand hauls each in years before and/or after the comparative trawling experiment. Data from these additional hauls are informative on gear behaviour and gear’s catchability; we thought they might be taken into account when comparing any catches.

Random stratified surveys considers that all possible hauls in each stratum have the same probability, i.e., all possible catches of each species in each stratum have a common statistical distribution, which is well described by its mean, standard deviation and characteristic distribution. It is important to note that distribution of each species inside each stratum is different from its distribution in the whole stock area, which has received much more attention. Distribution in the whole bank is expected to have wider dispersion than inside any stratum: variance of catches in the whole area is an upper limit of variance in any stratum.

The above assumption of a common statistical distribution for catches in each stratum is probably a good approach in most cases, because it provides an adequate statistical description. However, catches have an “inherent” variability, i.e. repeated hauls in the same position would result in different catches. This “inherent” variability would be the adequate rule to measure differences between catches of parallel hauls, like those of the comparative trawling experiment. The problem is that such variability cannot be measured. However, variance in every stratum is an upper limit for this “inherent” variance, i.e. variance in every stratum should be considered an upper limit of variance of catches done repeatedly on the same position. This consideration must be taken into account when variance in stratum is used to evaluate differences between catches of parallel hauls, as we try to use.

Let us assume that the characteristic distribution of survey catches is independent of species, year, vessel, and stratum. That is to say that, once catches has been transformed to their standardized deviates (subtracting mean and dividing by their standard deviation), their characteristic distribution is the same, so catches from different stratum and year could be gathered together in the same distribution. As we will show later, there is no evidence to reject this principle.

Methods

On the whole survey series

Results of the EU bottom trawl survey on Flemish Cap from 1988 to 2012 were used to analyse the characteristic distribution of catches and their mean-variance relationship, trying to determine their parametric values. As much as 2061 hauls were available from RV Cornide de Saavedra and 1694 from RV Vizconde de Eza.

We have proceeded in two independent ways: using the original catch figures of each haul, and using their log-transformed values. This will help to capture the characteristic distribution of them. Mean and variance were calculated for each set of species/survey/stratum/vessel where more than one hauls were valid and some catch was taken. The following scheme shows the names used in figures. In the whole text, “catch” means “catch per mile towed”.

	Original data	Log-transformed data
Variate	c = catch per mile towed	log (c+1)
Statistics	mean (c) sd (c) = standard deviation z = (c – mean(c)) / sd(c) = standardized deviates	mean log(c+1) sd (log(c+1)) z = [log(c+1) – mean log(c+1)] / sd [log(c+1)]
Transformed statistics to facilitate view	log (mean) log (sd)	

Mean-variance relationship

We calculate sample mean and sample variance for catches of each species in each survey, vessel and stratum where two or more hauls were done. Figure 1 shows the mean-variance relationship with all data when original catches were used. This sample mean-variance relationship should be used as a proxy for the parametric relationship. Very high dispersion was observed when all cases were considered, but it decreases when only cases containing more hauls and catches were used.

The upper limit of sample standard deviation (sd) corresponds to maximum diversity, which is only one catch in *n* hauls. In that case:

$$\text{sd}(c) = \text{mean}(c) * \sqrt{n},$$
$$\log(\text{sd}) = \log(\text{mean}) + \log(n) / 2$$

Maximum number of hauls per stratum has been 11, and log(11)/2=0.52. The upper red line in Figure 1 is 0.6 above diagonal, and it illustrates this limit.

Strata with only few hauls or few catches were bad estimators of mean and variance, so we repeated the plots in Figure 1 only using the best estimators:

- strata with 5 or more hauls
- strata with 10 or more hauls
- strata with 5 or more catches
- strata with 10 or more catches

Results indicate the consistency of the relationship: mean = standard deviation, which is equivalent to 100% variation coefficient.

Characteristic distribution of catches

Figure 2 shows distribution of standard deviates in the above five cases. These sample distributions are a proxy for the parametric characteristic distribution. We noted that, when only one catch was achieved in a stratum, when there was only one haul with catches and several hauls without them, standard deviates are fix and discrete values, only dependent of the number of hauls. This implies that, in those cases, normalized deviates from sample statistics are very poor proxies of the parametric distribution: they have fixed values instead of being distributed in the whole range of possible values.

The observed characteristic distribution, which is best approximated using catches from most abundant species in strata with more hauls, is close to normal, even it shows positive skewness.

Log-transformed catches

Same approach was done with log-transformed catches (catch + 1). Mean-variance relationship is shown in Figure 3. In there, the general grouping of data around several sloping lines hide the fact that expected limits are constant values.

In theory, when the squared mean of a variable is equal its variance (as we have concluded for catches in one stratum), the log-transformed values have a constant variance.

Let it be: $x = \log N(\mu, \sigma^2)$

Then: $\mathcal{E}(x) = EXP(\mu + \sigma^2/2)$ $V(x) = [EXP(\sigma^2) - 1] * EXP(2\mu + \sigma^2)$

If variance … $V(x) = [\mathcal{E}(x)]^2$

then: $\sigma = \sqrt{\log(2)} = 0.55$

So, in such cases, the standard deviation of log-catches is expected to be close to a constant if they were log-normal distributed. Available catch data only allows a limited confirmation of this fact (Figure 3), mainly due to those cases with scarce hauls or catches. When only cases with the highest number of hauls and the most frequent catches are selected, the parametric value sd=0.55 is better supported.

Characteristic distribution of log-transformed data approaches normal, even it has negative skewness (Figure 4), but the goodness of fit was at the same level that untransformed catches (Figure 2). We concluded that catches are equally fitted to a normal or log-normal distribution: differences are not conclusive.

Both Figures 1 and 2 were repeated plotting data from each vessel in a different colour, and no segregation was observed. The exercise was repeated by differentiating surveys, strata or species, and again, no discrimination was observed. We concluded that distribution of survey catches is independent of species, year, vessel, and stratum, as pointed out in the Introduction.

Paired comparison

We are now focused on the 117 parallel hauls done by the two RVs in 2003 and 2004. The following analysis is a test of the null hypothesis: both vessels have the same catchability for each species. In our case, mean and variance is different for each pair, so no standard pair comparison ANOVA is possible. Assuming a particular mean and variance for each paired catches, one of each vessel, we calculated to the standard deviate of catch difference in each pair.

Let it be c1 and c2 catches of one pair. Accepting a normal distribution of catches (c), we assume:

$$\text{mean}(c) = (c1 + c2) / 2$$

Sample mean is used instead of parametric mean, and it is an important source of dispersion.

Null hypothesis: $(c1 - c2) = N(0, sd^2)$.

$sd(c) = \text{mean}(c)$ - this is a key point: it is the results of the previous section on mean-variance relationship.

$sd(c1 - c2) = \sqrt{2} \times sd(c)$

standardized deviate of (c1 – c2), $z = (c1 - c2) / [\sqrt{2} \times (c1 + c2) / 2] = (c1 - c2) / (c1 + c2) \times \sqrt{2}$

Taking into account that z = N(0,1), mean (z) for each species in each year when *n* pairs are available is:

$$\text{mean}(z) = N(0,1/n)$$

A test of the null hypothesis is departure of mean(z) from zero:

$$\mathcal{Z} = \text{mean}(z) / \sqrt{(1/n)} = \sum[(c1 - c2) / (c1 + c2)] \times 1.414 / \sqrt{(n)} \qquad [1]$$

We use $\mathcal{Z}$ instead of z to differentiate the global mean from the value of each pair of parallel hauls. Both are standardized deviates: N(0,1).

$\mathcal{Z}$ is a mean of z's from each sets of pair hauls; it is an overall measure of differences between the two vessels for one species in one year and expressed in standard deviate units: positive values indicate a greater catchability of RV Vizconde de Eza than RV Cornide de Saavedra, and negative values the opposite relationship.

The same approach, but based on a log-normal distribution of catches, gives to:

$\text{mean} = [\log(c1) + \log(c2)] / 2$

$sd[\log(c)] = 0.55$ - this is also the key point from previous section on mean-V() relationship.

$sd[\log(c1) - \log(c2)] = 0.55 \times \sqrt{2} = 0.776$

standardized deviate, $z = [\log(c1) - \log(c2)] / 0.776$

$$\mathcal{Z} = \text{mean}(z) / \sqrt{(1/n)} = \sum [\log(c1 / c2)] / 0.776 / \sqrt{(n)} \qquad [2]$$

Results

There was 114 species where the calculation was possible (Table 1).

Figures 5 and 6 show the results from [1] and [2] respectively. Each point of the left side graphics represents the results for one species in both years: 2003 in x axis vs 2004 in y axis. Both axes are $\mathcal{Z}$ values that measure how much catchability of RV Vizconde de Eza is bigger than RV Cornide de Saavedra. When both coordinates of a point are positive it means that catchability for that species was bigger in both years, that is to say, results are fully consistent. When both coordinates are negative it means the opposite catchabilities, but it is also consistent. When a point is the

+/– or –/+ region, it indicates some inconsistence of results. Upper left graphic in both figures indicates that most species belong to a common pool of values centred in some positive-positive (+/+) region. Cases out of this group are the various redfish species in the regions –/+ and +/–. This group of species shows highly significant differences, but with opposite sign from one year to the other. Other species outside the main group are:

Figure 5	Figure 6
Lumpenus lumpretaeformis	*Lumpenus lumpretaeformis*
Pontophilus norvegicus	*Sergestes arcticus*
Mallotus villosus	*Myctophidae*
Lycodes reticulatus	*Anarhichas minor*
Paguridae	*Pontophilus norvegicus*
Spirontocaris liljeborgii	*Gadus morhua*
Lebbeus polaris	*Paguridae*
	Lycodes esmarki

There is not any obvious common characteristic of these species that could explain their particular behaviour.

Instead of analysing the behaviour of individual species, plots in Figures 5 and 6, left, the distribution of the whole points could be considered. The points shows a common global distribution and it seems to indicate a random dispersion of values around some point in the +/+ region. This approach is interpreted as all points belonging to a common distribution, so the particular position of each species is meaningless. The only firm conclusion would be that this global distribution is centred in a +/+ region.

In support of this last interpretation is that plots in Figure 5 (assumed normal distribution) are enclosed in a -2.5 to 2.5 square, the 99% limits. The global distribution is slightly displaced to some +/+ point equidistant of both axes. Dispersion is higher in Figure 6 (assumed log-normal distribution): plots are in a -5 to 5 standard deviation square. This high dispersion would be the results of variance underestimation: the use of sample mean as a proxy for parametric mean and, hence, for standard deviation, increases dispersion of any results.

In the right side of Figures 5 and 6, the same Z values of both 2003 and 2004 are plotted vs number of available paired hauls with catches for that species. Plots are presented to judge the existence of some relationship between the deviation (z) and the number of available paired hauls. Points with high x values correspond to wide distributed species, while low x values belong to scarce species or those restricted to a particular area. Plots in top-right of both figures indicated a positive relationship, but redfish was the main responsible. If those species are excluded, no relationship is observed.

Discussion

In this exercise we deal with sample distribution of catches, trying to understand its parametric distribution. Because sample distribution of scarce species catches is not a continuous distribution but a discrete one, only catches of most abundant species provide a good approximation to a parametric distribution. It allows to justify parametric mean and variance for catches in the original scale or log-transformed.

The availability of comparative surveys in two years allows to compare results from one year with the other, and to get a better view of the significance of differences. Two year experiments have been a good procedure. It is well known that there was some differences in procedures of each year, which were not consider here, but it does not question the method, and we hope it does not modify main conclusions.

Changes in catchability of redfish are unexplainable. It reinforces the idea that catchability of redfish is quite dependent of many factors from both the trawl gear and the oceanographic conditions, and it is clear that those factors are uncontrolled. In this context, it is remarkable that deep changes in survey abundance year to year were often observed, and they were attributed to some uncontrolled source of variability in catchability.

Species cited in the Results' section are candidates to have catchability differences by vessel. All other species seem to produce a common pool of deviates centred in the +/+ region (Figures 5 and 6, left), which could be interpreted as catchability of RV Vizconde de Eza being somewhat higher than RV Cornide de Saavedra. This common pool of deviates could be due to each species having its own behaviour, and catchability being quite sensible to any change in gear/vessel.

The occurrence of some higher catchability of RV Vizconde de Eza than RV Cornide de Saavedra is coherent with more stability of the gear provided by RV Vizconde de Eza. It uses a trawl winch that maintains equal tension on each wire; it should allow a symmetric and more stable shape of the trawl gear. The occurrence of a common behaviour of all species is reasonable taking into account that both vessels use the same gear and the same rigging; results do not allow a differentiated behaviour for each species.

References

González-Troncoso, D. and M. Casas – 2005. Calculations of the calibration factors from the comparative experience between the RV Cornide de Saavedra and the RV Vizconde de Eza in Flemish Cap in 2003 and 2004. *NAFO SCR Doc.* 05/29.

Pérez-Rodriguez, A. and M. Koen-Alonso – 2010. Standardization of time series for the EU bottom trawl Flemish Cap survey: Estimation of conversion factors between RV Cornide de Saavedra and RV Vizconde de Eza. *NAFO SCR Doc.* 10/22.

Vázquez, A.– 2002. Catchability comparison between Lofoten and Campelen gears. *NAFO SCR Doc.* 02/74.

Table 1 – List of species. Overall number of data and z with both catches and log-catches.

	catch		log-catch	
	n	z	n	z
Petromyzon marinus	2	2	2	9.75
Centroscyllium fabricii	2	0.68	2	1.57
Raja sp.	3	2.45	3	11.54
Amblyraja radiata	99	2.96	99	10.31
Malacoraja senta	33	1.31	33	1.34
Rajella fyllae	6	-1.15	6	-7.78
Dipturus linteus	1	1.41	1	7.76
Bathyraja spinicauda	19	0.23	19	1
Synaphobranchus kaupii	10	3.14	10	10.4
Serrivomer beanii	12	-0.05	12	-0.03
Nemichthys scolopaceus	15	0.57	15	1.74
Notacanthus chemnitzii	4	-0.13	4	-3.06
Mallotus villosus	44	4.01	44	11.55
Argentina silus	5	1.9	5	4.75
Bathylagus euryops	6	2.31	6	4.01
Normichthys operosus	1	1.41	1	3.3
Alepocephalidae	3	2.45	3	3.21
Xenodermichthys copei	2	0	2	-0.99
Gonostoma elongatum	1	1.41	1	4.59
Maurolicus muelleri	5	-1.33	5	-1.85
Argyropelecus sp.	2	2	2	1.96
Argyropelecus hemigymnus	2	2	2	1.63
Flagellostomias boureei	1	-1.41	1	-1.76
Malacosteus niger	4	1.05	4	2.52
Chauliodus sloani	16	0.63	16	2.48
Stomias boa	24	2.69	24	7.78
Arctozenus risso	25	1.29	25	4
Magnisudis atlantica	24	0.05	24	0.1
Myctophidae	26	4	26	13.19
Ceratoscopelus maderensis	1	-1.41	1	-1.76
Lampanyctus sp.	1	1.41	1	3.69
Notoscopelus kroeyeri	9	-0.67	9	-3.61
Benthosema glaciale	13	2.18	13	4.93
Lampadena speculigera	6	2.2	6	6.88
Myctophum punctatum	9	2.36	9	3.15
Lophius americanus	2	0	2	-0.2
Antimora rostrata	9	-0.22	9	-0.41
Gadus morhua	59	2.57	59	14.04
Pollachius virens	1	1.41	1	8.7
Melanogrammus aeglefinus	7	0.12	7	2.55
Micromesistius poutassou	2	0	2	-0.07
Phycis chesteri	70	3.56	70	8.49
Urophycis tenuis	14	1.76	14	6.12
Enchelyopus cimbrius	25	1.2	25	4.25
Gaidropsarus ensis	40	0.89	40	1.03
Gaidropsarus argentatus	2	2	2	6.53
Coryphaenoides rupestris	6	-0.34	6	0.45
Nezumia bairdii	69	1.87	69	4.18
Macrourus berglax	26	-0.15	26	-1.65
Lycenchelys paxillus	1	-1.41	1	-3.53
Lycodes reticulatus	67	5.17	67	20.42
Lycodes esmarkii	38	-1.87	38	-12.71
Lycodes vahlii	7	-0.15	7	-0.52
Lycodonus flagellicauda	5	1.9	5	7
Anarhichas denticulatus	55	1.58	55	9.27
Anarhichas lupus	89	2.53	89	7.93
Anarhichas minor	71	3.49	71	17.2
Lumpenus lampretaeformis	82	8.91	82	36.46
Leptoclinus maculatus	1	1.41	1	1.47
Scomberesox saurus	1	-1.41	1	-4.49
Poromitra megalops	4	1.41	4	3.89
Scopelogadus beanii	2	-2	2	-6.73
Sebastes (sobrecopo)	10	-4.47	10	-15.01
Sebastes (juveniles)	92	6.63	92	53.6
Sebastes norvegicus	92	1.77	92	25.11
Sebastes sp.	99	-2.13	99	-28.16
Sebastes mentella	71	2.45	71	29.19
Sebastes fasciatus	97	2.28	97	29.23
Triglops murrayi	30	0.96	30	2.08
Cottunculus microps	18	1.48	18	6.44
Cottunculus thomsonii	7	-2.07	7	-7.27
Aspidophoroides monopterygius	15	3.26	15	4.05
Leptagonus decagonus	1	1.41	1	4.24
Liparidae	1	1.41	1	2.41
Liparis sp.	1	1.41	1	2.08
Liparis fabricii	2	2	2	4.73
Glyptocephalus cynoglossus	75	3.27	75	13.78
Hippoglossoides platessoides	73	1.23	73	5.16
Reinhardtius hippoglossoides	89	-0.58	89	-3.17
Hippoglossus hippoglossus	10	-0.89	10	-7.58
Gastropoda	7	3.74	7	12.36
Cephalopoda	1	1.41	1	1.05
Semirossia sp.	44	3.03	44	5.12
Oegopsida	2	2	2	4.3
Histioteuthis sp.	3	0.82	3	1.92
Histioteuthis bonnellii	1	-1.41	1	-7.09
Ommastrephidae	1	1.41	1	4.48
Illex illecebrosus	99	4.11	99	11.58
Octopoda	5	3.16	5	5.85
Bathypolypus arcticus	17	0.99	17	2.58
Cirroteuthidae	1	1.41	1	8.35
Eusergestes arcticus	21	4.62	21	17.92
Sergia robusta	8	2.49	8	5.36
Aristaeopsis edwardsiana	1	-1.41	1	-4.38
Acanthephyra pelagica	10	2.01	10	4.63
Acanthephyra purpurea	3	0.82	3	4.71
Pasiphaea tarda	12	1.11	12	1.49
Pasiphaea multidentata	1	1.41	1	5.07
Parapasiphae sulcatifrons	12	0.82	12	-2.06
Spirontocaris liljeborgii	28	6.17	28	14.34
Lebbeus polaris	35	5.73	35	13.82
Pandalus borealis	102	2.42	102	5.17
Atlantopandalus propinquus	2	2	2	4.65
Sabinea hystrix	10	-0.89	10	-0.44
Sabinea sarsii	58	3.14	58	6.31
Pontophilus norvegicus	54	8.82	54	17.48
Stereomastis sculpta	3	0.82	3	3.11
Paguridae	17	5.83	17	15.74
Lithodes maja	20	-0.64	20	-2.79
Neolithodes grimaldii	2	0	2	0.43
Hyas araneus	1	-1.41	1	-2.47
Hyas sp.	1	1.41	1	2.32
Chionoecetes opilio	63	2.07	63	3.28
Euphausiacea	2	2	2	3.64

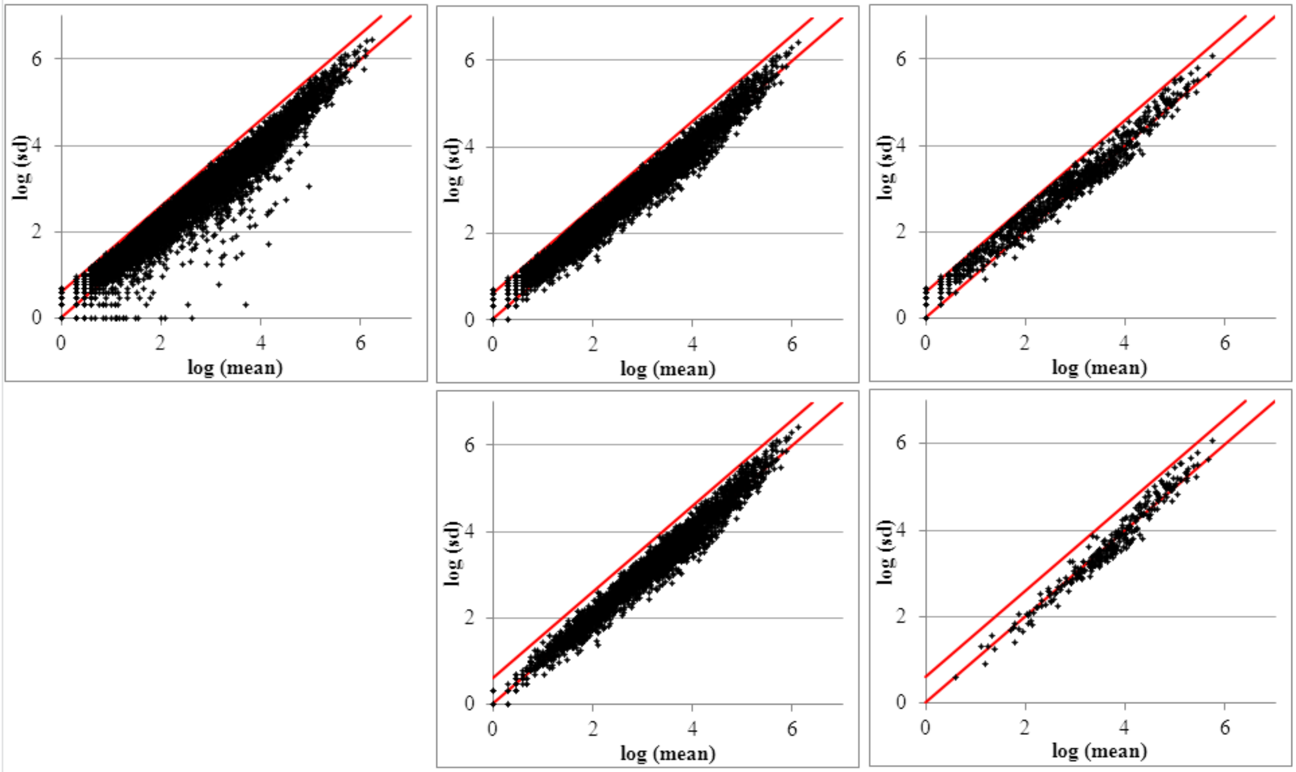

Figure 1 – Relationship between mean catch and standard deviation (sd) of catches in each stratum. Red lines indicate angle bisector of axes (y = x) and angle bisector + 0.6, i.e.: (y = x+0.6).

Upper left – total set of data (14 150 cases)
Upper middle – Strata with 5 or more hauls: nh>4 (9 835 cases)
Upper right – Strata with 10 or more hauls: nh>9 (1 114 cases)
Lower left – Strata with 5 or more catches: nc>4 (3 863 cases)
Lower right – Strata with 10 or more catches: nc>9 (285 cases)

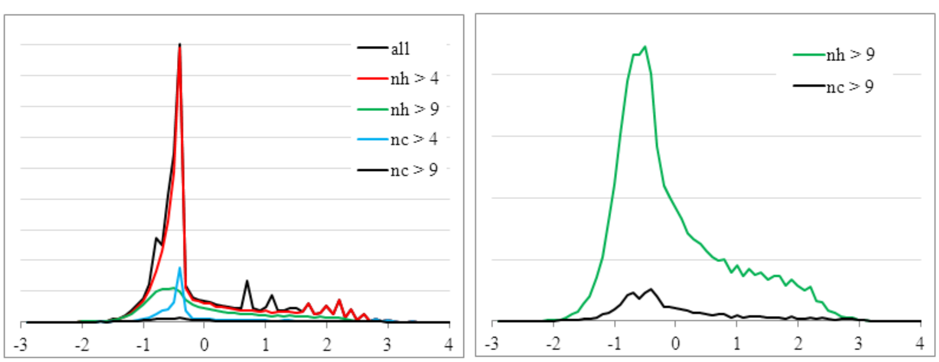

Figure 2 – Normalized deviation of the catch using sample mean and standard deviation.

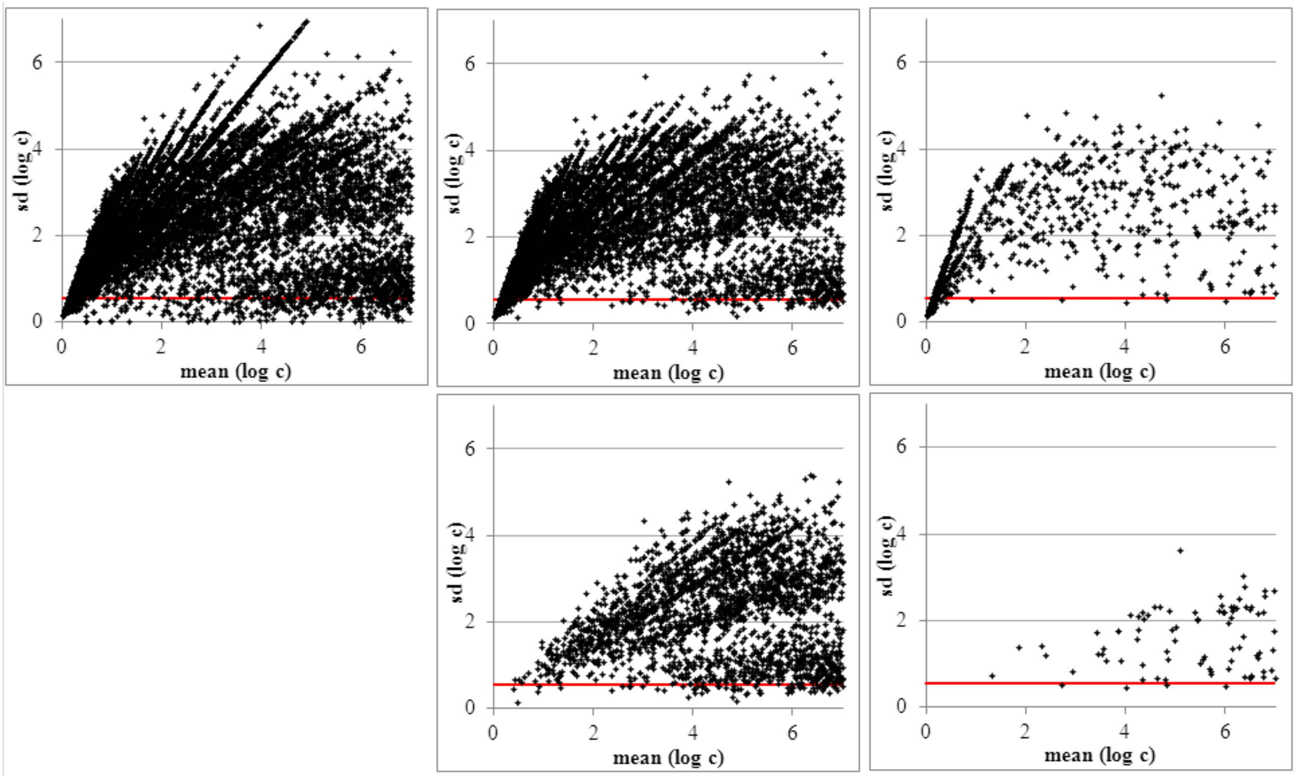

Figure 3 – Mean-standard deviation relationship of log-transformed catch. The five pictures have the same source as in Figure 1. Red line indicates the line sd = 0.55.

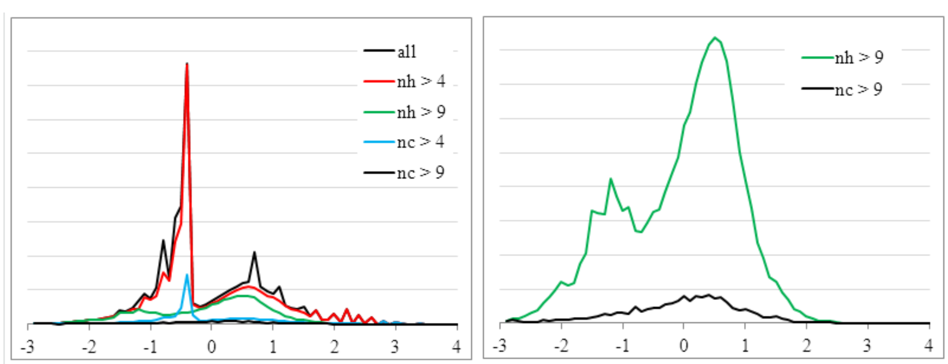

Figure 4 – Normalized deviation of the log-transformed catch using sample mean and standard deviation.

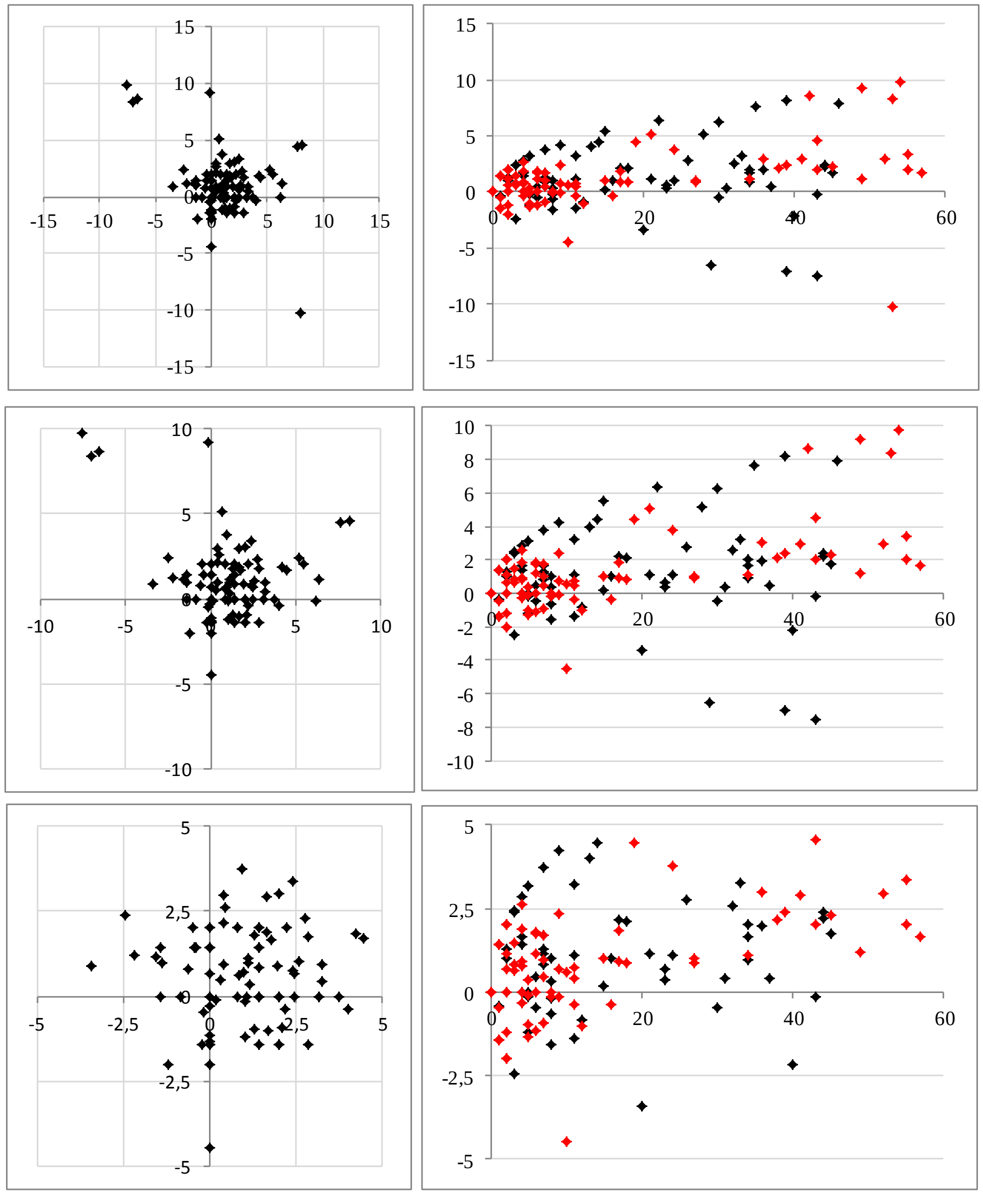

Figure 5 – Each point represents the standard deviate (*z*) of each species from the null hypothesis: both vessels have the same catchability. All graphics have the same points but organized in a different way. Left side graphics: z of 2004 vs z in 2003. Right graphics: z of both years in different colours (2004 in black, 2003 in red) vs number of paired hauls available.

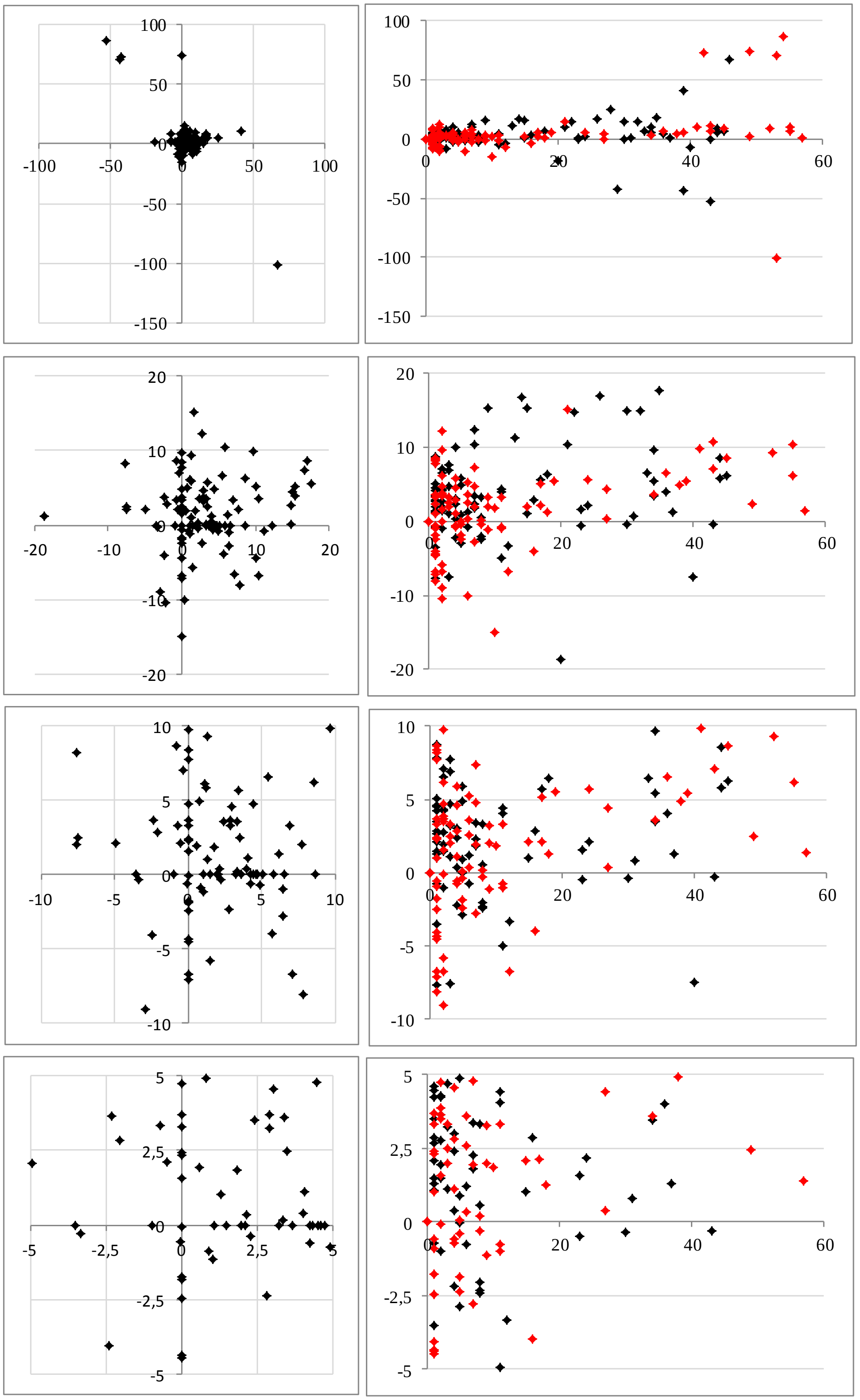

Figure 6 – Same as in Figure 5, but using log-transformed catches.