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Comparison of Species Composition in a Bottom Trawl Calibration Experiment

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Abstract

The species composition in a comparative trawl fishing experiment on the Scotian Shelf was analysed to determine if two ships using different gear resulted in different pictures of assemblage structure. A multiple regression technique was used with an index of biological dissimilarity as the dependent variable, and dummy variables to control day-night differences, sampling stratum and location. The analysis showed that the dissimilarity index values between vessels were not significantly larger than those within vessels. Pairs of tows by the different vessels and gear at the same location, were significantly less dissimilar than pairs of tows by the same vessel in the same sampling stratum (i.e. nearby). The study shows that it is valid to compare assemblage structure on the basis of surveys by these two vessels. The results also suggest that there are spatial patterns in the demersal fish assemblages on the Scotian Shelf at a scale between the area covered by a trawl tow and the area of a stratum.

Introduction

Trawl survey data are often used for analyses of assemblage structure (Fager and Longhurst, 1968, Day and Pearcy, 1968; Gabriel and Tyler, 1980; Mahon *et al.*, 1984; Overholtz and Tyler, 1986). Abundance indices from different survey vessels and trawl types are commonly calibrated by comparative fishing experiments in which two vessels fish simultaneously, as close together as possible. In these experiments, correlation of catch-per-tow of individual species are usually statistically significant, but are also highly variable (Fanning, MS 1985). In some surveys more than one type of gear and/or vessel may be used and some experiments may also be conducted under different conditions, for example in different seasons (Colvocoresses and Musick, 1984; Mahon *et al.*, 1984). If assemblage structure from surveys using different gear or vessels is to be compared quantitatively, analysis of comparative fishing experiments is important. The authors know of no reported comparison for assemblage structure.

On the Scotian Shelf, a series of surveys was conducted in July from 1970 to 1981 with one vessel and trawl type while concurrent surveys were also carried out in spring and autumn from 1978 to 1981 with another vessel and using a different trawl type. To calibrate the vessels and the gears, comparative fishing was conducted in July 1981. In this study, a dissimilarity index is used to determine if the differences in assemblage composition between comparative tows by these vessels and gears are significantly different from those between pairs of tows by the same vessel and gear.

Methods

A comparative fishing experiment was conducted, by the vessels *A. T. Cameron* (53 m, 1000 HP) using a Yankee 36 trawl and the *Lady Hammond* (58 m, 2500 HP) using a Western Type IIA trawl, on the Scotian Shelf between 7–25 July 1981, when a total of 109 stations were occupied simultaneously and as close together as possible (Fig. 1). Full details of these vessels and trawls are reported in Fanning (MS 1985).

These trawls differ in several ways which may affect fishing efficiency for different species; for example, roller size and spacing, door area and codend mesh size. However, the most important difference with respect to possible effects on the species composition of the catch was regarded as the heights of the headlines, which were 3 m and 5 m in the Yankee and Western trawls respectively. We are unable to comment on the relative contributions of gear differences (e.g. headline height), environmental differences and small scale distribution to the biological dissimilarity between comparative tows. These questions could be examined with appropriately designed trawl sampling experiments.

At each station, each vessel attempted a standard survey tow of 30 min duration at 3.5 knots resulting in a standard towed distance of 1.75 naut. miles. Where the

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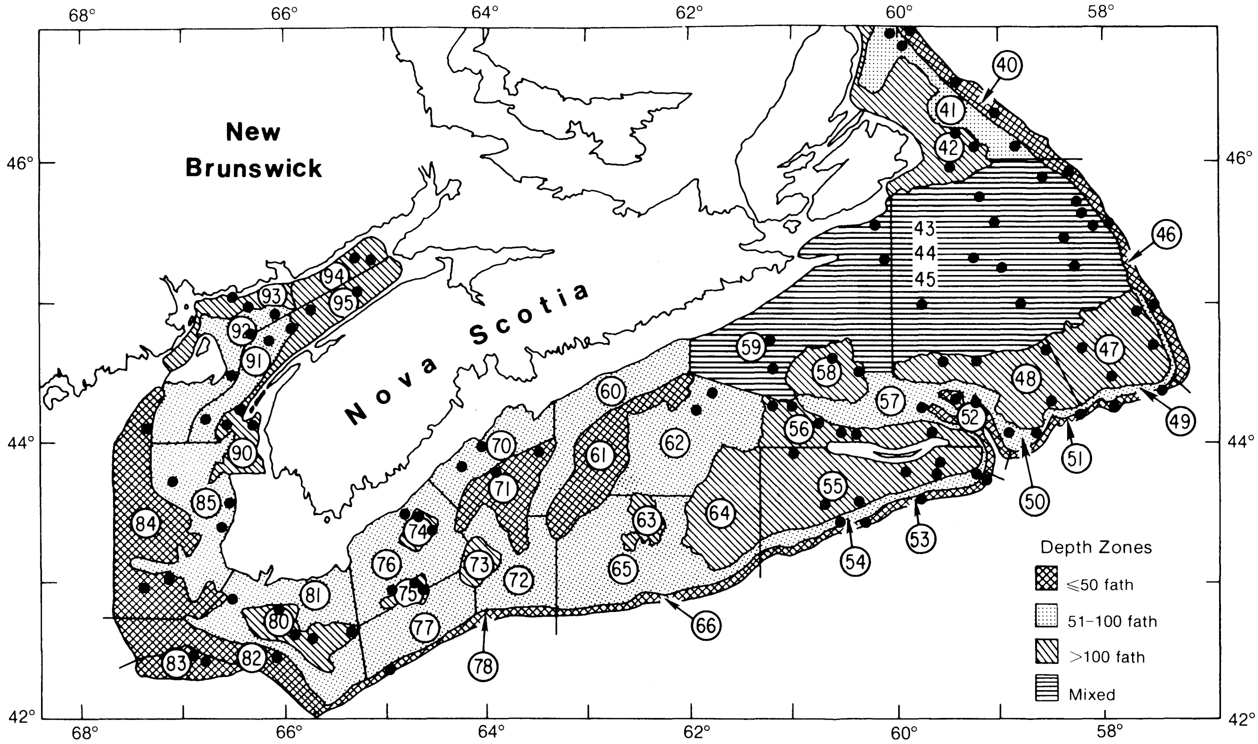

Fig. 1. Sampling strata and locations of comparative sets (●) on the Scotian Shelf and in the Bay of Fundy.

actual towed distance measured as the difference between LORAN positions at the start and end of the tow differed from this, the catch was adjusted by a factor of 1.75/actual distance.

The assemblages in pairs of tows were compared using dissimilarity indices. The numbers of individuals of each species were used in calculating dissimilarity values. To demonstrate the generality of the results over the various types of indices available, five analyses were run with four different dissimilarity indices (Table 1). The species included in the analyses are the most common in the entire survey data set (Mahon *et al.*, 1984).

There are two types of problems associated with determining if comparative tows from different vessels were significantly more alike than pairs of tows by the same vessel. The first problem is that, pairs of dissimilarity indices which have a trawl tow in common, are not statistically independent. Consequently, conventional statistical tests of significance are not valid for dissimilarity indices. The second problem is that, whereas comparative tows are in the same location and at same time of day, pairs of tows by the same vessel are at different locations and necessarily at different times of day. It would be optimal if it were practical to take four comparative tows at a time. Then, for tows taken at the same time, the dissimilarities between tows with the same gear type could be compared with the dissimilarities between the tows with different gear types.

The first problem was resolved by utilizing methodology which takes the lack of independence of the dissimilarity values into account as proposed by Dyer (1978). This is a multiple regression model in which the dissimilarity values are the dependent variable, and the computations are adjusted to account for the interdependence of the dissimilarity values. Analysis of variance tests can then be performed by using dummy variables as independent variables in the model. In this study, the following dummy variables were created to determine whether community differences measured by the dissimilarity index are significantly different from that expected by chance when comparing tows within and between comparative pairs, within and between strata, by the same or different ships, or during the same or different times of day (day *versus* night):

COMP	= 0 if both tows are a comparative pair
SAMESTRAT	= 0 if both tows are in the same stratum
SAMESHIP	= 0 if both tows are taken from the ship
SAMETIME	= 0 if both tows were taken during the day or during the night

If a dummy variable is not set equal to zero using these criteria, its value is set equal to one. Daytime hours were considered to span 0600–1800 hr.

TABLE 1. Dissimilarity indices tested and their properties.

Index	Reference	Property
Bray-Curtis (1957)	Clifford and Stephenson (1975)	Much greater weight to the more abundant species
Morisita (1956)	Morisita (1956)	Much greater weight to the more abundant species
Bray-Curtis (1957)[1]	Smith (MS 1976)	Somewhat greater weight to the more abundant and variable species
Canberra-metric	Clifford and Stephenson (1975)	Equal weight to all species
ZAD[2]	Mahon *et al.* (1984) Stull *et al.* (1986)	Measures greater range of community change; equal weight to all species

[1] Species abundance data transformed by a square root and standardized by a species mean (of values > 0) before index computations.
[2] Zero Adjusted Distance.

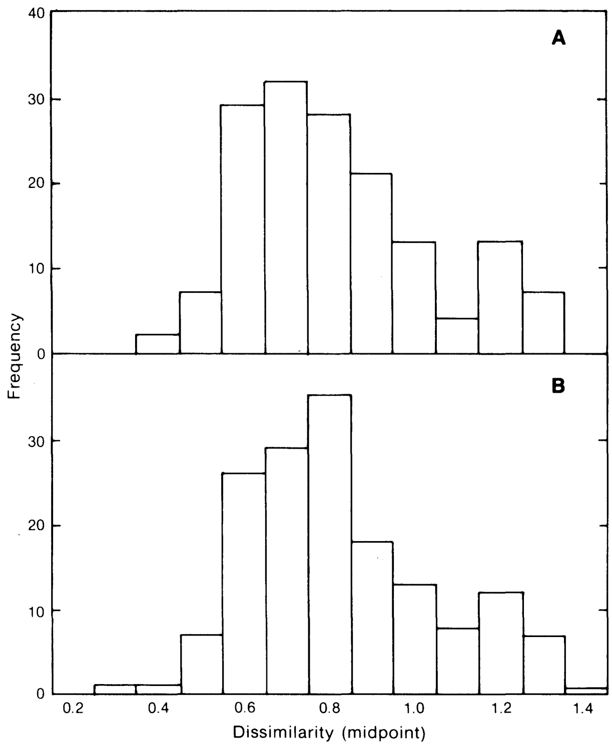

Fig. 2. The distributions of Zero Adjusted Distance (ZAD) dissimilarites between (**A**) tows from the same ship, and (**B**) tows from different ships. To remove the effects of stratum and time of day, dissimilarities between tows in different strata and times of day (day *versus* night) are excluded. In addition, dissimilarities between tows in a comparative set are excluded from (**B**). Otherwise (**B**) could include dissimilarities between tows in a comparative set (which are always different ships), while (**A**) could not. Dissimilarities along the horizontal axis of the histograms are midpoints of dissimilarity intervals.

The inclusion of the contrasts defined above in the analysis also solves the second problem, specifically by having the same-ship tows at different locations [the results below, see especially Fig. 2; provides further details of how this is accomplished].

Results

The multiple regression results (Table 2) show that, for all analyses: (1) the dissimilarities between strata are significantly larger than the dissimilarities within strata; (2) dissimilarities between comparative pairs were significantly larger than dissimilarities within comparative sets; and (3) the dissimilarities between tows from different ships are not significantly larger than tows from the same ship.

The results with the Bray-Curtis (1957) and the Morisita (1956) indices (Table 1), which give greater weight to the more abundant species, indicate that dissimilarities between tows from the same time of day are not significantly higher than dissimilarities between different times of day. The remaining analyses, which tend to give equal weight to the different species, show the opposite result.

The multiple regression slopes are partial slopes, meaning that a slope and statistical test (t-tests) for an independent variable are based on variation of the independent variable with the values of the other independent variables held constant. For example, when we state that the dissimilarities between comparative pairs of trawl tows were significantly larger than dissimilarities within pairs of comparative trawl tows, this is only true for dissimilarities within the same stratum and time of day.

Figures 2–5 show the distributions of dissimilarities within and between a condition, with the other condition held constant utilizing the Zero Adjusted Distance (ZAD) dissimilarity index. The results were similar in all dissimilarity indices tested. These figures also illustrate the relative magnitudes of the community variation at different sampling scales.

The distributions of dissimilarities between tows from the same ship and tows from different ships are

TABLE 2. Multiple regression results for the five analyses. The properties of the dissimilarity index values are described in Table 1. The slopes indicate the average differences between the "between" and "within" dissimilarities for the corresponding variables (with the other independent variables held constant). The null hypothesis tested by the t-test is that the slopes equal zero. The probabilities that the null hypothesis is true (P(t)) are based on a two-sided test.

	Dissimilarity index														
	Bray-Curtis			Morisita			Bray-Curtis[1]			Canberra-metric			ZAD[2]		
Variable	slope	t	P(t)	slope	t	P(t)	slope	t	P(t)	slope	t	P(t)	slope	t	P(t)
COMP	0.076	8.584	<0.0001	0.006	5.959	<0.0001	0.055	6.367	<0.0001	0.048	9.721	<0.0001	0.049	4.72	<0.0001
SAMESTRAT	0.206	30.616	<0.0001	0.011	16.103	<0.0001	0.207	28.850	<0.0001	0.112	28.017	<0.0001	0.208	24.05	<0.0001
SAMESHIP	0.001	0.461	0.645	0.000	0.236	0.813	0.001	0.889	0.374	0.000	0.524	0.600	0.002	1.01	0.311
SAMETIME	0.001	0.871	0.384	0.000	−1.048	0.295	0.005	3.581	0.0003	0.003	3.193	0.001	0.004	2.25	0.024

[1] Species abundance data transformed by a square root and standardized by a species mean (of values > 0) before index computations.

[2] Zero Adjusted Distance.

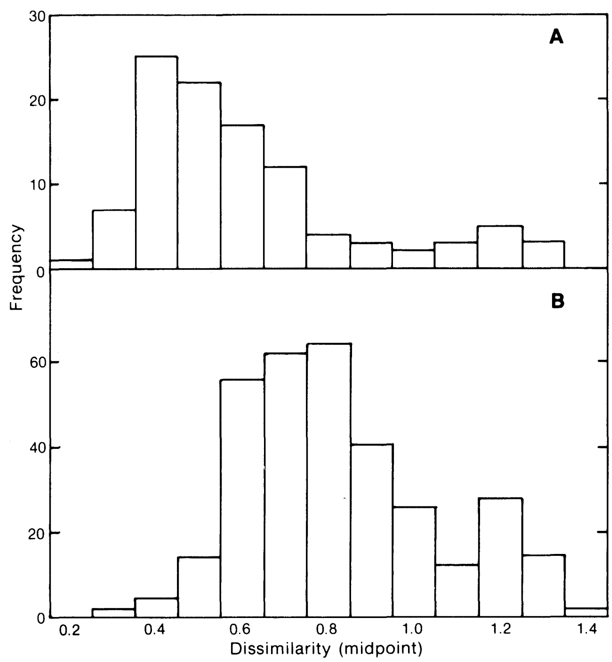

Fig. 3. The distributions of Zero Adjusted Distance (ZAD) dissimilarities betwen (**A**) tows from the same comparative set, and (**B**) tows from different comparative sets. To remove the effects of stratum and time of day and ship, dissimilarities between tows in different strata and times of day (day *versus* night) and ships are excluded.

broadly overlapping, with the highest numbers of dissimilarities in the 0.6-0.8 range (Fig. 2). Consequently, we are not able to detect differences in the demersal fish communities sampled from different ships.

The dissimilarities between tows from comparative pairs of tows of different ships were smaller than those between pairs of tows of the same ship, in the same stratum and same time period (Fig. 3). The modes of these distributions were 0.4 and 0.8 respectively. Again this agreed with the analysis in Table 2, which shows the dissimilarities between sets were significantly larger (P<0.0001).

The distributions of dissimilarities between tows taken during the same time of day (day *versus* night) and those taken during different times of the day are

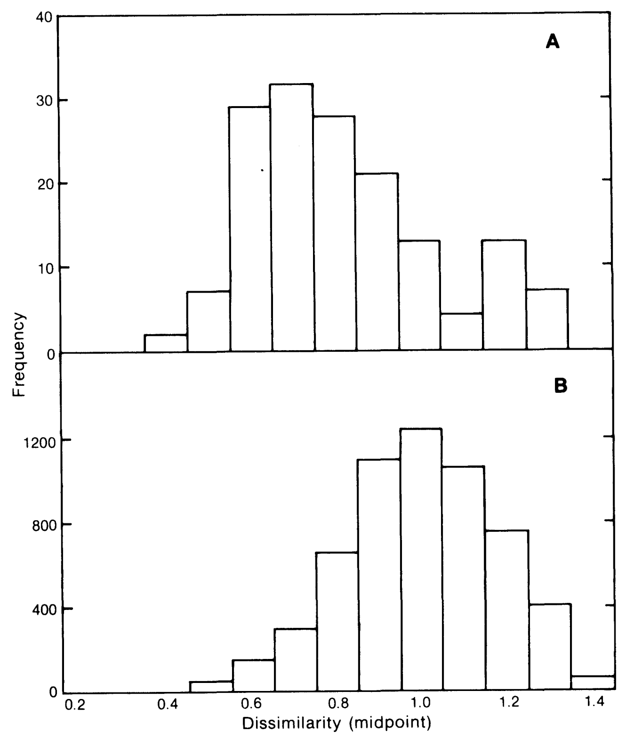

Fig. 4. The distributions of Zero Adjusted Distance (ZAD) dissimilarities between (**A**) tows taken during the same time of day (both in the day or both in the night), and (**B**) tows taken during different times of day (one during the day and the other during the night). To remove the effects of stratum and ship, dissimilarities between tows from different strata and different ships are excluded.

broadly overlapping and with the same mode at 0.7 (Fig. 4). Although the ZAD analysis in Table 2 shows a significant difference in this contract (p = 0.024), no such difference is apparent here. It should be noted that the computations used in contrasts shown in Fig. 2-5 are not the same as those used in the multiple regression analyses. In the regressions, the different factors other than the one being tested at the time were held constant mathematically, while in Fig. 2-5, the different factors were held constant by exclusion of pertinent dissimilarities. This difference in approach may have led to the different conclusions for this contrast. We place more faith in what can be seen directly (i.e. Fig. 4), so it is necessary to be very cautious when

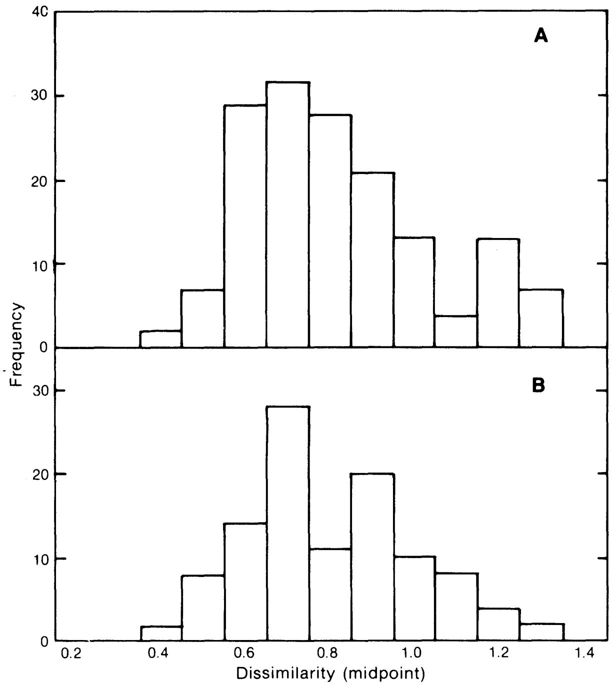

Fig. 5. The distributions of Zero Adjusted Distance (ZAD) dissimilarities between (**A**) tows taken from the same stratum, and (**B**) tows taken from different strata. To remove the effects of time of day, dissimilarities between tows taken during different times of day are excluded. In addition, dissimilarities between tows in a comparative set are excluded from (**A**). Otherwise (**A**) could include dissimilarities between tows in a comparative set (which are only in the same stratum), while (**B**) could not.

making any conclusions concerning day-night differences in tows.

The regression analyses in which the indices give greater weight to the more abundant species (Table 1) show that the dissimilarities within and between tows at different times of day were not significantly different (Table 2). These results are consistent with the corresponding histograms, which show completely overlapping distributions of within the between time-of-day dissimilarities.

As expected, the dissimilarities between tows in different strata tend to be larger (mode = 1.0) than those between tows in the same stratum (mode = 0.7) (Fig. 5).

Figures 2–5 illustrate the relative magnitudes of community variation at the different scales of sampling.

The 13 cases which had the highest dissimilarity values and which comprised the second mode for comparative sets (Fig. 3A) were examined in detail. For the three largest dissimilarity values for either of the vessels (Table 3, cases 11, 12, 13) the catch in the other vessel was zero. In each of the three cases, the catch recorded by one vessel appeared 'normal' in terms of weight and species composition. Mahon *et al.* (1984) could find no pattern in space, or in relation to environment for such zero catches, and concluded that they were probably due to gear malfunction which went undetected.

For the remaining 10 comparative tow locations (Table 3, cases 1–10), the species abundances between the pairs of tows were compared to determine if some species tended to contribute more frequently to the large dissimilarity values. Species abundance in each tow is represented by one of five categories relative to the mean abundance for that species on that cruise. By using symbols for the categories, differences in abundance of a species in each pair of tows (shown side by side in Table 3) were easily discerned. For example, in the pair of tows with the lowest dissimilarity (case 1), witch flounder and sea raven are present only in one tow, and haddock and wolffish only in the other, while cod was scarce in the first set of the comparative pair but not in the second. Such differences increased as the dissimilarity values progressively increased, however no species could be singled out as particularly likely to contribute to a large dissimilarity.

Discussion

The large bottom trawl used in this study is a relatively poor sampling tool for fish community studies. However, given the large scale of the ecosystem being studied and the difficulty of sampling marine fish populations, there are at present no economically feasible alternatives.

The significantly larger dissimilarity values between tows from different strata than between those from the same strata are expected as stratification is by depth. Mahon *et al.* (1984) found depth to be the dimension along which most community variation took place.

Day-night differences in the species composition of trawl catches have not been previously studied for northern waters. In the south Atlantic Bight, assemblages of fishes associated with sponge-coral habitat exhibited considerable day-night variability, which was assumed to relate to diel activity patterns (Wenner, 1983). The extent to which this feature of fish assemblages becomes apparent in trawl samples is probably related to the availability of cover for each group during its inactive period. On the Scotian Shelf, our data suggests (Fig. 4) that day-night differences in species composition are relatively unimportant. However, the analysis of variance showed differences which were marginally significant. A detailed species by species analysis of diel patterns is therefore necessary before firm conclusions as to the importance of time of day are drawn.

TABLE 3. Comparison of species composition and relative abundance in 13 comparative tows with the largest dissimilarities. The symbols reflect the abundance of species relative to its average in all tows. (No symbol in columns = 0; • = 0.1–0.5; – = 0.6–1.0; + = 1.1–2.0; * = 2.0 times the mean.)

	Pairs of tows (side by side) in order of increasing dissimilarity												
Species	1	2	3	4	5	6	7	8	9	10	11	12	13
Grenadier													
Longfin hake											+		
Vahl's eelpout												•	
Eelpouts			+										
Redfish										– –	*	+	
Argentine					•		+			• *	•		
Spiny dogfish							– –	•		– +			
Pollock			– +			•		• •		+ *			
Cusk						+				+			
Halibut				+			+		– +				
Witch flounder	–	–	+ +	–	• •					+			
Smooth skate			– –				–	–	–	+			
Angler			–	–		–				–			
Red hake			+ +					•					
White hake			– –	+			•	• •	+	•	–		
Thorny skate	* +		– +		* *	– •	•	+ +	•		–	+	
Plaice	* *		– –	+	* *	+ –	• •		+		–	*	•
Cod	– *	– –	+ +	• •	– –	* +	•	+ +	+	• –			–
Silver hake			– +	•			• +		•	•			
Winter skate					* *		–		–		+		
Haddock	•		– –	• •		* –	• –	• •	•	–			–
Mailed sculpin								–				*	–
Wolffish	–		– +	–			–	– +				–	
Ocean pout			–					– +					
Longhorn sculpin			+ *	•	+ +	–		* *					+
Sea raven	•		– +		–			+ *					•
Winter flounder			• •			•		• –					
Sand lance					•								
Yellowtail flounder	+ +			–	+ –	+ +							
Little skate													

Variability in trawl catches is well documented. In this study the dissimilarity index values were not expected to be significantly less between comparative tows than between other tows by both vessels within a stratum and time period (Fig. 3). Mahon *et al.*, (1984) considered the problem of the scale of assemblage patterns which could be discerned from trawl surveys. Given the sampling intensity and area swept, they considered that surveys could only reveal coarse patterns (10–100 km). However, this study suggests that there are assemblage patterns at smaller scales (1–10 km), somewhere between the area swept by a tow and the size of a stratum (which in itself is quite variable).

We are however able to conclude that it appears valid to compare between surveys with these two vessels when the objective is to evaluate assemblage patterns on spatial scales in order of the size of a stratum.

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