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TOWARDS A CATCHABILITY CONSTANT FOR TRAWL SURVEYS OF NAMIBIAN HAKE

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A trawl catches only a portion of the fish in its path. The term catchability therefore refers to the fraction of the available fish caught. A method was developed and tested to establish catchability constants for trawl surveys of Namibian hake *Merluccius* spp. A catchability constant can be expressed as a simple relationship between hake area densities calculated from trawl catches and acoustic biomass estimates. Initial values were on an order of magnitude of 0.8, meaning that the catch takes 80% of the hake available to the trawl. The methodology depends on careful area selection (flat bottom, homogenous fish distribution), following the same trawl lane during subsequent hauls in an area, and thorough acoustic post-processing. A pronounced and repetitive pattern in catchability within surface daylight hours was found. Early morning and early afternoon catches were low, and the best catches of the day were made around noon, a result that may influence stock assessments based on trawl data, because morning and afternoon data would under-represent actual abundance.

Key words: acoustics, catchability, hake, trawl surveys

Trawl survey data are applied in fish stock assessment mainly to provide relative indices of abundance to be used either to tune stock assessment models such as VPA (Virtual Population Analysis, e.g. Magnússon 1995) or directly in management procedures.

To date, no successful attempts at producing absolute fish stock abundance estimates from trawl survey data have been reported. This can be attributed to a general failure to establish the efficiency (Engås 1994) of a trawl, as well as difficulties in determining the availability of the species in question to the trawl (Godø 1994, Aglen *et al*. 1999). Absolute abundance estimates from trawl surveys can only be achieved through calibrating the trawl catch against an estimate of the true spatial density of the target fish species. The validity of such a calibration depends upon the method used to establish absolute fish density in the area where the calibration experiment takes place. Determining availability of fish to the trawl gear depends on a quantitative expression of vertical (Aglen 1996) and horizontal (Engås and Godø 1989) herding, because fish often do not just passively enter the net, but are influenced by the trawl doors and bridles, as well as by noise from the vessel (Ona and Godø 1990), particularly in shallow water.

Merluccius capensis (shallow-water Cape hake) and *M. paradoxus* (deep-water Cape hake) off Namibia provide an opportunity for trawl catchability calibration. Shallow-water Cape hake in particular seem to exhibit little or no herding (IH and J. W. Valdemarsen, Institute of Marine Research, Bergen, Norway, unpublished data), meaning that the horizontal trawl opening will define the width of the swept area. Hake also perform substantial diurnal vertical migration (Pillar and Barange 1997, Huse *et al*. 1998), making them available for acoustic detection at night. Accordingly, an independent measurement of abundance can be made, against which the trawl catch can be calibrated.

Hake trawl catches vary diurnally (Gordoa and Macpherson 1991, Pillar and Barange 1997, Huse *et al*. 1998), a phenomenon related particularly to variation in availability to the trawl attributable to vertical migration. In the latter case, the pelagic component can be measured by means of acoustics. However, diurnal variation in trawl catches may also be caused at least partly by changes in efficiency resulting from variation in herding at different *in situ* levels of illumination (Glass and Wardle 1989).

In this paper, a methodology of determining calibration constants of trawl efficiency for Namibian hake is described, and some calculations of trawl catchability constants based on data collected during a methodology survey are presented. This is a first effort, and further investigations are needed to produce catchability constants or functions to be applied in hake stock assessment. Potentially, however, the corrected trawl-based area densities, together with acoustic recordings of hake biomass unavailable to the trawl, can be used to establish absolute estimates of stock abundance from survey data. The potential problem of basing stock assessment on diurnally variable data is also addressed.

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MATERIAL AND METHODS

The investigation was carried out aboard the Norwegian research vessel *Dr Fridtjof Nansen* on the Namibian shelf during May and June 1999. The trawl equipment used was a Gisund Super demersal two-panel trawl with a headline length of 31 m, a footrope length of 47 m, a wingspread of 22 m and a vertical opening of 4.5 m. The trawl was equipped with light bobbin gear with disc rollers of 30 cm diameter. All hauls were monitored by SCANMAR trawl sensors for vertical opening, bottom contact and distance between the doors. Some hauls were also monitored for distance between wingtips. Pelagic hauls were also carried out. For that purpose, the trawl used was an Aakra pelagic trawl with 15 m vertical opening, monitored by a SCANMAR Trawl Eye sensor that showed vertical opening, depth and distance from the bottom. All pelagic hauls were made as close to the bottom as advisable, normally with the lower part of the trawl a clear 5 m above the seabed. The acoustic equipment consisted of a Simrad EK500 echosounder at 38 kHz, and a Bergen Echo Integrator (Foote *et al*. 1991) post-processing system.

The experiments took place at around 25°S, 13°E, at depths between 321 and 411 m. In order not to reduce the local hake density substantially, four areas were fished, all fairly near each other (within 90 miles) on the Namibian midshelf. In all, 35 hauls were made, 9 in Area 1, 10 in Area 2, 9 in Area 3 and 7 in Area 4. Seven of these were night hauls. Of the 8 pelagic hauls made, 2 were in Area 1, 3 in Area 2 and 3 in Area 4.

Trawls were performed starting from the same position and following the same trawl path throughout the day. One haul was also performed along the same path at night to establish night-time hake concentration on the bottom. Trawls lasted 30 minutes (bottom time) and the towing speed was 3 knots. Fish samples were processed in the manner described by Anon. (1995). Area densities from trawl catches were calculated using a sweeping width of the trawl of 18.5 m, the value applied when calculating abundance indices from Namibian hake trawl surveys. The swept distance was measured by GPS from the position where the trawl was settled onto the seabed, to the position where the ground gear left the bottom. All trawl catches were sampled for species composition by mass and number, as well as total fish length.

Acoustic data were recorded at all times throughout the day, and during the night the ship was steaming along the trawl lane at 3 knots, also recording continuously. The pulse rate was around one transmission per second and the pulse length was set at one millisecond. These and the other settings applied have been used routinely for hake surveys off Namibia. Data were stored with a horizontal resolution of 0.1 nautical miles, and a vertical resolution of 10 m in the pelagic zone and 2 m in the 10 m closest to the bottom. Acoustic data were post-processed twice daily. Hake recorded between the surface and 4.5 m above the bottom (corresponding to the headrope height) were separated from plankton and mesopelagic fish by means of thresholding, and from other fish based on the trawl catch composition. Echo-integration values (s_A) were converted to biomass using the formula

$$d = \frac{1.08 s_A \bar{l}}{34} \quad , \qquad (1)$$

where d is the density of hake in kg nautical mile^{-2}, s_A (m^2 nautical mile^{-2}) the acoustic integration value of hake referred to one square nautical mile, and $\bar{l}$ is the mean length of hake (cm) in the bottom trawl sample. The mean length is calculated from the length frequency samples, and 0.5 cm is added to the mean to compensate for downward rounding of all length measurements. If both species of hake were present their length frequencies were pooled, using the catch rate of each species as a pooling factor.

The constant 1.08 in the above equation is the equivalent density (tons nautical mile^{-2}) of hake for an s_A value of 1 if all fish were 34 cm long. This is calculated as follows:

$$const = \frac{1}{\sigma} w_l 10^{-6} = \frac{1}{4\pi 10^{(TS/10)}} w_l 10^{-6} \; , \qquad (2)$$

where w is the body mass (g) of a fish with length l cm, and σ is the acoustic cross-section (m^2 nautical mile^{-2}) of one fish with a given length, and has the same unit as s_A, so representing the contribution to the integrated s_A value by a single fish.

Target strength (TS) is the acoustic contribution of a single fish in dB, and is calculated using the relationship $TS = 20\log l - 68$ (Foote 1987, Svellingen and Ona 1999). The relationship between TS and σ is given in Equation 2.

The equation is solved for $l = 34$ cm and $w = 249$ g, yielding a constant of 1.08 (Equation 1). The mean weight of 249 g for a hake of 34 cm is used in the Namibian hake surveys and has been established through numerous measurements. In Equation 1 the density is therefore calculated for a fish length of 34 cm and then corrected with the ratio $\bar{l}/34$, assuming that there is a linear relationship between area density and fish length for a given s_A value.

Mean s_A values to represent the pelagic hake not available to the trawl were calculated on the basis of

10 individuals 0.1 nautical mile^{-1}. Values of s_A were recorded during the corresponding trawl, excluding the first three and the last two of the 15 normally recorded each haul.

The model described below is based on the general trawl catchability function

$$q = c/W_{tot} \quad , \qquad (3)$$

where q is the catchability constant for the species in question, c the trawl catch of the same species, and W_{tot} is the total weight of the species available in the path of the trawl. Factors such as escapement under the footrope are included in q. Solving for W_{tot} gives

$$W_{tot} = c/q \quad .$$

A conceptual model for estimating q_{trawl} is based on the assumption that the sum of demersal and pelagic densities should be constant in the area investigated, i.e. that the sum of a set of daylight recordings should equal a set of night-time ones:

$$\frac{C_D}{q_{trawl}} + A_D = \frac{C_N}{q_{trawl}} + A_N \quad , \qquad (4)$$

where q_{trawl} is the catching efficiency of the trawl for the target species, C_D and C_N respectively the area densities in weight units calculated from daylight and night-time trawl catches, and A_D and A_N are respectively the area densities in weight units calculated from daylight and night-time acoustic recordings. Solved for q_{trawl}, the equation becomes

$$q_{trawl} = (C_D - C_N) / (A_N - A_D) \; .$$

The assumptions this model is based upon are:

- that neither vertical nor horizontal herding takes place, meaning that all hake encountered between the wings and within the vertical opening of the trawl have an equal probability of being caught, and that no hake outside of this area are caught;
- that the acoustic recordings represent all hake more than headline height from the bottom;
- that the target strength function for hake is correct;
- that the total fish density in the area is constant during the experiment;
- that the catchability is the same by day and night.

Total hake area density (D_{tot}) for each of the trawl hauls was calculated from

$$D_{tot} = (C_{(D \text{ or } N)}/q_{trawl}) + A_{(D \text{ or } N)} \quad , \qquad (5)$$

where $C_{(D \text{ or } N)}$ and $A_{(D \text{ or } N)}$ are day/night trawl and acoustics-based area densities respectively, depending on the time of the actual trawl.

Relative densities were established by calculating the percentage that the D_{tot} for each trawl constituted of the highest D_{tot} for any trawl within each area and for single days.

All times of day referred to in this paper are in UTC (same as GMT).

RESULTS

Mean total lengths (with *SD*) of hake from bottom hauls are presented in Table I. There was no significant variation within areas. However, except for Area 2 where very few small hake were caught, the highest mean lengths in single trawl stations always occurred at night or late in the day. Only one pelagic trawl catch had a statistically different mean length from an adjacent bottom trawl catch. This was the second bottom haul in Area 2. The pelagic haul was taken after the bottom haul, and the mean length of the pelagic hake catch was 10.26 cm less than that of the bottom catch. The mean length of hake caught in all pelagic hauls was lower than in adjacent bottom trawls.

Table I also lists calculations of q_{trawl} for the four experimental areas. The q_{trawl} value was calculated for each daylight trawl against each of the night-time trawls from the same area. There was substantial variation in the data, emphasizing the need to extend the experiments before reaching firm conclusions.

Validation criteria for q_{trawl} calculations were based on the following assumptions:

- Trawl catches should be higher by day than by night (it is well known that Cape hake migrate diurnally, taking them completely or partly off the bottom by night). Catch rates violating this assumption are indicative of immigration into or emigration from the trawl path or other anomalies).
- Acoustic recordings of hake should be higher by night than by day.
- Values of $q_{trawl} > 2$ are indicative of immigration into or emigration from the trawl path, or other anomalies (even if there was horizontal herding, it would not include fish outside the doors, and the door distance is about twice the wing spread).

This led to the following validation criteria:

- no negative values of q_{trawl} were accepted because this would have been a breach of one of the first two assumptions;

Table I: Calculations of q_{trawl} from relevant trawl stations. The q_{trawl} values are calculated for each daylight trawl station and corresponding acoustic biomass estimates against corresponding data for available night-time trawl stations for each of the four areas. Mean values are calculated for all accepted values of q_{trawl}, and also separately for accepted q_{trawl} values that are based on data from the same day and night (Day 1 and Night 1, or Day 2 and Night 2; framed cells in the "Accepted values" columns). Light shaded cells contain data outside the selected diurnal time scope, and dark shaded cells contain data outside the range of the eligibility criteria (see Results). Neither are included in the calculation of mean q_{trawl}

Day or night number	Trawl time	Depth	Mean total length (cm)	*SD*	Acoustic estimate (kg) per nautical mile	Trawl catch (kg) per nautical mile^2	q_{trawl} night 1	q_{trawl} night 2	Accepted values	
Day 1	07:23	325	39.80	7.60	4 689	22 624	0.41	0.55	0.41	0.55
Day 1	10:06	328	38.60	6.43	5 477	24 026	0.51	0.66	0.51	0.66
Day 1	14:53	328	43.97	9.03	5 593	13 314	-0.13	0.04		
Day 1	16:28	329	56.39	9.00	15 118	8 009	-1.04	-0.59		
Day 2	05:38	327	37.32	7.97	8 826	11 913	-0.26	-0.05		
Day 2	07:40	327	37.38	7.66	7 635	29 866	0.98	1.13	0.98	1.13
Day 2	12:31	328	37.08	7.59	5 267	36 640	1.24	1.36	1.24	1.36
Night 1	23:32	327	52.88	9.15	22 305	15 450				
Night 2	20:59	327	50.24	6.38	22 918	12 580				
Day 1	05:35	365	56.37	7.24	1 717	11 279	0.35	1.80		
Day 1	07:35	364	55.32	6.68	13 307	31 167	-7.75	-3.84		
Day 1	12:14	364	50.74	7.02	1 797	23 559	1.79	4.70	1.79	
Day 1	16:08	364	50.62	6.91	1 714	11 679	0.39	1.89		
Day 2	05:39	366	52.19	8.07	6 464	13 715	1.40	-26.84		
Day 2	07:41	367	57.39	7.89	1 854	26 562	2.15	5.47		
Day 2	12:06	361	44.46	5.61	1 003	31 534	2.49	5.53		
Day 2	16:10	367	56.23	5.42	12 070	4 772	2.04	-0.22		
Night 1	21:05	368	47.75	7.62	10 353	8 276				
Night 2	21:19	364	48.00	10.67	6 081	3 437				
Day 1	10:41	329	34.85	3.41	4 531	114 590	4.94	0.47		0.47
Day 1	12:14	329	34.78	3.20	6 092	105 214	4.82	-0.02		
Day 1	16:17	330	36.65	3.10	24 060	30 867	1.58	159.19		
Day 2	05:44	329	33.06	3.76	16 106	98 773	14.91	-0.91		
Day 2	07:45	329	33.52	3.15	41 510	82 723	-2.16	1.28		1.28
Day 2	12:13	329	34.54	3.32	17 367	109 518	25.13	0.63		0.63
Day 2	16:10	330	35.80	3.81	15 644	61 533	5.34	-5.54		
Night 1	21:29	329	39.10	4.26	20 258	36 873				
Night 2	21:26	329	36.57	3.79	23 591	105 581				
Day 1	05:43	390	45.85	7.91	55 316	16 551	-2.26			
Day 1	08:03	388	42.84	6.28	34 054	12 747	-1.26			
Day 1	09:11	387	46.98	7.86	18 694	57 996	-0.17			
Day 1	13:06	390	42.15	6.51	14 992	78 985	0.17		0.17	
Day 1	13:10	390	39.77	4.34	28 023	51 155	-0.34			
Day 1	14:56	386	43.34	6.48	9 816	5 339	-0.92			
Night 1	21:01	390	49.23	8.40	78 230	68 407				

Global mean 0.86±0.28; mean for the same night 0.81±0.47

- no positive values of q_{trawl} arising from two negative sums (in the q_{trawl} formula) were acceptable because this would have been a breach of both the first two assumptions;
- no values of q_{trawl} >2 were acceptable because this would have been a breach of the third assumption.

In addition, no values of q_{trawl} between 0 and 0.1 were accepted because such values are highly unlikely to be correct. Also, the results of only daylight hauls conducted between 06:00 and 16:00 were used for the analysis, based on the diurnal variation shown in Figure 1. These two last exclusion criteria are somewhat arbitrarily chosen, and are consequently debatable.

The remaining 13 of the total 50 q_{trawl} calculations yielded a mean of 0.86±0.28. These calculations were based partly on a combination of daylight trawl stations with night hauls of the same night, the succeeding night, and the preceding night if the area was the same. If the results of the daylight trawl stations were only to be combined with the results from the

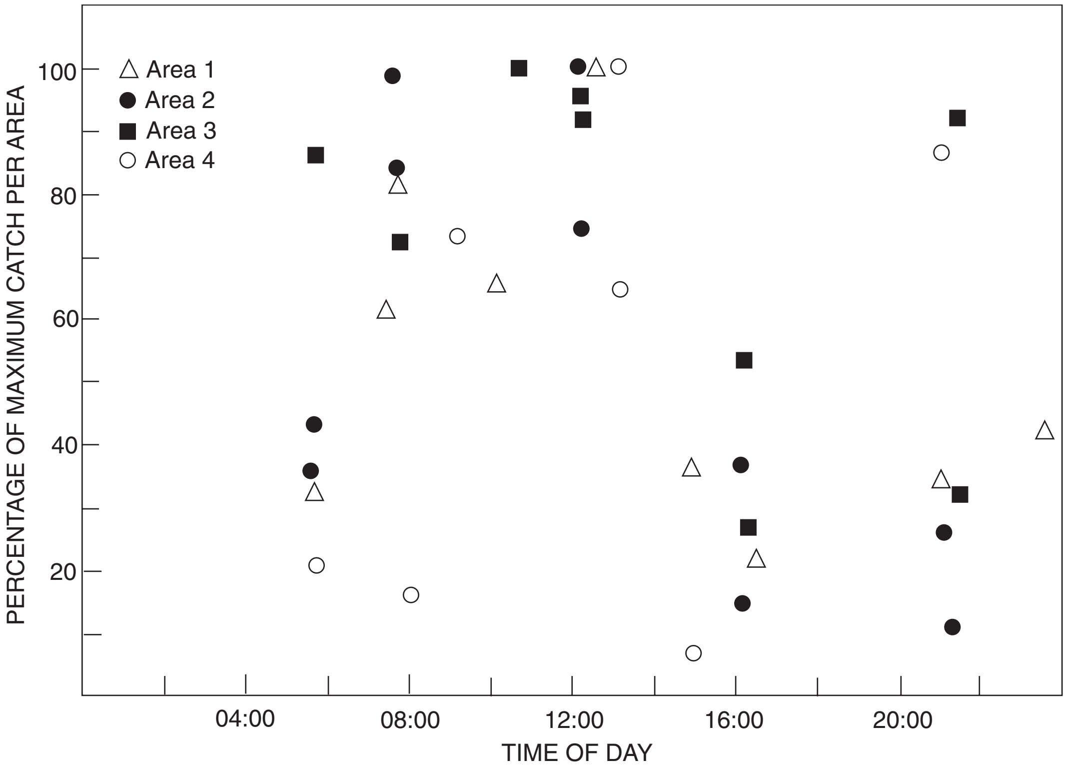

Fig. 1: Hake catches per trawl station within each of the four experimental areas relative to the biggest catch in each area

trawl station of the same night (Day 1/Night 1, Day 2/Night 2; Table I), the eight eligible values of q_{trawl} gave a mean of 0.81±0.47.

Relative variation in densities within each area separately is presented in Figure 1. There was great variation in measured abundance within the data with respect to the time of day of the haul, characterized by high midday catches and low morning and afternoon catches. Most night-time catches were also small, but Areas 3 and 4 had high night-time catches. Those were also the areas with the highest absolute hake densities. Also notable was the big morning catch in Area 3, the area with the greatest density of hake. These results indicate that care must be taken when collecting and selecting data for q_{trawl} calculations, because diurnal aspects may influence both trawl catches and acoustic recordings. The extent of diurnal variation was more or less the same in all four areas.

Figure 2 shows individual trawl catches relative to the maximum catch the same day. Except for one large catch made at 07:31, all the other seven big catches were made between 10:06 and 13:10. All catches outside this period were smaller, indicating diurnal variation in trawl catch rates. Further, morning and afternoon catches were substantially smaller than midday ones. Variable morning values may indicate variation in *in situ* dawn, caused either by variable incidental illumination (cloud coverage, fog) or by variable turbidity (algae). The functional response of hake to *in situ* dawn seemed to be around 07:00 in this experiment, whereas *in situ* dusk seemed to start as early as 14:30.

DISCUSSION

Estimating catchability constants for hake caught by demersal trawl is, in principle, possible. Further dedicated experiments are needed, however, to furnish high quality data for the purpose. The q_{trawl} values established on the basis of the selected subset of the

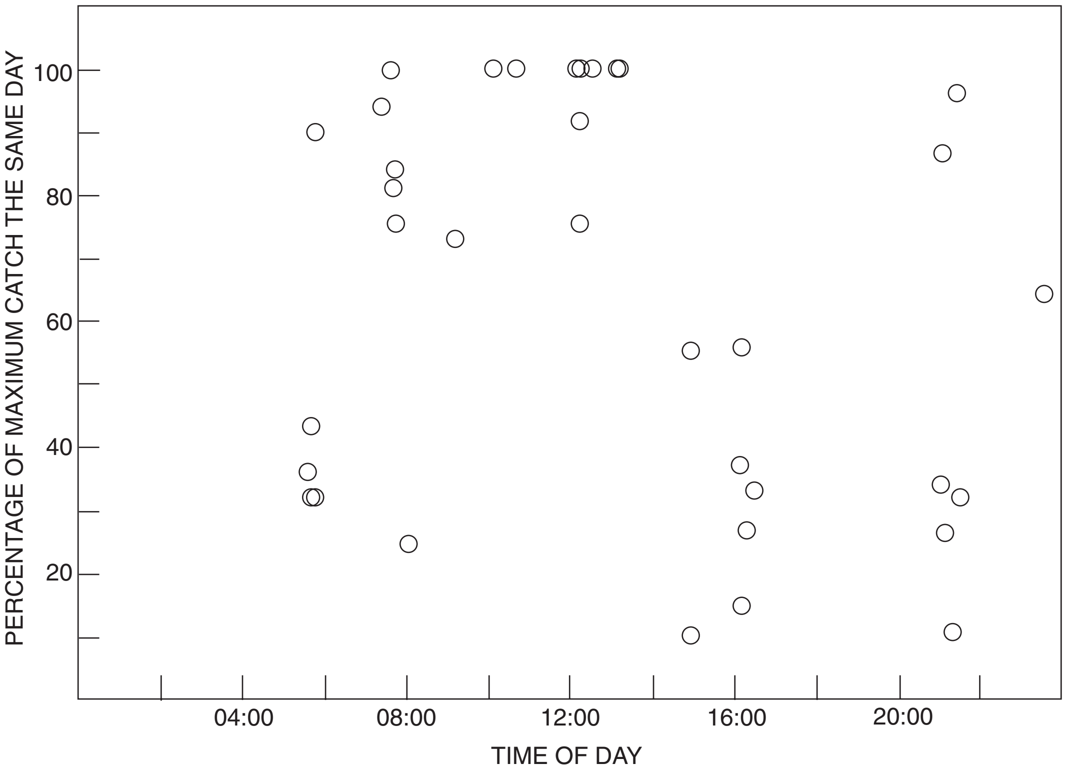

Fig. 2: Hake catches per trawl station relative to the maximum trawl catch that day

present material, with a mean of around 0.8, should only be considered as a demonstration of the potential feasibility of the methodology. New data should cater for the need to be more specific regarding the two species of Cape hake, as well as to be more comprehensive in terms of regions, depth ranges and times of day.

One major problem encountered was the substantial variation in total estimated abundance within the same area. Such variation can generally not be attributed to one data source alone, but seems to be a feature of both. This problem can hopefully be remedied by careful attention to selection of time of day to trawl, area selection (selecting areas with uniform fish distribution), following the specified trawl lane meticulously, ensuring contact of the trawl on the seabed, and acoustic post-processing. However, local patchiness and movements are going to remain sources of error in this methodology. More night-time hauls to compare against daylight trawls would also potentially improve precision of the calculated values of q_{trawl}. In a study of parallel trawling with identical rigging (Strømme and Iilende 2001), it is shown that catch rates in parallel hauls on hake are on average 20% different from their mean value, demonstrating high natural variation, probably attributable to patchiness. In order to obtain precise estimates of true density at a location, many daylight and night-time hauls will be necessary to compensate for patchiness.

Differences in mean length between night-time and daylight hauls, as well as between bottom and pelagic catches, were generally not significant, perhaps indicating that smaller hake tend to stay higher in the water column and become unavailable to the bottom trawl by night (Pillar and Barange 1995, Huse *et al.* 1998). It is also possible that the mean length of hake in midwater is less than that of the hake available to the bottom trawl, at least at night. As the bottom trawl catches were used as a basis for converting acoustic values into biomass, an error may have been introduced. Such an error would lead to a smaller difference between A_N and A_D (Equation 4) if both mean lengths in Equation 1 calculations were reduced equally, and consequently to a larger q_{trawl}.

The calculation of q_{trawl} is assumed to incorporate escapement under the trawl (Engås and Godø 1989) as well as escapement through the meshes in the front part of the trawl. These are the main factors causing a trawl to catch less than the total number of fish encountered in the trawl path. Horizontal herding by doors, sand clouds and bridles are normally the most important sources of bias in trawl sampling (Engås 1994, Godø 1994). However, these issues were not considered here, because the observed passive behaviour of Namibian Cape hake (IH and W. Valdemarsen, unpublished data) is the basis for the present investigation. These issues should, however, be readdressed both with regard to species and fish length in future investigations, if the aim is to establish functional values of q_{trawl}. The issue of dissolved oxygen concentration should also be considered, because it has a bearing on swimming capacity, and so may influence herding.

The daylight appearance of mesopelagic fish and plankton in combination with pelagic hake and making precise post-processing difficult presented a problem in some areas. This matter must be addressed when selecting areas for further experiments.

The validity of q_{trawl} calculations based on this methodology is of course dependent on the correctness of the acoustic measurements. If these cannot be assumed to represent fish abundance in absolute terms, neither can the q_{trawl} calculated be assumed to be correct. The s_A values recorded are correct as such, disregarding post-processing, but the reflective properties of fish vary with behavioural and physiological parameters (Nakken and Olsen 1977). This is reflected in the target strength (*TS*) function normally applied, which is an average of a large number of measurements (Foote 1987, Svellingen and Ona 1999) modulated by fish length.

In situ target strength measurements of hake have been carried out in Namibia (Svellingen and Ona 1999); they support the use of 68 as a constant. It can be argued that fish migrating vertically would be expected to show increased *TS* after their upward migration at night and decreased *TS* nearer the bottom by day. A migration from, for example, 350 to 300 m, would incur a 14% increase in swimbladder volume but only a <6% increase in swimbladder cross-section area, proportional to the measured acoustic abundance. As most pelagic hake are closer to the bottom than 50 m, and as the above *in situ TS* measurements (Svellingen and Ona 1999) were also carried out on pelagic hake at night, this factor would seem to be negligible. It would, however, be potentially beneficial to count the number of pelagic hake traces included in the acoustic integration from the echograms to compare with the *TS* function applied, as well as the pelagic and total biomass calculated for the area. Consequently, the q_{trawl} calculations based on this methodology are restricted by the present accuracy of the hydroacoustic methodology.

There seems to be significant variation in catchability within the hours of daylight when hake trawl surveys are normally carried out (Anon. 1995). The general pattern found here is for catches to be large around midday and lower in the morning and early afternoon. This pattern is found in all experimental areas and is also reflected in the total estimated abundance, perhaps indicating that the pattern is also present in the acoustic data, rather than simply being compensated for by them. This finding may be related to the vertical migration of hake. In the morning, pelagic hake are not yet on the bottom and available to the trawl. In the early afternoon, they have already left the bottom (Huse *et al*. 1998). The acoustic recordings were also low at those hours of the day owing to the aspect angle articulation of the fish during vertical migration, resulting in a substantially lower *TS* of the fish (Nakken and Olsen 1977, Huse and Ona 1996). It is therefore not advisable to use data from those hours of the day for q_{trawl} calculations.

The diurnal variability in trawl catch rates emphasizes the need for a catchability function rather than a constant for application to trawl surveys. A number of factors would have to be addressed to establish an acceptable basis for calculating a useful catchability function. Most of them pertain to the fact that not all hake migrate off the seabed during the night and, at times, not all hake are available to the bottom trawl during the day. The size and species distribution of the residual daylight pelagic hake would have to be established in order to transform acoustic measurements into biomass correctly. This would require near-bottom pelagic trawling. The same requirement applies to the night-time pelagic hake. Both pelagic and demersal trawl catches as well as acoustic recordings should then be applied to establish a total size distribution for each species. The size distribution of the daylight pelagic component can then be estimated from the difference between the total distribution and the daylight demersal component, and the size distribution of the night-time pelagic component for each species can be estimated from the difference between the total distribution and the residual demersal component. Care should therefore be taken to optimize this aspect in future investigations.

In the context of a bottom trawl survey, the observed variations in catchability during the day may not be of great importance with regard to the representivity of relative indices as long as the survey is carried out in the same manner from year to year. It would, however, potentially improve the interannual stability of such indices if they could be compensated for in terms of time of day, given that a basis for such corrections could be established. It would also be useful to determine whether such corrections should be based on *in situ* illumination rather than on time of day, because the variation in catchability is related to the fact that hake migrate diurnally (Huse *et al*. 1998). In many fish species, the latter is, of course, itself probably related to *in situ* illumination (Neilson and Perry 1990, Helfman 1993).

Since 1991, Namibian hake stocks have been monitored by combined swept-area surveys and acoustic monitoring of off-bottom hake (Sætersdal *et al.* 1999). From an analysis of the dynamics of pelagic hake during these surveys, it was shown that, on average, the pelagic biomass in the morning and afternoon is about 20% of the demersal biomass, whereas around noon the value is reduced to around 10% (Iilende *et al.* 2001). Notwithstanding the discussion above, it may be possible at least partially to compensate for diurnal variation in demersal catch rates by monitoring the pelagic zone acoustically. Further improvements to this approach could be achieved through provision of more reliable calibration factors between demersal and pelagic estimates. This can be obtained from more precise estimates of q_{trawl}, by improved discrimination of hake in acoustic post-processing, and from conducting more trawling in the pelagic zone to check if the vertical migration is dominated by a specific size-class or species.

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