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Estimating end effects in trawl catches

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Abstract:

The end effect in trawl catches is defined as the proportion of the fish catch taken during shooting and hauling of the net, a period excluded from that nominally referred to as haul duration. If important, this effect will lead to biased abundance estimates, because the swept area will be underestimated. An experimental survey was carried out to compare catch numbers obtained in standard research 30-min hauls with those from 0-min hauls, the latter referring to the trawl being hauled as soon as the trawl geometry stabilized on the seabed. Average catch ratios (0-min/30-min hauls) ranged from 0.05 (s.d. 0.06) for sole to 0.34 (s.d. 0.64) for hake, indicating that the end effect might be more important and more variable for highly mobile species. As a consequence, the bias in abundance indices derived from swept area estimates that ignore end effects will be species-dependent.

Keywords: abundance index; bias; trawl survey

Introduction

Recent studies have shown that CPUEs for fish and crustaceans can be relatively higher for 15 min hauls compared to 30 min hauls (Godø *et al.*, 1990; Walsh, 1991; Somerton *et al.*, 2002). These observations serve to suggest that by systematically shortening haul durations during scientific surveys, the total number of samples could be increased, resulting in increased precision of abundance index estimates (Folmer and Pennington, 2000; Kingsley *et al.*, 2002; Pennington *et al.*, 2002). However, the reasons for increased CPUEs in shorter hauls are not obvious, and several hypotheses can be put forth: i) fish escapement is lower at the beginning of the haul as individuals are surprised by the arriving haul; ii) fish are caught before and after the standard haul duration, both while the gear is settling and after the trawl starts to be hauled; and iii) the net saturates for longer hauls which increases escapement. Evidence for the surprise effect comes from visual observations at the trawl opening. Albert *et al*. (2003) observed that proportionally more Greenland halibut entered the trawl during the first few minutes on the sea floor compared to the later parts of the haul. Second, the time elapsed after arrival at the sea floor but before trawl geometry is stabilised, which is often taken as the nominal starting time, and while hauling, has been estimated to be non-negligible for shrimp in Greenland waters (Kingsley, 2001). Finally, net saturation will probably occur in certain circumstances but should not generally be a problem due to the short haul duration in scientific surveys. Thus, the two most plausible hypotheses, not excluding that other factors will also contribute, are a surprise effect and end effect. Both effects are independent of haul duration and thus might be proportionally more important for shorter hauls. This will be particularly problematic if surveys with different tow duration were to be compared, or if tow duration and sinking and hauling time vary among stations within a survey. Whereas tow duration generally varies within prescribed limits, sinking and hauling times depend on depth, so surveys covering a larger depth range might be more affected. In addition, the size of fish caught while sinking and hauling might differ markedly from those caught during the nominal towing period (e.g. for saithe, Huse *et al.*, 2002). For these reasons, end effects might introduce significant bias in survey data, especially for species with low densities. This note reports the results of an experiment designed to estimate the number and length of fish caught before and after the nominal haul duration, conducted in 2003 in the Bay of Biscay.

Materials and Methods

The experiment was conducted 17-19 May and 11-18 November 2003 onboard R.V. "Gwen Drez". *Nephrops* twin trawls were used with a 25.15 m headrope and a 28.60 m footrope consisting of a cable with 70 mm diameter rubber disks, and 2 m trawl doors weighting 280 kg. The same twin trawl was used on both occasions, but with different mesh sizes (Table 1). Due to technical problems, haul duration and trawl geometry were not always recorded. In cases with measurements, average vertical opening was 1.8 m and horizontal opening 11.6 m. Towing speed was approximately 3.4 knots. Six hauls of 30 min duration were carried out (Table 1). Hauls are considered to begin when the net has nearly reached a stable shape. This might happen a few minutes after the chain has settled on the bottom. Similarly, after 30 minutes the haul is considered ended and hauling begins. For each full haul, three "zero-duration" hauls were carried out. In "zero-duration" hauls, the trawl is hauled as soon as nominal haul duration would start in an ordinary haul. These zero-duration hauls were located approximately at the beginning, middle and end of the full haul. All fish caught were identified to the lowest taxonomic level possible, weighted, enumerated, and measured. For this analysis, the catch of the two twin-trawl nets were summed. For nine species, enough individuals were caught to allow comparison between full and "zero-duration" catches. Densities were estimated as number caught divided by swept area, *i.e.* horizontal trawl opening multiplied by distance trawled (not including the unknown additional area swept during sinking and hauling). Length distributions of the catch for each species were compared between zero-duration and full hauls by a Kolmogorov-Smirnov test (Sokal and Rohlf, 1995). [author: other than the length frequency analysis, you really do not explain how you did your comparisons and analysis. Some detail is needed for anyone to reproduce your findings. Degrees of freedom in your analysis are not reported, and to be convincing, I think readers will need to have some measure of what your conclusions are based upon.]

Table 1: Haul characteristics. Durations in minutes, depth in m, mesh size in mm (stretched), densities in Nb.km^{-2}. Hake, *Merluccius merluccius*, sole, *Solea solea*, bib, *Trisopterus luscus.*

Date	Event number	Stretched mesh (mm)	Sinking depth	Sinking duration	Haul duration	Hauling duration	Total catch	Hake density	Sole density	Bib density
May-03	1	70	41	05:05	00:52	04:09	8			
May-03	1	70	41	05:29	00:29	04:45	11			
May-03	1	70	40	–	–	–	3			
May-03	1	70	40	05:01	31:42	04:41	27	47	16	–
May-03	2	70	51	05:35	31:56	05:40	78	348	–	87
May-03	2	70	35	05:00	01:13	04:31	4			
May-03	2	70	37	05:11	01:49	04:00	8			
May-03	2	70	35	–	–	–	20			
Nov-03	3	20	33	–	30:00	–	362	52	451	4114
Nov-03	3	20	29	–	–	–	42			
Nov-03	3	20	25	–	–	–	49			
Nov-03	3	20	22	–	–	–	31			
Nov-03	4	20	29	–	30:00	–	336	67	401	4039
Nov-03	4	20	29	–	–	–	24			
Nov-03	4	20	28	–	–	–	31			
Nov-03	4	20	27	–	–	–	26			
Nov-03	5	20	41	–	30:00	–	864	51	84	5360
Nov-03	5	20	41	–	–	–	40			
Nov-03	5	20	42	–	–	–	25			
Nov-03	5	20	40	–	–	–	50			
Nov-03	6	20	20	–	30:00	–	935	88	1391	11237
Nov-03	6	20	19	01:59	00:21	01:58	63			
Nov-03	6	20	19	01:39	00:33	02:22	20			
Nov-03	6	20	25	01:36	00:38	02:14	64			

Results

The time between the trawl settling on the bottom and the start of the nominal haul was found to vary between 1.5 and 5 minutes (Table 1), in accordance with the results reported by Kingsley (2001). Time between nominal and actual haul end (identified by a change in headline height*)* was of similar magnitude.

Estimated densities ranged between 15 and 11,000 individuals per km^2 (Table 1). An analysis of variance on the log-transformed catch numbers (ln (catch+1)) showed that the location of the zero hauls did not matter, *i.e.* the three "zero-duration" hauls can be considered as replicates. This was true for all species (Table 2).

Table 2: Analysis of variance results for effect of zero haul position (beginning, middle or end of full haul) on log-transformed number caught. Df, degrees of freedom.

	Df	Sum Squares	F value	P-value
Species	34	74.048	4.4651	$1.058\ e^{-08}$
Haul position	2	0.992	1.0168	0.3660
Species-position interaction	42	11.338	0.5535	0.9820
Residuals	86	41.947		

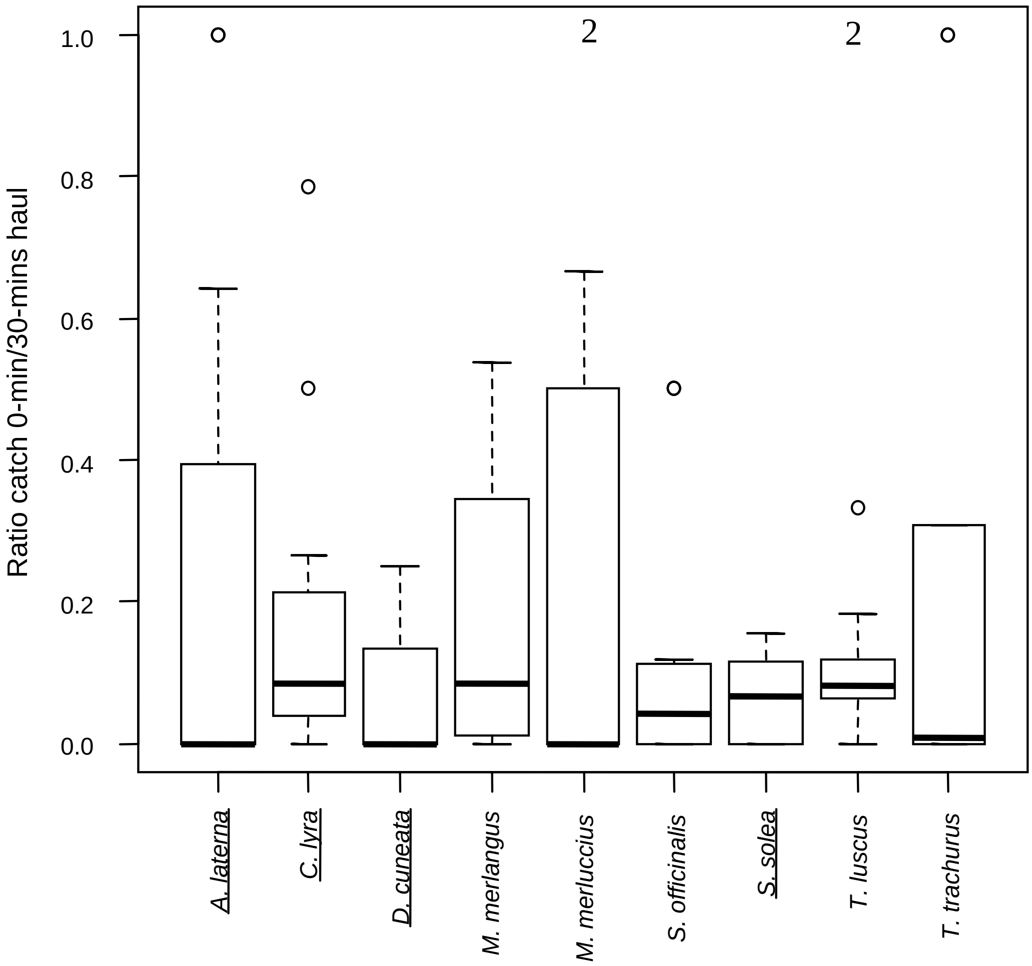
Comparative plots indicated positive correlations between "zero-duration" and full haul catches (not shown). The catch ratio was strongly species dependent (Figure 1). For highly mobile, demersal species, such as whiting and bib (*Merlangius merlangus* and *Trisopterus luscus*), the proportion caught in "zero-duration" hauls was high and variable, while for benthic species such as sole (*Solea solea*) it was below 10%. The exception seems to be scaldfish (*Arnoglossus laterna*), which had a high average ratio despite being a benthic species. The low number of individuals caught (see Table 3) might contribute to this result.

No significant difference was detected between length distributions in zero-duration compared to full hauls, except for wedge sole (*Dicologlossus cuneata*), which were smaller in zero-duration hauls (Table 3).

Table 3: Results of Kolomogorov-Smirnov (Ks) tests for difference in length-distribution between zero- and full-duration hauls (November experiments).

Species name	Number caught in 0 duration hauls	Number caught in 30' hauls	Ks statistic	P-value
Arnoglossus laterna	200	305	0.196	0.612
Callionymus lyra	606	3787	0.145	0.401
Dicologlossus cuneata	158	1582	0.536	0.005
Merluccius merluccius	129	295	0.563	0.042
Merlangius merlangus	625	1348	0.084	0.970
Solea solea	476	2514	0.087	0.995
Trisopterus luscus	5674	22569	0.069	0.133
Trisopterus minutus	231	1213	0.081	1.000
Trachurus trachurus	116	2038	0.330	0.123

Figure 1: Distribution of catch ratio (numbers) zero-duration / full hauls per species. Thick solid line: median; box ends: upper and lower quartiles; whiskers: extreme values, excluding outliers (which are plotted individually; numbers indicate ratio values outside plot limits). Behaviour type: benthic (underlined species names) and demersal (other species).



Discussion

For less mobile and truly benthic species, the catch due to fishing before and after the nominal haul duration might be proportional to the duration of that period, while for demersal or more mobile species such as hake, it can be hypothesised that the end effect is more important. The latter observation sheds doubts on swept area based abundance indices for highly mobile species. End effects generally did not affect length distributions.

The catch of animals before and after nominal haul, or end effect, introduces a bias in abundance estimates that varies among species, the magnitude of which is inversely related to haul duration. This can be particularly important for surveys conducted in regions with low fish densities as in this study. Thus the end effect might counterbalance the benefits expected from shorter hauls. End effects will also increase the variability in abundance indices and more generally, in indicators derived from survey data. This adds to the uncertainty induced by spatial heterogeneity in fish density and in trawl geometry. In the future, this problem might be overcome by technology, *i.e*. using trawls that are open while lowered and closed before hauling (Engås *et al.*, 1997), although certain technical difficulties remain in the practical operation of such systems (Sarda *et al.*, 2002).

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