Abundance Estimates for Hake – Nansen vs Africana

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Hake OMP-2010 (will soon be revised and replaced by OMP-2014) uses the abundance estimates for hake from the January (Summer) and April (Autumn) surveys, in addition to the commercial catch & effort data, to calculate the recommended TAC for the upcoming year. No April surveys have been completed since 2011 and the January 2013 survey was completed on the *FV Andromeda*, as the *RV Africana* was not operational. This document will present comparisons of the abundance estimates calculated from the *RV Africana* with the *RV Dr Fridtjof Nansen* as a starting point for assessing how to incorporate the survey results collected on the *FV Andromeda* into the time series required for the OMP.

The *RV Dr Fridtjof Nansen* uses a transect survey design as opposed to the random stratified design (Appendix A). Calculation of error associated with abundance estimates derived from a transect design is statistically invalid which complicates the comparison of the two time series. Cotter (2012) completed an extensive study comparing and calibrating the recent time series and his findings echoed the results of a report by Stielau (2000) which concluded that the biomass and length data provided by the two survey designs are very similar. The distinct advantage of the random stratified design is that error can be calculated. Thus the *Dr Fridtjof Nansen* data was utilized as if it had been a random stratified survey, allowing the calculation of a comparable time series. Table 1 illustrates that the Nansen tends to under sample the shallowest strata when completing a "transboundary" survey (post 2001) but otherwise the trawl distribution is similar to that of the Africana in corresponding years.

Table 1: Summary of surveys conducted by the *RV Africana* and the *Dr Fridtjof Nansen* in South African west coast waters since 2000; the number of stations per depth strata as used to calculate the abundance estimates is given.

year	surveys completed by the Dr Fridtjof Nansen							surveys completed by the RV Africana and FV Andromeda						
	cruise	000-100	101-200	201-300	301-400	401-500	TOTAL	cruise	000-100	101-200	201-300	301-400	401-500	TOTAL
2000	NAN00001	9	41	28	12	10	100	*national surveys completed on Nansen as Africana broken*						
2001	NAN00004	14	38	24	7	7	90							
2002	*intercalibration survey - too few stations*							AFR00165	10	46	30	12	13	111
2003	NAN00007	5	45	28	19	18	115	AFR00173	7	42	28	13	11	101
2004	*intercalibration survey - too few stations*							AFR00188	7	47	29	12	10	105
2005	NAN00015	4	44	25	21	22	116	AFR00203	7	48	30	15	13	113
2006	NAN00016	4	48	28	19	19	118	AFR00214	7	43	26	11	11	98
2007	NAN00017	1	27	26	16	19	89	AFR00228	9	42	27	12	11	101
2008	NAN00018	5	44	26	23	25	123	AFR00238	8	43	28	14	12	105
2009	NAN00019	4	42	24	20	24	114	AFR00249	8	45	29	15	11	108
2010	NAN00020b	4	44	31	23	24	126	AFR00259	7	43	24	13	11	98
2011	NAN00021	5	39	30	22	23	119	AFR00270	8	38	27	15	15	103
2012	NAN00022	2	40	28	21	23	114	AFR00279	6	42	27	13	10	98
2013	NAN00023	3	41	30	24	24	122	AND00001	6	41	29	16	11	103

Nansen trawls (post 2001) were considered valid for calculating the abundance estimates if they met the following criteria:

1. region >= 6000 and <7000 [i.e. trawls within South African territorial waters]
2. survey type = 3 or 4 [i.e. demersal]
3. gear = BT [i.e. Bottom Trawl]
4. purpose =3 or 2 [one record in 2012 is marked as 1 and was excluded; remainder are 3]
5. trawl duration =>15 and <40 minutes [i.e. excludes 3 trawls (<15min) from 2012 & 1 (570min) from 2013]

The trawl duration limitation is applied to the Africana data and assumes that "timestart" and "timestop" in Nansis are equivalent to the start (we call it "net on bottom time") and end ("start haul time") of the fishing event. Furthermore, the mouthwidth of the net, used to calculate the area swept, is either 21m or 18m (still to be confirmed by IMR). For the purposes of this analysis 21m was used. As it is a relative estimate, using 18m should not change the trend.

The full time series of abundance indices for the two species of hake are illustrated in Figure 1. Calibrating the 2013 Nansen abundance estimate to an Africana New Gear equivalent is described in Appendix B and the model is fitted to data from 2003 to 2012 (Table 2).

Table 2: Abundance estimates (thousands of tons) and associated standard error for *Merluccius capensis* and *Merluccius paradoxus* calculated from the *RV Africana* and the *Dr Fridtjof Nansen* surveys. Gear relates to whether the Africana new gear (with rockhopper footrope & multi-purpose trawl doors) or old gear (with chain footrope & WV doors) was utilized.

		M. paradoxus				*M. capensis*			
		Nansen (mw 21)		Africana		Nansen (mw 21)		Africana	
Year	Gear	Abundance	SE	Abundance	SE	Abundance	SE	Abundance	SE
2003	old	434.45	47.25	411.18	69.43	111.01	36.82	75.96	13.31
2005	new	281.30	50.19	286.42	39.85	52.63	7.03	70.98	13.84
2006	old	384.33	49.36	315.31	49.49	134.16	34.55	88.42	22.85
2007	new	388.72	59.43	397.05	71.56	88.11	11.34	82.04	11.49
2008	new	342.97	57.92	246.54	51.97	60.24	6.50	50.88	5.35
2009	new	463.30	83.27	330.23	28.53	79.64	11.32	175.29	39.92
2010	old	539.58	68.68	589.53	85.69	108.63	20.90	163.54	34.44
2011	new	461.10	126.95	347.08	92.54	173.15	49.87	89.39	23.22
2012	new	390.37	57.71	377.52	50.69	124.56	50.81	92.59	11.93
2013	new	326.42	37.55	233.80	70.86	51.74	7.40	31.88	4.62

The parameters estimated are given in Table 3, while the 2013 Africana abundance estimate equivalent, together with CV and 95% confidence intervals are given in Table 4. Figure 2 plots the data and the estimated relationship between the Nansen and the Africana Old Gear abundance estimates for each species.

Table 3: Parameters estimated in the model fitting procedure, with Hessian-based standard errors in parenthesis.

	M. paradoxus		*M. capensis*	
	value	se	value	se
r	0.069	(0.079)	-0.078	(0.191)
r^*	0.057	(0.050)	0.111	(0.184)
l^2	0.000	(0.000)	0.092	(0.090)
$r+r^*$	0.126	(0.077)	0.034	(0.151)

Table 4: Calibrated 2013 "*Africana*" abundance estimates, together with CV and 95% confidence intervals.

	M. paradoxus		*M. capensis*	
	B_y	CV	B_y	CV
Nansen 2013	326.42	0.115	51.74	0.143
Africana Old Gear	304.63	0.140	55.91	0.238
95% PI	(231.65;	400.62)	(35.05;	89.19)
Africana New Gear	287.74	0.138	50.03	0.208
95% PI	(219.48;	377.24)	(33.27;	75.21)

Figure 1: Abundance estimates (with ± 1 standard error) in thousands of tons for *Merluccius paradoxus* and *M. capensis* on the west coast; the estimates derived from Dr Fridtjof Nansen surveys are depicted as grey diamonds and the Africana as black squares, the 2013 survey completed on the FV Andromeda is depicted as a hollow square.

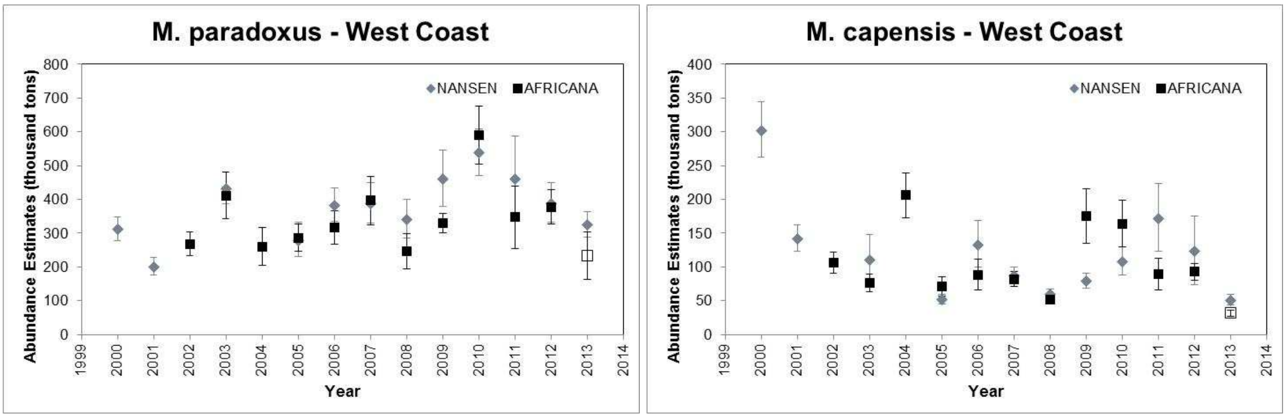


Figure 2: Abundance estimates (2003, 2005-2012) for *Merluccius paradoxus* and *M. capensis* on the west coast derived from Dr Fridtjof *Nansen* plotted against the Africana (for the opened triangles the Africana New Gear estimates have been rescaled by the New Gear/Old Gear calibration factor). The red dot shows the 2013 Nansen estimate against the 2013 predicted Africana.

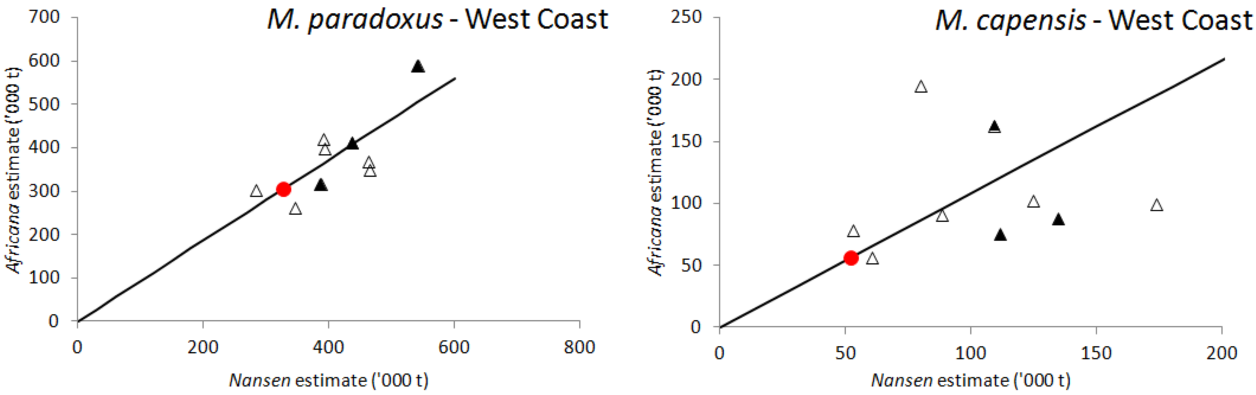
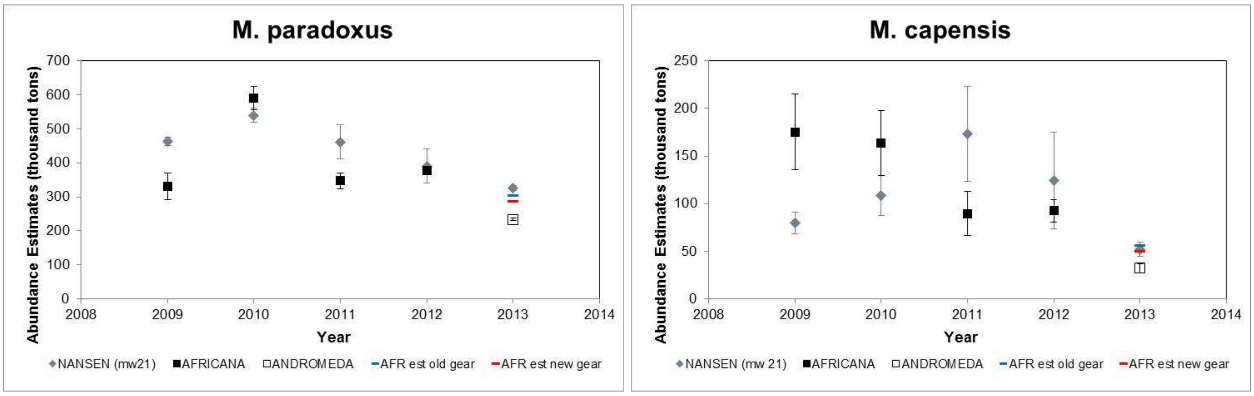


Figure 3: Abundance estimates in thousands of tons for *Merluccius paradoxus* and *M. capensis* on the west coast; the Dr Fridtjof Nansen estimates are depicted as grey diamonds and the Africana as black squares, the 2013 FV Andromeda survey is a hollow square, all with ± 1 standard error. The Africana 2013 calibration estimates given in table 4 are shown as a blue line for old gear and a red line for new gear, both without any error for display purposes.



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Cotter J. 2012. An inter-calibration study for surveys of hake, *Merluccius capensis* and *M. paradoxus*, carried out by RS Africana (South Africa), RS Blue Sea (Namibia), and RV Dr. Fridtjof Nansen (Norway-FAO). 167pp.

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Appendix A: Swept area assumptions & method for calculating abundance estimates

Catch data collected during the surveys is used to calculate an abundance estimate by the swept-area survey method. Two basic assumptions of the swept area method are that all fish in the path of the net are caught, and that the fish are distributed homogeneously over the survey area. Both of these assumptions are open to criticism and are difficult to defend. However, it is reasonable to assume that the effects of these two assumptions will not vary much from year to year. Therefore abundance estimates obtained using the swept area method are not regarded as absolute estimates, but rather as relative abundance indices.

The assumption is that each trawl (*j*) within a stratum (*i*) gives an independent estimate of the density in that stratum. Then the average density for all trawls in a stratum will be an estimate of the average density in the stratum. Therefore multiplying the average density (kg/nm^2) by the area of the stratum (nm^2) gives an estimate of the total abundance in that stratum.

1. Calculate the area swept (nm^2) a_{ij} for each trawl: where s_{ij} is the towing speed (knots, nm/hr), t_{ij} is the duration (minutes) and w_{ij} is the horizontal mouth width (m) i.e. the width of the trawl track in the *j*-th trawl of the *i*-th stratum;

$$a_{ij} = s_{ij} \times \frac{t_{ij}}{60} \times \frac{w_{ij}}{1852}$$

2. Calculate the observed density (kg/nm^2) d_{ij} in the *j*-th trawl of the *i*-th stratum for each trawl where C_{ij} is the observed catch weight (kg) of the species and a_{ij} is the area swept (nm^2);

$$d_{ij} = \frac{C_{ij}}{a_{ij}}$$

3. Calculate the mean density (kgs/nm^2) $\overline{d_{i.}}$ per stratum and its standard error $SE(\overline{d_{i.}})$ where d_{ij} is the observed density and n_{ij} is the number of trawls in the *j*-th trawl of the *i*-th stratum;

$$\overline{d_{i.}} = \frac{\sum_{j=1}^{n_{ij}} d_{ij}}{n_{ij}}\text{; } SE(\overline{d_{i.}}) = \frac{1}{\sqrt{n_{ij}}} \sqrt{\frac{n_{ij}\sum_{j=1}^{n_{ij}} d_{ij}^2 - \left(\sum_{j=1}^{n_{ij}} d_{ij}\right)}{n_{ij}\left(n_{ij}-1\right)}}$$

4. Estimate abundance per stratum B_i where $\overline{d_{i.}}$ is the mean density and A_i is the area (nm^2) of the i-th stratum, division by 1000 is to get from kg to tons;

$$B_i = \frac{\overline{d_{i.}} \times A_i}{1000}$$

5. The total abundance estimate for the survey area B is the sum of the abundance per stratum B_i over all strata n_s;

$$B = \sum_{i}^{n_s} B_i$$

6. Multiply the standard error of the mean density mean density per stratum by the area of the stratum area to get estimated standard error per stratum;

$$SE(B_i) = \left(SE\left(\overline{d_{i.}}\right) \times A_i\right)$$

7. Sum the abundance per stratum over all strata to get the total abundance estimate for the survey area.

$$SE(B_i) = \sqrt{\sum_{i}^{n_s} SE(B_i)^2} = \sqrt{\sum_{i}^{n_s} \left(SE\left(\overline{d_{i.}}\right) \times A_i\right)}$$

Where *B* is the abundance index for the total survey area, $SE(B_i)$ is the standard error of the abundance index for the *i*-th stratum and $SE(B)$ is the standard error of the overall abundance index.

Appendix B: Calibrating the 2013 *Nansen* abundance estimate to an Africana New Gear equivalent

The abundance indices from the Nansen and the Africana are taken to be related by:

$$B_y^N = RB_y^{AO}e^{\varepsilon_y} = RR^*B_y^{AN}e^{\varepsilon_y} \text{ with } e^{\varepsilon_y} \text{ from } N\left(0,\lambda^2\right) \tag{B1}$$

where

B_y^i is the "true" biomass estimate (i.e. in the limit of zero observation error) in year *y*, with *i=N* for *Nansen*, *i=AO* for *Africana* Old Gear and *i=AN* for *Africana* New Gear,

λ^2 is the process error CV^2 (arises from the two surveys not taking place at identical times, etc.),

R is the calibration (multiplicative) from AO to N

R^* is the calibration (multiplicative) from AO to AN

$r = \ln R$

$r^* = \ln R^*$

b_y is the log of the survey estimate e.g. $b_y^N = \ln B_y^N + \eta_y^N$ where η_y^N is the CV for the year *y* Nansen survey

The model is then:

$$b_y^N = r + b_y^{AO} + \gamma_y \quad \text{with } \gamma_y \text{ from } N\left(0,\mu_y^2\right) \tag{B2}$$

where $\mu_y^2 = \lambda^2 + \left(CV_y^N\right)^2 + \left(CV_y^{AO}\right)^2$

or

$$b_y^N = r + r^* + b_y^{AN} + \delta_y \text{ with } \delta_y \text{ is } N\left(0,\varphi_y^2\right) \tag{B3}$$

where $\varphi_y^2 = \lambda^2 + \left(CV_y^N\right)^2 + \left(CV_y^{AN}\right)^2$

The negative log-likelihood is then:

$$\begin{aligned} -\ln L = &\sum_y \left\{ \ln\mu_y + \frac{1}{2\mu_y^2}\left(b_y^N - r - b_y^{AO}\right)^2 \right\} \\ &+ \sum_y \left\{ \ln\varphi_y + \frac{1}{2\varphi_y^2}\left(b_y^N - r - r^* - b_y^{AN}\right)^2 \right\} + \frac{1}{2\sigma^2}\left(r^* - \bar{r}^*\right)^2 \end{aligned} \tag{B4}$$

r, r^* and λ^2 are estimated in the fitting procedure.

$\bar{r}^*$ and σ are provided by the calibration experiment results (Brandão *et al*. 2004):

$\bar{r}^*_{paradoxus} = 0.053$ with $\sigma_{paradoxus} = 0.117$ and

$\bar{r}^*_{capensis} = 0.223$ with $\sigma_{capensis} = 0.141$

The 2013 Africana abundance estimate equivalent is then:

$$B_{2013}^{AO} = B_{2013}^N e^{-r} \quad \text{with } \left(CV_{2013}^{AO}\right)^2 = \left(SE(r)\right)^2 + \left(CV_{2013}^N\right)^2 \tag{B6}$$

or

$$B_{2013}^{AN} = B_{2013}^N e^{-r}e^{-r^*} \quad \text{with } \left(CV_{2013}^{AN}\right)^2 = \left(SE(r+r^*)\right)^2 + \left(CV_{2013}^N\right)^2 \tag{B7}$$